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20th African Water Association (AfWA) International Congress, Kampala, Uganda, February 2020

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Books:

Paul G, Pearson S. 2005. *The Vitamins* (2nd edn). Academic Press: New York.

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International Journal of Biological and Chemical Sciences

AVANT-PROPOS

Quarante ans !1980-2020 !

C'est bien l'âge de la maturité, eh bien l'Association Africaine de l'Eau (AAE), initialement créée sous la dénomination de Union Africaine des Distributions d'Eau (UADE) a fait du chemin.

En effet, depuis ses pères fondateurs, l'AAE a été créée pour être une plateforme d'apprentissage par les pairs, de partage de connaissance et d'expérience et/ou de formation. L'un des moyens d'action à son actif est l'organisation sans interruption d'un Congrès biannuel qui regroupe outre le personnel des sociétés d'eau et d'assainissement de toutes catégories, les exposants sur les innovations technologiques des équipements entrant dans les travaux et services d'eau et d'assainissement. Un volet scientifique et technique dont le Conseil Scientifique et Technique (CST) de l'AAE assure l'organisation, constitue le côté prospectif de ces congrès, car il donne l'occasion aux chercheurs académiques et industriels et aux professionnels de présenter les résultats de leurs recherches, de leurs innovations techniques et technologiques ou des bonnes pratiques professionnelles à partager.

Le 19ème Congrès de l'AAE à Bamako, Mali du 11 au 16 février 2018 a été l'occasion d'innover dans l'organisation du volet scientifique des Congrès de l'AAE, car il a donné l'occasion au Comité Scientifique de sélectionner un nombre de communications de haute qualité et valeur ajoutée au secteur, et de les publier dans une revue scientifique de haut niveau qui à terme, permettrait à leurs acteurs d'avancer en grade académique.

Pour le 20ème Congrès et Exposition Internationale de l'AAE qui s'est tenu du 24 au 27 février 2020 à Kampala en Ouganda, l'AAE a renouvelé l'expérience de Bamako, tout en l'améliorant par l'implication de ses partenaires africains et européens des grandes écoles de renom tels que : l'Institut des Hautes Etudes sur l'Eau (IHE), de Delft, Pays Bas ; l'Institut International de l'Eau et de l'Environnement (2iE), Ouagadougou, Burkina Faso ou encore l'Université des Science et Technologie de Makerere à Kampala, en Ouganda pour ne citer que celles-là.

Ce document est un recueil des meilleures publications issues du 20è Congrès et qui ont valu leur publication dans la revue *International Journal of Biological and Chemical Sciences* dont le facteur d'impact scientifique est de 2,170 selon le site International Scientific Indexing (ISI).

Nous osons croire que le secteur africain de l'eau s'en sortira grandi!

Sylvain USHER
Directeur Exécutif de l'AAE

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FOREWORD

Forty years! 1980-2020!

For sure, this is the age of maturity; the African Water Association (AfWA) originally created as Union of African Water Suppliers (UAWS) has in fact come a long way since 1980!

Indeed, from inception by its founding fathers, AfWA was designed as a platform for peer-to-peer learning, knowledge and experience sharing and/or training. AfWA can boast of the continued organization of bi-annual Congresses as one of its action mechanisms, which brings together various levels of water and sanitation utilities' staff, exhibitors of innovative technology solutions used in the operation and delivery of water and sanitation services. A scientific and technical component which is the Scientific and Technical Council (STC) of AfWA organizes and represents the prospective side of congresses, as it gives academia, industrial researchers and WASH professionals the opportunity to showcase the results of their research and their technical & technological innovations or to share best professional practices.

The 19th AfWA Congress held in Bamako, Mali from 11 to 16 February 2018 was the time for innovation in organizing the scientific side of AfWA Congresses, with the identification by the Scientific Committee of a number of high quality papers adding value to the WASH sector, to be subsequently published in a top level scientific journal; an action which in the long run will help their authors advancing their academic degree.

Under the 20th AfWA International Congress and Exhibition held from 24 to 27 February 2020 in Kampala, Uganda, AfWA renewed the Bamako's experience with some improvements, through the involvement of renowned schools which are AfWA partners in Africa and Europe: the IHE Delft Institute for Water Education, Netherlands; the International Institute for Water and Environmental Engineering (2iE), Ouagadougou, Burkina Faso and the Makerere University College of Science and Technology in Kampala, Uganda to name just a few.

This proceedings book is a compilation of the best publications made during the 20th AfWA Congress to be featured in the *International Journal of Biological and Chemical Sciences*, whose scientific impact factor stands at 2.170 as per the International Scientific Indexing (ISI) website.

We hope that this would make the African water sector stronger!

Sylvain USHER
Executive Director

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EXECUTIVE SUMMARY

The 20th African Water Association (AfWA) International Congress and Exhibition (AfWAICE2020) was convened at the Serena International Conference Centre, Kampala, Uganda during 24–27 February 2020, and brought together a wide range of global practitioners, researchers, development partners and industrialists involved in the water, sanitation, and hygiene (WASH) sector. The theme of the Congress was '*Breaking new grounds to accelerate access to safe water and sanitation for all in Africa*.' AfWA holds its Congresses every two years. The AfWA ICE 2020 provided the opportunity to reflect on Africa's progress in achieving the Sustainable Development Goal 6 (SDG 6) targets, identify new breakthroughs in addressing the WASH challenges on the continent, discuss opportunities for translating research into practice, and provide a platform for continuous development and expansion of various international, regional, and national partnerships and associations.

Global and regional statistics on WASH service coverage often mask disparities between countries and within countries. Most African countries are lagging in achievement of SDG 6 targets, and the need has never been more urgent to cooperate between countries, sectors, and disciplines; and share ideas and resources to search for new breakthroughs and innovations.

The 20th AfWA Congress was meticulously and successfully organized, with involvement and full participation of relevant institutional structures at AfWA; Uganda, the host country; and the Uganda National Water and Sewerage Corporation (NWSC), the host utility. Strategic marketing for and publicity of the Congress was extensive, leading to a record number of participants. In total, 2,312 participants were registered.

The official opening ceremony was graced by **His Excellency Yoweri Kaguta Museveni, President of the Republic of Uganda**, during which Eng. Abderrahim El Hafidi, Director General of ONEE - Morocco, the outgoing AfWA President handed over the administrative instruments of power to the incoming President, Dr. Eng. Silver Mugisha, Managing Director of NWSC – Uganda. In his opening remarks, His Excellency the President of Uganda emphasized the need for a holistic, multi-sectoral and multi-disciplinary approach and the need to shift from water supply to demand-driven practices in dealing with water issues; as the best way forward for effective and sustainable transformational socio-economic development.

During the Symposium held on the first day under three sub-themes: (a) Status of SDG4 in Africa: Are we on track? (b) New and emerging breakthrough innovations to accelerate SDG6 implementation, and (c) Reflections on the way forward to accelerate SDG6 implementation in Africa and how this fits within the World Water Forum it was demonstrated that globally we are on track with the achievement of SDG6. It was however noted there is still room for improvement and measures that can be undertaken to ensure countries particularly those in Africa catch up. There is however need for more dedication and commitment from all stakeholders.

Prior to the official opening, there were three pre-Congress events to create and establish a network among the different players in the water sector. The School Water and Sanitation (SWAS) Forum that took place on 21st February 2020 was addressed by key water professionals from the NWSC and international WASH agencies, to mobilize the young people to improve WASH in their schools, and act as change agents in their homes and communities. The Fourth Forum of Young Professionals in the Water and Sanitation Sector was held on 23rd February 2020, in which keynote speakers urged the young professionals to embrace continuous learning, aim high, and network

extensively to break new grounds in acceleration of water and sanitation services. Concurrently, a group of game-changing Women Water and Sanitation professionals met at their Third forum to brainstorm on the theme 'Women stewards breaking new grounds in Water and Sanitation'. The main message delivered by the guest of honor, Hon Rebecca Kadaga, the Right Honorable Speaker of Parliament of the Republic of Uganda, was that women already in positions of influence should pave way and create opportunities for other women so as to form a critical mass of 'women power' in WASH.

The main part of the Congress had a variety of activities that included three symposium sessions, two morning and two evening plenary sessions, ten side events, and 70 parallel sessions, including 18 in water management, 20 in sanitation, seven in capacity building and innovation, nine in climate change and environment, ten in financing, six in governance and regulation, and six in sanitation financing. For the first time sanitation was emphasized throughout the whole Congress programme. Rich and informed discussions deepened understanding of and proposed solutions to the water and sanitation challenges facing African countries. Over 500 exhibitors showcased the latest water and sanitation technologies as part of the innovation pavilion.

The following points present some of the highlights of the discussions:

General points:

- We are not on track to achieve SDG6 in Africa, but there is time to catch up.
- As Africa's population continues to grow, there is escalating demand and competition for the water resources, whose seasonal and geographical variations are being exacerbated by impacts of climate change.
- The availability and quality of water affect people much more than we think, this resource is important for the well-being and health of populations and we cannot achieve the SDGs if we do not assess the needs linked to water, if we do not manage the resource better at local and even macro levels, and if we do not create new systems with better solutions;

Specifically for utilities and practitioners:

- Many utilities in Sub-Saharan Africa face the challenge of high physical leakages from old water distribution network pipes, and water theft in high-density, low-income urban settlements.
- Although groundwater sources are more resilient to geophysical, hydrological, hydrogeological, and climate changes, there is not enough data for monitoring groundwater, surface water, climate, land use change, abstraction rates, recharge and asset operation/management.
- New pathogenic risks are continually emerging in the water cycle, and the utilities' water quality laboratory facilities are not able to keep up, due to inadequate resources.
- Mechanisms and institutional arrangements for accelerating inclusive and safely managed sanitation services in urban settings should consider the involvement of the private sector in the provision of WASH services across the sanitation chain; and also involve institutions with the mandate of sanitation services delivery to champion and extend their services to these pro-poor urban areas.
- Non-sewered sanitation remains an important option for most African countries, because of the high costs of sewered systems. To stop open defecation and to maintain dignified sanitation practices for improved health, these facilities need to be standardized by streamlining operational procedures to ensure that they are hygienic, accessible, sustainable, and convenient.
- Scientific knowledge and practice approaches enhances decision making by offering information on (a) what parts of the city are at high risk for pathogens, (b) how changes in a particular sanitation stream and technology reduce pathogen emissions, and (c) relationships between disease hotspots and sanitation coverage, among others.

Regarding financing:

- Creditworthiness and a certain degree of financial independence can help leverage commercial finance, reduce sovereign debt, and enable providers to focus on customers. Universal access will not be met with public and concessional finance only. Therefore, blending commercial and public\concessional funds is a critical first step to increase the ratio of commercial to public/concessional funding. Domestic debt is highly preferable to international debt in the water and sanitation sectors.
- Subsidies need to be well-targeted and well-implemented to ensure they reach the intended beneficiaries. The regulator should develop policies and approaches for monitoring subsidies.

Key Recommendations from the AfWA ICE 2020 include:

- To accelerate progress, we need to establish and operate good national monitoring systems to collect data on pollution, places of water shortage, finance, and others on which to base decisions. The AfWA knowledge management platform should be fully operationalized to enable all members to benefit from this.
- Utilities still need to focus on the following to improve water management: (a) data management and decision support system, (b) utilization of and innovations in ICT systems and tools, and (c) well-tailored utility reforms and integrated asset management.
- The sector needs to adopt ICT and technology more broadly. Applicable areas include remote sensing for water resources management; mobile services for customer management; geographical information service, supervisory control and data acquisition (SCADA) systems and telemetry for network monitoring and maintenance and for wastewater recycling for energy and fertilizer production.
- Policy makers, practitioners, and researchers in the water and sanitation sectors should adopt a holistic, multisector, multi-disciplinary and a pan-African approach to deal with water issues.
- Governments need to create an enabling environment for operation of rural water utilities by offering subsidies to reduce tariffs, and grants for major rehabilitation. Governments should set up utility regulators to avoid exploitation of the communities by the private water utilities.
- To effectively manage non-revenue water, utilities should build on the efforts already undertaken by AfWA to strengthen the capacity of utilities to carry out water audits and establish their water balances on a regular basis. Utilities need to compute properly their water losses; and implement an incremental approach informed by cost-benefit analysis.
- Water utilities should work with water user communities to institutionalize water safety planning, which is not only effective but cost-efficient.
- Water sector professionals should develop cross-sectoral collaborations and partnerships in researching innovations for climate change mitigation. Water service providers should network with international peers to avoid ‘reinventing the wheel’ to maximize synergies for innovation partnerships.
- Training and capacity building are at the heart of the development of the water and environment professions with a view to achieving the SDGs in 2030. To reach the SDGs, development capacities must be created. These capacities require human resources, appropriate investments, planning, and strengthening of management and cooperation at local, national, regional, and even global levels.
- There is need to establish and/or strengthen collaborative frameworks (both nationally and internationally) between utilities and academic/research institutions to ensure that capacity building, research, and innovation effectively feed into improved WATSAN service delivery.

- Climatic change awareness needs to be stepped up across the entire WATSAN value and service chain with resilient components incorporated in the design, construction, operation and maintenance phases of all WATSAN projects.
- Sanitation coverage is still well below 75% in most Sub-Saharan countries both for urban and rural areas. Although. There have been some notable successful pilot sanitation initiatives such as: attempts to city-wide inclusive sanitation, Sanitation Operators partnerships, more private public partnerships, new toilet innovations there is need to pursue measures for scaling and acceleration in order to achieve significant gains.
- Non-sewered sanitation remains an important option for most African countries, because of the high costs of sewered systems. To stop open defecation and to maintain dignified sanitation practices for improved health, these facilities need to be standardized by streamlining operational procedures to ensure that they are hygienic, accessible, sustainable, and convenient.
- Mechanisms and institutional arrangements for accelerating inclusive and safely managed sanitation services in urban settings should consider the involvement of the private sector in the provision of WASH services across the sanitation chain; and also involve institutions with the mandate of sanitation services delivery to champion and extend their services to these pro-poor urban areas.
- Various forms of funding for water and sanitation services (commercial loans, concessional loans, equity, guarantees, grants, and the like) need to be considered. Utilities should address challenges, such as weak institutional regulatory frameworks, high financial risks, operational inefficiencies, and poor communication, among others to attract funding from diverse sources. Utilities need to undertake innovative reforms and prepare bankable projects to attract financing.
- Finally, professionals in the African WASH sector should think big, but adopt an incremental development approach.

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RÉSUMÉ ÉXÉCUTIF

Le 20ème Congrès International et Exposition de l'Association Africaine de l'Eau (AAE) (CIE AAE 2020) s'est tenu à Serena International Conference Center, Kampala, Ouganda du 24 au 27 février 2020, et a rassemblé bon nombre de praticiens, chercheurs, partenaires de développement et industriels du monde entier du secteur de l'eau, de l'assainissement et de l'hygiène (EAH). Le thème de ce 20ème Congrès était « *Explorer de nouvelles solutions pour accélérer l'accès à l'eau et à l'assainissement pour tous en Afrique*. » L'AAE organise ses congrès tous les deux ans. Le CIE AAE 2020 a permis d'offrir un cadre de réflexion sur les progrès de l'Afrique en matière de réalisation des cibles de l'Objectif de Développement Durable 6 (ODD 6), d'identifier de nouvelles avancées dans la résolution des problèmes du secteur EAH sur le continent, de discuter des possibilités d'application de la recherche à la pratique et a servi de plateforme pour l'expansion et le développement continus de divers partenariats et associations internationaux, régionaux et nationaux.

Les statistiques mondiales et régionales sur la couverture des services EAH ne donnent pas souvent une visibilité sur les disparités entre les différents pays et au sein d'un même pays. La plupart des pays africains sont en retard dans la réalisation des cibles de l'ODD 6 et plus que jamais, les actions de coopération entre les pays, les secteurs et les disciplines sont urgentes, ainsi que le partage des idées et des ressources pour chercher de nouvelles avancées et innovations.

Le 20ème Congrès de l'AAE a été organisé méticuleusement et avec succès, grâce à l'implication et la pleine participation des structures institutionnelles pertinentes de l'AAE, de l'Ouganda, pays hôte et de National Water and Sewerage Corporation (NWSC), société d'eau hôte en Ouganda. Le caractère intensif du marketing stratégique et de la publicité autour du Congrès ont entraîné un taux de participation record. Un total de 2312 participants a ainsi été enregistré.

Son Excellence Yoweri Kaguta Museveni, Président de la République de l'Ouganda a honoré de sa présence la cérémonie d'ouverture officielle, au cours de laquelle Ing. Abderrahim El Hafidi, Directeur Général de l'ONEE - Maroc et Président sortant de l'AAE a remis les instruments de pouvoir administratif au nouveau Président, Dr. Ing. Silver Mugisha, Directeur Général de NWSC - Ouganda. Dans son allocution d'ouverture, Son Excellence Monsieur le Président de l'Ouganda a mis l'emphase sur la nécessité de parvenir à une approche holistique, multisectorielle et multidisciplinaire et la nécessité de passer de l'approvisionnement en eau linéaire à un service axé sur la demande pour résoudre les problèmes du secteur, en tant que meilleure voie à suivre pour l'efficacité et la viabilité du développement socio-économique transformationnel.

Au cours du Symposium organisé le premier jour sous trois sous-thèmes : (a) Statut de l'ODD4 en Afrique : sommes-nous sur la bonne voie ? (b) Innovations et avancées nouvelles et émergentes pour accélérer la mise en œuvre de l'ODD6, et (c) Réflexions sur les moyens d'accélérer la mise en œuvre de l'ODD6 en Afrique et comment cet objectif s'intègre dans le cadre du Forum Mondial de l'Eau, il a pu être montré qu'au niveau mondial, nous sommes sur la bonne voie pour atteindre l'ODD6. Toutefois, il a également été noté que beaucoup reste à faire, et des actions doivent être initiées pour la mise à niveau de certains pays, notamment en Afrique. Toutes les parties prenantes doivent donc renforcer leur dévouement et leur engagement.

Avant l'ouverture officielle, trois événements pré- congrès ont été organisés dans l'optique de créer et d'animer un réseau entre les différents acteurs du secteur de l'eau. Le Forum de SWAS (School Water and Sanitation) s'est tenu le 21 février 2020 sous la facilitation des professionnels de l'eau clés de NWSC et des organismes internationaux du secteur EAH, dans le but d'encourager les jeunes à contribuer à l'amélioration des services EAH dans leurs écoles, et servir de catalyseurs de changement au sein de leurs familles et de leurs communautés. Le quatrième Forum des Jeunes Professionnels du secteur de l'Eau et de l'Assainissement s'est tenu le 23 février 2020, au cours duquel les principaux conférenciers ont exhorté les jeunes professionnels à adopter l'apprentissage continu, à viser haut et à tisser des réseaux de manière intensive pour innover dans l'accélération de l'accès aux services d'eau et d'assainissement. Parallèlement, un groupe dynamique de femmes professionnelles de l'eau et de l'assainissement s'est réuni à l'occasion de son troisième Forum, pour réfléchir sur le thème « Des femmes engagées innovent pour l'accès à l'eau et à l'assainissement ». Le principal message délivré par l'invitée d'honneur, l'Honorable Rebecca Kadaga, Très Honorable Présidente du Parlement de la République de l'Ouganda a porté sur le rôle des femmes déjà en position d'influence pour ouvrir la voie et créer des opportunités pour les autres femmes, afin de former un grand nombre pour assurer le « pouvoir aux femmes » dans le secteur EAH.

Le Congrès proprement dit s'est décliné en plusieurs activités, notamment trois (03) sessions de symposium, deux (02) sessions plénières le matin et deux (02) en soirée, dix (10) événements parallèles et soixante-dix (70) sessions parallèles, dont dix-huit (18) sur la gestion de l'eau, vingt (20) sur l'assainissement, sept (07) sur le renforcement des capacités et l'innovation, neuf (09) sur le changement climatique et l'environnement, dix (10) sur le financement, six (06) sur la gouvernance et la réglementation et six (06) sur le financement de l'assainissement. Pour la première fois et tout au long du programme du Congrès, l'accent a été placé sur l'assainissement. Des discussions riches et éclairées ont permis de renforcer la compréhension sur et de proposer des solutions aux défis du secteur de l'eau et de l'assainissement auxquels font face les pays africains. Plus de 500 exposants au pavillon de l'innovation ont présenté les technologies les plus récentes du secteur de l'eau et de l'assainissement.

Quelques conclusions des discussions sont présentées ci- après :

Points généraux :

- Nous ne sommes pas sur la bonne voie pour atteindre l'ODD 6 en Afrique, mais il reste du temps pour se mettre à niveau.
- La population africaine continue de croître, au même titre que la demande et la concurrence pour les ressources en eau, dont les variations saisonnières et géographiques sont exacerbées par les effets du changement climatique.
- La disponibilité et la qualité de l'eau affectent les populations plus qu'on ne le pense, car cette ressource est importante pour le bien-être et la santé des populations ; et nous ne pouvons pas atteindre les ODD sans l'évaluation des besoins en l'eau, sans l'adoption de meilleures pratiques de gestion de la ressource au niveau local et global, et sans la création de nouveaux systèmes dotés de meilleures solutions ;

Particulièrement pour les sociétés d'eau et les praticiens :

- Bon nombre de sociétés d'eau en Afrique subsaharienne sont confrontées au problème de grandes fuites sur les systèmes vétustes de distribution d'eau par canalisations et au vol d'eau dans les quartiers urbains à forte densité et économiquement faibles.
- Même si les sources d'eaux souterraines sont plus résistantes aux changements géophysiques, hydrologiques, hydrogéologiques et climatiques, il n'existe pas suffisamment de données pour suivre le changement au niveau des eaux souterraines, des eaux de surface, du climat, de l'utilisation des terres, des taux de captages, de la recharge et de la gestion/l'exploitation du patrimoine.
- De nouveaux risques pathogènes apparaissent régulièrement dans le cycle de l'eau, et les laboratoires de contrôle de la qualité de l'eau des sociétés d'eau ne sont pas en mesure de suivre le rythme en temps réel du fait de l'insuffisance des ressources.
- Les mécanismes et dispositions institutionnelles pour accélérer l'accès aux services d'assainissement inclusifs gérés en toute sécurité en milieu urbain doivent impliquer le secteur privé dans la prestation de services EAH le long de la chaîne d'assainissement, ainsi que les institutions dont le mandat est de fournir des services d'assainissement au-delà des zones urbaines défavorisées.
- L'assainissement autonome est une option à ne pas négliger par la plupart des pays africains en raison des coûts élevés des systèmes d'égouts. Pour mettre un terme à la défécation à l'air libre et promouvoir des pratiques d'assainissement dignes qui favorisent l'amélioration des conditions de santé, ces installations doivent être normalisées par la simplification des procédures opérationnelles pour garantir leur caractère hygiénique, accessible, durable et pratique.
- La recherche scientifique et les approches pratiques permettent d'améliorer la prise de décision grâce aux informations sur (a) les secteurs de la ville les plus exposés aux agents pathogènes, (b) la réduction des émissions d'agents pathogènes comme conséquence des changements des flux et des technologies d'assainissement particuliers, et (c) la relation entre les foyers d'infections virales et la couverture d'assainissement, entre autres.

À propos du financement :

- La solvabilité et un certain niveau d'indépendance financière peuvent permettre de mobiliser le financement commercial, réduire la dette souveraine et aider les prestataires à se focaliser sur les clients. L'accès universel ne sera pas assuré par des financements publics et concessionnels uniquement. Par conséquent, la combinaison de fonds commerciaux et publics/concessionnels est une première mesure indispensable pour améliorer le rapport financement commercial à public/financement concessionnel. La dette intérieure est nettement préférable à la dette internationale dans les secteurs de l'eau et de l'assainissement.
- Les subventions doivent être bien ciblées et adéquatement utilisées pour atteindre les principaux bénéficiaires. Le régulateur doit élaborer des politiques et des approches de suivi des subventions.

Les principales recommandations du CIE AAE 2020 comprennent :

- Pour accélérer les progrès, nous devons mettre sur pied et assurer le fonctionnement de bons systèmes nationaux de suivi de collecte des données sur la pollution, les sites de pénurie d'eau, le

financement et autres informations sur lesquelles axer la prise de décisions. La plateforme de gestion des connaissances de l'AAE doit être pleinement fonctionnelle afin que tous les membres de l'Association puissent en bénéficier.

- Les sociétés d'eau doivent se focaliser davantage sur les aspects suivants pour une meilleure gestion des services d'eau : (a) système de gestion des données et d'aide à la décision, (b) utilisation des systèmes et outils de TIC et des innovations associées, et (c) réformes bien adaptées au sein des sociétés d'eau et gestion intégrée du patrimoine.
- Le secteur doit adopter l'utilisation des TIC et de la technologie de manière plus large. Les domaines applicables comprennent la télédétection pour la gestion des ressources en eau ; le recours aux services mobiles pour la gestion des clients ; les services d'informations géographiques, les systèmes de contrôle de supervision et d'acquisition de données (SCADA) et télémétrie pour la surveillance et la maintenance du réseau et pour le recyclage des eaux usées destinées à la fabrication d'énergie et d'engrais.
- Les décideurs politiques, les praticiens et les chercheurs des secteurs de l'eau et de l'assainissement doivent adopter une approche holistique, multisectorielle, multidisciplinaire et panafricaine pour la résolution des problèmes du secteur.
- Les gouvernements doivent créer un environnement propice au fonctionnement des sociétés d'eau en milieu rural, à travers l'allocation des subventions pour la réduction des tarifs et pour les grands travaux de rénovation. Les gouvernements doivent mettre en place des organes de réglementation des sociétés d'eau pour éviter l'exploitation de la population par les sociétés d'eau privées.
- Pour une gestion efficace de l'Eau Non Facturée, les sociétés d'eau doivent tirer profit des initiatives déjà entreprises par l'AAE relatives au renforcement des capacités des sociétés d'eau pour la réalisation des audits sur les consommations d'eau et l'établissement des bilans hydriques de manière régulière. Les sociétés d'eau doivent calculer correctement leurs pertes en eau et mettre en œuvre une approche progressive fondée sur une analyse coûts-avantages.
- Les sociétés d'eau doivent travailler avec la communauté des consommateurs d'eau pour institutionnaliser la planification de la salubrité de l'eau, qui est à la fois efficace et rentable.
- Les professionnels du secteur de l'eau doivent développer des synergies et des partenariats intersectoriels dans la recherche d'innovations pour l'atténuation du changement climatique. Les prestataires de services d'eau doivent travailler en réseau avec des pairs internationaux pour éviter de « réinventer la roue » et maximiser les synergies des partenariats d'innovation.
- La formation et le renforcement des capacités sont au cœur du développement des métiers de l'eau et de l'environnement pour l'atteinte des ODD d'ici 2030. Pour atteindre les ODD, les capacités de développement doivent être créées. Ces capacités nécessitent des ressources humaines, des investissements et une planification appropriée, ainsi que le renforcement de la gestion et de la coopération aux niveaux local, national, régional, voire mondial.
- Il est nécessaire de mettre en place et/ou de renforcer les cadres de collaboration (au niveau national et international) entre les sociétés d'eau et les institutions universitaires/de recherche pour s'assurer que le renforcement des capacités, la recherche et l'innovation contribuent efficacement à l'amélioration de la prestation de services d'eau et d'assainissement.
- La sensibilisation au changement climatique doit être intensifiée sur toute la chaîne de valeur et de service eau et assainissement, et les mesures de résilience doivent être incorporées dans les phases de conception, de mise en place, d'exploitation et de maintenance de tous les projets du secteur de l'eau et de l'assainissement.
- La couverture en services d'assainissement est encore bien en dessous de 75% dans la plupart des zones urbaines et rurales des pays de l'Afrique subsaharienne. Même s'il y a eu des initiatives

pilotes fructueuses en matière d'assainissement telles que : des tentatives vers un assainissement inclusif à l'échelle de la ville, des partenariats entre opérateurs d'assainissement, plusieurs partenariats privés et publics, de nouvelles innovations en matière de conception de toilettes, il est nécessaire de poursuivre la mise à échelle et l'accélération afin de parvenir à de grands résultats.

- L'assainissement autonome est une option à ne pas négliger par la plupart des pays africains en raison des coûts élevés des systèmes d'égouts. Pour mettre fin à la défécation à l'air libre et promouvoir des pratiques d'assainissement dignes qui favorisent l'amélioration des conditions de santé, ces installations doivent être normalisées par la simplification des procédures opérationnelles pour garantir leur caractère hygiénique, accessible, durable et pratique.
- Les mécanismes et dispositions institutionnelles pour accélérer l'accès aux services d'assainissement inclusifs gérés en toute sécurité en milieu urbain doivent impliquer le secteur privé dans la prestation de services EAH le long de la chaîne d'assainissement, ainsi que les institutions dont le mandat est de fournir des services d'assainissement au-delà des zones urbaines défavorisées.
- Des formes de financement diverses doivent être envisagées pour le secteur de l'eau et de l'assainissement (prêts commerciaux, prêts concessionnels, fonds propres, garanties, subventions, etc.). Afin d'attirer des financements de diverses sources, les sociétés doivent être capables de relever les défis tels que la faiblesse des cadres réglementaires institutionnels, les risques financiers élevés, les inefficacités opérationnelles et la mauvaise communication, entre autres. Les sociétés doivent également entreprendre des réformes innovantes et préparer des projets bancables pour attirer des financements.
- Finalement, les professionnels du secteur EAH en Afrique devraient voir grand, tout en adoptant une approche progressive au développement.

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LA DECLARATION DE DAKAR

Dix sociétés d'eau et d'assainissement de l'Afrique de l'Ouest se sont réunies à Dakar le 22 janvier 2020 dans le but d'évaluer les mesures actuellement mises en œuvre pour atteindre l'ODD 6 en Afrique de l'Ouest. La réunion s'est soldée par la déclaration de Dakar, qui a encouragé les sociétés d'eau à partager avec tous les pays membres de l'AAE les meilleures pratiques pour atteindre les ODD, à organiser au niveau régional des actions conjointes de plaidoyer auprès de l'AAE pour réduire les carences institutionnelles du secteur de l'assainissement par rapport à l'eau potable, et à faire de l'assainissement autonome un levier important de mobilisation du secteur privé en y allouant 30% des budgets consacrés à l'assainissement d'ici 2023.

Lors du Congrès de l'AAE en février 2020, la poursuite des discussions sur la déclaration a permis l'adoption du plan d'action ci-après en vue de sa réalisation :

- La nécessité de pousser la réflexion sur la mobilisation du secteur privé, des sociétés d'eau et des partenaires financiers pour relever les défis de l'ODD 6.
- Développer un plan d'action africain qui encourage la forte implication du secteur privé.
- Modifier le nom de l'« AAE » en « Association Africaine de l'Eau et de l'Assainissement », tout en veillant à ne pas créer de conflit entre l'eau et l'assainissement.
- La nécessité de parvenir à un accord afin de faire passer le budget de l'assainissement autonome des sociétés africaines à 30% du budget total alloué à l'assainissement.
- Partir de Kampala avec une « Déclaration de Kampala ».
- Parvenir à des résolutions opérationnelles.
- Créer un environnement favorable pour la participation du secteur privé à la prestation de services d'assainissement.
- Veiller à l'acceptation de la Déclaration de Dakar par tous les membres de l'AAE présents au Congrès.

Le panel de discussion a porté sur la question suivante : « Que pensez-vous de la Déclaration de Dakar ? » Les panélistes ont relevé les éléments ci-après :

- Le secteur privé est un acteur clé pour le développement des services d'approvisionnement en eau et d'assainissement. La déclaration reconnaît l'importance de la contribution du secteur privé pour la réalisation de l'ODD 6 en Afrique ;
- Modifier le nom « AAE » en « Association Africaine de l'Eau et de l'Assainissement » pour prendre en compte l'importance de l'assainissement.
- Développer une structure de valorisation des déchets/boues de vidange en tant que ressources.
- Concevoir des outils de planification, des normes en matière d'assainissement et des mesures d'application pour parvenir à une prestation de services durable.
- Renforcer les capacités et accroître les investissements dans les sociétés d'eau qui se focalisent nouvellement sur l'assainissement autonome.
- Utiliser les ressources en place pour faire de l'assainissement autonome une activité rentable pour les sociétés d'eau et le secteur privé.
- Les gouvernements devraient proposer aux sociétés d'eau des mesures incitatives pour une meilleure prestation de services aux secteurs les plus mal desservies (pauvres en milieu urbain et secteur informel).
- Il incombe aux autorités locales de prendre les devants en qualité d'autorités de réglementation qui veille à la mise en application.
- Impliquer les autorités locales pour renforcer leurs capacités et leur expertise afin qu'ils puissent mieux remplir leurs missions.
- Procéder à un benchmarking sur les indicateurs de performance pour mesurer les progrès.

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THE DAKAR DECLARATION

A meeting of ten water and sanitation utilities of West Africa was held in Dakar, on 22nd January 2020, to evaluate the measures being put in place to achieve SDG 6 in West Africa. The meeting resulted in the Dakar declaration, which called on the utilities to share best practices to achieve SDGs with all AfWA member countries, implement joint regional advocacy towards AfWA to reduce institutional weaknesses of sanitation relative to safe water, and make non-sewered sanitation an important lever with strong private sector engagement by allocating 30 percent of budgets dedicated to sanitation by 2023.

A further discussion of the declaration at the AfWA Congress 2020 resulted in the following action plan towards its fulfilment:

- The need for a deeper reflection on engagement of the private sector, water companies, and financial partners to meet the challenges of SDG 6.
- Develop African action plan and strong involvement of private sector.
- Change the name of 'AfWA' to 'African Association for Water and Sanitation,' bearing in mind that it is not a battle between water and sanitation.
- Need for an agreement to raise the budget for on-site sanitation for utilities in Africa to 30 percent of the total budget for sanitation.
- Leave Kampala with a "Kampala Declaration."
- Come up with operational resolutions.
- Create a favorable environment for the private sector to participate in sanitation provision.
- Ensure that the Dakar Declaration has been accepted by all AfWA members in the meeting.

The panel discussion focused on "What do you think about the Dakar Declaration?" Panelists noted the following:

- The private sector is a key actor for the development of water and sanitation services. The declaration recognizes the role of the private sector in attaining SDG 6 in Africa;
- Change the name of 'AfWA' to 'African Water and Sanitation Association' to recognize the importance of sanitation.
- Develop a framework that would recognize sanitation waste as a resource.
- Develop planning tools, sanitation standards, and enforcement tools to achieve sustainable service delivery.
- There is a need for capacity building and greater investment in utilities which are going into the new space for on-site sanitation.
- There is a need to use existing resources to make on-site sanitation a viable business for utilities and the private sector.
- There is a need for governments to provide utilities with incentives to serve the under-served (urban poor, and informal sector).
- Local authorities need to take lead as regulators and enforcers.
- There is a need to engage local authorities to build their capacity and expertise to fulfill their role.
- There is a need for benchmarking of performance indicators to measure progress.

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https://www.afwa-hq.org

Proceedings Book of the 20th AfWA International Congress, Kampala, Uganda, 24-27 February 2020

Thème: Explorer de nouvelles solutions pour accélérer l'accès à l'eau et à l'assainissement pour tous en Afrique.

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Challenges and solutions for the eradication of sanitation backlogs in the policy context of Free Basic Sanitation

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ABSTRACT

Despite the constitutional obligation for municipalities to provide Free Basic Sanitation (FBSan) services to all, many people living in informal settlements in South Africa are still lacking access to adequate sanitation facilities. This study used qualitative methods to examine challenges and identify solutions for the eradication of sanitation backlogs in informal settlement of South Africa in the policy context of the FBSan. Findings suggest that the disconnection between the policy and its application in practice has created a deep divide between the service providers and consumers as recipients of the services. Consumers' perceptions and expectations are a major barrier to the acceptance of the sanitation services provided by municipalities, often resulting in violent protests. Service providers face challenges when addressing the disjuncture between what people aspire to and what is possible in providing sanitation services. These findings infer that consumers' needs, sanitation practices and settlement conditions should be thoroughly examined prior to the selection and deployment of sanitation facilities in informal settlements. Consumers should be engaged and involved in the choice of sanitation technologies and facilities. Such engagement should evolve around various sanitation technologies and facilities applicable to the nature and context of informal settlements, so as to address negative perceptions, attitudes and behavior concerning services provided by municipalities. Addressing challenges related to the eradication of the sanitation backlogs in the policy context of FBSan services needs to be grounded in the clarification of sanitation policy, a deep understanding of consumers' needs, challenges and practices as well as settlements conditions, coupled with meaningful consumers' participation at various stages of the decision-making process and coordination amongst institutions involved. Municipalities need to engage all stakeholders (mainly consumers) in order to ensure that the selected infrastructure and service level deployed are consensual. Unless subjective clauses of the FBSan policy are clarified, monitoring, enforcement and accountability mechanisms established and implemented and, consumers are engaged in the decision making processes, the eradication of sanitation backlogs in informal settlements as currently planned may not materialize.

Keywords: Backlog, challenges, consumers, free basic sanitation, informal settlement, policy.

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INTRODUCTION

Access to basic sanitation services is a human right, which is implicitly enshrined in the Constitution of South Africa and is explicit in Section 3 of the Water Services Act, 108 of 1997 (RSA, 1997). The provision of sanitation in South Africa is guided and regulated by three policy documents which are the White Paper on Water Supply and Sanitation (DWAF, 1994), the National Sanitation Policy (DWAF, 1996) and the White Paper on Basic Household Sanitation (DWAF, 2001) which focused on the provision of basic sanitation services in areas with the greatest need, including informal settlements. According to the 1997 Water Services Act (RSA (1997), basic sanitation is 'the prescribed minimum standards of services necessary for the safe, hygienic and adequate collection, removal, disposal or purification of human excreta, domestic waste water and sewage from households, including informal households'. Due to various discrepancies (mainly related to rural and informal settlements) observed in these regulations, a National Sanitation Strategy (DWAF, 2004) in which the FBSan services are set to include basic sanitation infrastructure, health and hygiene promotion and support for operation and maintenance, and guidance for the provision of facilities to informal settlements was published. Due to persisting implementation challenges, the FBSan Implementation Strategy (DWA, 2009) which prescribes the right of access to a basic level of sanitation services for poor households was published. However, these changes did not have sufficient impact on increasing implementation challenges (Dugard, 2016; SAHRC, 2018), thus leading to the review of the 1996 sanitation policy and subsequent publication of 2016 sanitation policy (DWS, 2016) in which discrepancies from the previous policies and regulations were clarified. Despite these amendments, Dugard (2016) and SAHRC (2018) identified several challenges that is believed to hinder the implementation of the policy.

Undoubtedly, the South African government has made great advances in addressing sanitation backlogs since 1994 by extending basic sanitation services to poor households. This has resulted in reducing sanitation backlogs from 52% in 1994 to 21% in 2010, thus achieving the 2015 Millennium Development Goal for halving the proportion of population without sustainable access to basic sanitation in 2008 (DPME, DWA and DHS, 2012). However, the advances made in the provision of adequate sanitation services, addressing outstanding backlogs and sustaining access have been delayed by various challenges. There are still significant backlogs in basic sanitation service delivery (Overy, 2013), with 11% of households lacking sanitation services and 26% at risk of service failure and/or are experiencing service delivery breakdowns (DPME, DWA and DHS, 2012).

Challenges to implementing the sanitation policy have been viewed from perspectives including institutional (in terms of institutions involved and their roles), spatial (in relation to the density of the settlements), economic (in reference to the cost of interventions), social (in terms of consumers' participation), political (in reference to the roles of politicians) and informational (in terms of knowledge of consumers and their needs (Sinharoy et al., 2019). For example, implementation challenges have been attributed to the lack of clarity of the policy (Mjoli et al., 2009) that has led to diverging interpretation on a number of its clauses (Mjoli and Bhagwan, 2008), thus leaving a gap between what consumers want and what municipality proposes (SAHRC, 2018). The policy lacks clarity in terms of service level and standards, guidance because of maximum discretion to municipalities to decide on how and whether to implement the strategy as well as its inability to provide very little in the way of concrete recommendations, and not addressing the issues of appropriate forms of basic sanitation for informal settlements (Dugard, 2016). Furthermore, it remains vague on who qualify for FBSan services (Mjoli and Bhagwan, 2008; Tissington, 2011). There is also a lack of or inadequate institutional arrangements (Mjoli et al., 2009;

SAHRC, 2018) where the responsibility of sanitation service provision is confusingly shared by a number of different players at the national, provincial, and local government levels (Dugard, 2016). These concerns have been compounded by the lack of functional coherence within institutions of policy oversight and delivery, along with serious governance and management-related deficits and the chronic capacity/skills and personnel shortages at all functional levels (Managa, 2012). There is serious lack of capacity related to effective planning, implementation and management of infrastructure (DPME, DWA and DHS, 2012). The challenges have been further attributed to the adoption of top-down supply-driven and target driven approach (Mjoli et al., 2009) to achieve coverage with insufficient or no community participation (SAHRC, 2018). This approach has been criticised for its lack of accountability, inefficiency and, non-responsiveness to demands of poor households and deployment of environmentally unsustainable infrastructure (Mjoli, 2010), and has led to low acceptance and high failure rate of sanitation services provided by municipalities (DPME, DWA and DHS, 2012). Political interference (McGranahan, 2015), difficult settlements conditions characterised by high density, population growth and the influx of foreign nationals (Overy, 2013; Pan et al., 2015) have further deterred the implementation of the policy. Collectively, all these challenges significantly undermine the implementation of the FBSan policy and jeopardise the eradication of sanitation backlogs. Thus prompting scholars to label the FBSan policy as controversial (Dugard, 2016) and failing to achieve expected outcomes (Mjoli et al., 2009) in view the number of people lacking access to sanitation facilities.

While most studies have discussed individual challenges associated with the implementation of the FBsan policy, a few studies have focused on identifying the key challenges, their root causes and concrete solutions to address them. For example, a study by Mjoli and Bhagwan (2008) suggest the review and clarification of certain clauses of the policy and development of guidelines for identification of poor households and national standards for minimum acceptable level of a basic sanitation service. The Overseas Development Institute (2017) and Mjoli (2010) suggest compliance with consumers' participation, effective/good governance, addressing resources and skills shortages, while McGranahan (2015) suggests community participation and Chaplin (2011) the involvement of civic organizations.

The challenges and subsequent solutions suggested by scholars have led to the review of the initial FBSan policy. However, findings by Dugard (2016) and SAHRC (2018) reveal that the 2016 version is still lacking substances and has many gaps. This atusy aims at addressing these gaps by identifying and understanding of challenges associated with the implementation of the FBSan policy and possible interventions to contribute to the eradication of the persisting sanitation backlogs in informal settlements of South Africa. Although this study focused in the Western Cape, the findings are likely to be relevant to informal settlements beyond the Western Cape and South Africa where similar policies, developing country contexts and general sanitation concerns apply.

MATERIALS AND METHODS

Qualitative methods including documentary review, interviews and focus group discussions were conducted with representatives from organizations involved in providing water, sanitation and/or hygiene services and representatives of residents or beneficiaries of these services in three municipal jurisdictions in the Western Cape, South Africa. The sample size of interviews was not intended to be representative. Respondents were identified through the authors' engagement with local leaders in informal settlements. Purposive sampling method was used to select interviewees based on certain criteria including knowledge of informal settlements, involvement is service provision and willingness to participate in the research. The final sample size was achieved

once 'saturation' occurred and no further new information was revealed during subsequent interviews (Charmaz 2006).

The resulting 26 interviews included representatives from municipalities (3), national (1) and provincial (1) Water and Sanitation Departments, civic organizations (5), community leaders (5), advocacy groups (5), researchers (3) and entrepreneurs (3). As this research was seeking input on challenges and solutions related to the eradication of sanitation backlogs, resident lobby groups were interviewed. The project aims and core questions were reviewed for cultural and other sensitivities by researchers with extensive experience in informal settlement and service provision research. The project received ethical clearance from the Cape Peninsula University of Technology's Faculty of Engineering and the Built Environment Ethics Committee (reference dated 2017-10-03). Each interview lasted approximately 40 minutes while the focus group lasted 60 minutes. The interviews were transcribed, and analyzed using content analysis methods. Researchers analyzed the transcripts to identify emerging themes, which were validated by the research team. Quotes from the interviewees are provided in the results section to illustrate the key themes raised. Due to the small sample, interview transcripts were analyzed as a whole, rather than per sector or organization type, which may introduce a limitation to this study. The quotes are attributed using an identity code to avoid identification of specific individuals and organizations.

RESULTS AND DISCUSSION

This section presents and discuss the findings of this study. The interviewees reflected their understanding of the FBSan policy in terms of its impacts on the provision of sanitation services and eradication of the sanitation backlogs. Interviewees are of the view that the FBSan policy has increased the provision of sanitation services and reduced significantly the backlogs since its implementation. "*Since the implementation of the FBS policy, many of our people have regained dignity by accessing to at least adequate facilities*" (Community leader #4). However, these achievements have been viewed by many in terms sanitation coverage which does not necessarily reflect on access. Similar to Dugard (2016) and SAHRC (2018), all interviewees concurred that there are still challenges to implement the FBSan policy and eradicate the sanitation backlogs.

Challenges associated with the provision of sanitation services

The interpretation of the FBSan policy has been identified as one of the challenges affecting the provision of services (Dugard, 2016; Mjoli and Bhagwan, 2018; SAHRC, 2018). In this study, interviewees confirmed these findings by pointing out several subjective clauses of the policy that are read and interpreted differently. For instance, consumers often understood the FBSan policy in terms of the free nature of the service which covers everything from supply, operation and maintenance and even basic issues such as cleaning. This interpretation has developed an entitlement mentality (Pan et al., 2015) where consumers expect nothing else than what they have in their mind. The interviewees reflected their perceptions of the FBSan policy in addressing sanitation backlogs as: "*Although through the number of people lacking access to sanitation has been reduced, the FBSan policy lacks clarity in many aspects including sanitation choice, decision making process and governance arrangements…*" (Researcher # 3).

Interviewees pointed out the disconnection between the policy and its application in practice based on their own experience: "*The policy suggests a cost comparison of various sanitation options and select only option that is accepted by consumers and their willingness to pay…however, choices are made on undisclosed basis without considering this clause of the policy*" (Organisation #2). This disconnection has been previously addressed by Pan et al. (2015). In this study, found that the FBSan policy did not yet develop specific norms and standards related to the types of

facilities, the context of their deployment, and the selection of the recipients of the FBSan services. "*There is no mechanisms to distinguish between recipients and non-recipients of the FBSan service as everyone thinks they are eligible to free services*" (Advocacy group #1).

Interviewees indicated that the compliance with the norms (if developed) can be challenging given the lack of coordination amongst various stakeholders involved in the FBSan service provision. Such lack of coordination has been previously found by Managa (2012) to be a hindrance to the implementation of sanitation policy.

Another challenge was related to consumers' perceptions and expectations and the disjuncture between what people believe and aspire to, and what is possible in providing sanitation services. While Mjoli and Bhagwan (2008) pointed out the lack of standards for the level of service, in this study, interviewees indicated that "*Consumers expect high level of service to equate those living in formal settlements and are reluctant to accept any other solution than what is in their mind*" (Researcher#1). Such expectations (if not met) can cause tension, disregard and misuse of facilities provided my municipalities.

The political marketing and interference were mentioned because of the tendency of politicians to promise services that are or may not be feasible in the context of informal settlements. "*Election promises by politicians always do not translate into reality, hence creating friction between municipalities and residents*" (Organisation #5). While McGranahan, (2015) asserts that political interventions can accelerate the provision of infrastructre, this study has found that such interference has exacerbated consumers' perceptions and expectations, and has led to violent public protests mainly when political promises cannot be translated into practices.

Institutional arrangements were identified as a stumbling block for the failure to implement the FBSan policy. Similar to Mjoli et al. (2009), Dugard (2016) and SAHRC (2018) interviewees demonstrated their view by pointing out the lack of distinction of the roles and responsibilities and collaboration between institutions involved in the FBSan services provision: "*The provision of services is fragmented across the sanitation service unit, solid waste, road and stormwater and, environmental health services…We need to bring all these services together to ensure coordination, but this is not possible because of their conflicting mandate*" (Department #1).

Despite the separation of responsibilities stipulated in the policies, interviewees considered that other stakeholders (mainly consumers, NGOs, CSOs, CBOs) have minimal or no power of decision in the selection and deployment of sanitation services: "*The FBSan gave power to municipality to decide on provision of services with the participation of other stakeholders, but in practice this never happens. There is lack of clear guidance on how other stakeholders should be involved...*" (Organisation #4).

The interviewees described the lack of enforcement mechanisms on the participation of consumers in the sanitation project and decision making process as a shortfall of the FBSan policy. While this challenge has been reported by Mjoli (2010), Pan et al. (2015) and SAHRC (2018), this study confirms that the latest FBSan policy does not uphold the principles of consultation, service standards, access, courtesy, information, openness and transparency as claimed. "*Since there are no enforcement and accountability measures in place, municipalities do not consider any inputs from other stakeholders*" (Leader #5).

These findings concur with SAHRC (2018) and infers that policy cannot be successfully implemented without the participation of consumers and civic organizations. The latitude given to municipalities to regulate sanitation services, choose technology, service level and type of facilities (without pre-defined criteria) creates discontent amongst consumers. Sanitation technologies and facility types differ from one settlement to another, thus prompting

recipients to question the motive behind this difference. "*The minimum acceptable basic level of sanitation as currently stated is subjective and has not often been guaranteed when services are deployed ...Informal settlements located in the same municipality are being provided with different sanitation technologies*" (Leader #2).

This subjectivity has been attributed to the top-down supply-driven approach (UN-Habitat, 2015) which in many instances target coverage with least or no considerations for the needs of consumers and quality of services. The lack of skills, competencies and knowledge amongst those responsible for the service provision were exposed. Similar to Managa (2012), this study found that skills shortage and political appointments hinder the implementation of the FBSan provision. "*Those responsible for the provision of services do not know and understand the dynamic of informal settlements and lack technical and managerial knowledge which are necessary for successful FBSan implementation*" (Entrepreneur #1).

These findings suggest that there are political appointments that take precedence over skills and experience, the likelihood of policy failure is high. Thus appointment should be made based on skills, experience and knowledge of the subject at hand. Internal tension and conflict between the community and their elected leaders emerged as a hindrance for the deployment of services. "*Disagreement between community leaders and residents around the service level and many other issues has delayed the provision of FBSan services in many settlements*" (Municipality #1).

The findings of this study concur with Overy (2013) and Pan et al. (2015) who claim that challenging settlement conditions and patterns and status of the land affect the ability of municipalities to implement sanitation policy by extending services. "*Some of these settlements are located in wetlands or road reserves, far from any existing services, the only option is to give temporary mobile facilities which are often rejected by residents*" (Municipal #1).

Where such services may be deployed, their sustainability remains doubtful due the cost endured by municipalities for their deployment, operation and maintenance. These findings infer that the implementation of the FBSan policy may not be possible when the settlements conditions are not permitting. The difficult settlement conditions and the free nature of the services may prompt municipalities to provide services that do not respond to consumers' needs and settlements' conditions, thus not be sustainable.

Despite the publication of a revised sanitation policy, little has changed in terms of addressing the implementation challenges. The policy has several discrepancies (Dugard, 2016) which according to our findings have led to the continuous implementation challenges. Our findings add to those of previous studies (Pan et al., 2015; Dugard, 2016 ; SAHRC, 2018) by claiming that the FBSan policy, as currently formulated, is leading to confusion and friction between municipalities and consumers, creating expectations and enabling a persistent entitlement mentality.

Suggested solutions for addressed sanitation backlogs

Drawing from the above, interviewees were of the opinion that the revised sanitation policy has not been adequately formulated nor implemented, thus not conducive to the eradication of sanitation backlogs. Its promulgation and subsequent implementation did not bring about the much needed change. There are gaps within each of its seven pillars (as described in the 2016 sanitation policy) which need to be addressed to make the eradication of sanitation backlogs in informal settlements a reality. Suggestions to address these gaps (Table 1) have emerged from our analysis of inputs from interviewees, previous studies and experience.

While some studies (UN-Habitat, 2015) claim that upgrading policies for informal settlements should include their

regularisation and provision of services, this study suggests that success implementation of the FBSan policy relies on the clarification of certain of its clauses, existence of a capable policy championing, good governance and, development of mechanisms for improved collaboration and coordination across institutions, capacity building for those involved in the FBSan provision as well as the meaningful engagement of consumers.

Table 1 Stakeholders' suggestions for addressing sanitation backlogs.

Challenges associated with FBsan policies	**Proposed solutions**
Interpretation of the policies	Identification and clarification of sections of the policy (addendums) Propagation of the policy across communities Training of community leaders and influential individuals
Disconnection between the policy and its application in practice	Development of sanitation delivery monitoring team Development of policy implementation's evaluation criteria Verification and compliance monitoring of the implementation process
Lack of norms and standards to determine service levels, facility types and beneficiaries	Develop service level norms and standards Develop norms and standards to distinguish genuine beneficiaries Disseminate norms and standards to stakeholders and beneficiaries
Consumers' perceptions and expectations	Dissemination of the sanitation policy Develop compendium of available solutions and their context of application and dissemination of information prior to deployment of services Develop interaction mechanisms to liaise with consumers
Political marketing and interference	Depoliticise the sanitation service provision Decision to deploy services to be made by technocrats Politicians to be briefed about sanitation services and solutions
Ineffective institutional arrangements	Identification of institutions involved Development /assignment of roles and responsibilities Development of monitoring and performance criteria Develop and implement accountability mechanisms
Latitude given to municipalities to decide on several aspects of sanitation provision	Enforce the requirements for involving other institutions and consumers Develop a stakeholders' concertation mechanism for decision making Implement accountability measures and system
Lack of skills, competencies and knowledge	Skills and experience appointments process to be implemented (banish political appointments) Training of sanitation implementing agents Regular training, skills audit and performance appraisal to be implemented

Lack of enforcement and accountability mechanisms	Develop enforcement and accountability measures Monitoring of the enforcement and accountability measures Develop measures and actions to address non-compliance
Internal tension and conflict between the community and their elected leaders	Develop mediation mechanisms to ease tension NGOs/CSOs/CBOs to play facilitator and mediation roles Implementation of regular community forums and dialogue
Challenging settlement conditions and patterns, status of the land	Development of a compendium of informal settlement types and conditions – and applicable services to the context The compendium to be disseminated by municipal facilitators and civic organisations Develop alternative solutions for unsuitable or difficult settlements
Sustainability of sanitation services	Develop a compendium of sustainable sanitation solutions Disseminate information about sustainable sanitation solutions Conduct awareness with regard to cost of FBSan facilities

Conclusion

Although the FBSan policy has been recognised as a progressive policy aimed at addressed the serious sanitation backlog, increasing sanitation backlogs in informal settlements reflect gaps between the progressive policy and practical application on the ground. The disconnection between the policy and its implementation in practice has created a deep divide between municipalities and consumers. Translating the FBSan policy into action remains a subject of contention as many municipalities are failing to ensure that consumers are provided with decent basic sanitation facilities. Several challenges including lack of clarity of the policy, lack of coordination amongst institutions, consumers' expectation, lack of standards and skills shortages have impacted the implementation of the FBSan policy. Municipalities are facing challenges to address the disjuncture between what people believe and aspire to, and what is possible in providing FBSan services. Addressing challenges related to the eradication of the sanitation backlogs in the policy context of FBSan services needs to be grounded in the clarification of sanitation policy, a deep understanding of consumers' needs, challenges and practices as well as settlements conditions, coupled with meaningful consumers' participation at various stages of the decision-making process and coordination amongst institutions involved. Unless subjective clauses of the FBSan policy are clarified, monitoring, enforcement and accountability mechanisms established and implemented and, consumers are engaged in the decision making processes, the eradication of sanitation backlogs in informal settlements as currently planned may not materialize.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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Assessment of physical conditions and proposed best management practices of domestic storage tanks supplied by a water utility in a rapidly growing City

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ABSTRACT

The physical conditions of domestic storage tanks for customers supplied by a water utility were assessed in Kampala, a rapidly growing City in Uganda. A longitudinal assessment of 372 storage tanks in 6 sampled administrative Wards with a minimum of 6 samples collected from each site in both wet (March-May) and dry (June-August) months of 2017 was carried out. A set of guiding questions were used to establish tank conditions with a YES or NO response and a range of low to critical risk rating. It was revealed that there was a statistically significant relationship (p=0.001) between tank physical conditions and quality of stored water. Two of six Wards in the City had high levels of water contamination related to domestic water storage tanks with poor sanitary conditions and contaminated water with E. coli. The study therefore revealed that the physical conditions and management of domestic water storage tanks have an effect on water quality. This is important information for a water utility as it means that it is not enough to supply safe water if the quality may deteriorate upon storage at the consumer premises. A routine inspection checklist and consumer guidelines for domestic storage tank management are proposed.

Keywords: Conditions, contamination, storage, tank, utility, water.

INTRODUCTION

Worldwide, water supply systems include storage facilities. However, storage facilities were originally developed for hydraulic system operation and not water quality (Kirmeyer, 1999). Many cities in developing countries are still faced with water supply problems. Intermittent water supply has led some households to install water storage tanks to respond to water breaks (Malanda & Louzolo-Kimbembe, 2014), meaning that water utility customers use water storage facilities like overhead tanks to ensure reliable continuous water supply on their premises.

The US Environmental Protection Agency (EPA) (2002), has argued that despite the installation of water storage tanks, challenges still encountered involve excessive water age, sediment accumulation and loss of disinfectant residual. Similarly, the WHO

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(2017), reported that unsafe water for consumption still exists in storage facilities in the various parts of the world.

The cause of unsafe water in storage facilities has been majorly due to the deficiency in monitoring and management. A study by Craun et al. (2002) in the United States of America (USA) showed that one of the major causes of unsafe water, during water borne disease outbreaks, was distribution system infrastructure deficiencies. Another similar study by Clark et al. (1996), in Gideon, Missouri, documented that a *Salmonella typhimurium* outbreak was due to birds' droppings contamination of a municipal water storage tank. In developing countries, drinking water contaminations are most often due to deteriorated water distribution and storage infrastructure (Chalchisa, Megersa and Beyene, 2017).

According to the Ministry of Water and Environment (MWE) Sector Performance Report 2017, only 72% of this infrastructure is managed in urban Uganda (MWE, 2017). Studies have revealed that water storage tanks have their own impact on quality of water if not properly managed in hygienic ways such as routine cleaning and covering of openings (EPA, 2002; Levy et al., 2008; Schafer and Mihelcic, 2012; Chalchisa et al., 2017). Akuffo et al. (2013) and McLarnan (2017) reported the re-growth of bacteria in water stored during a short or long periods. The bacteria re-growth is especially as a result of high temperatures and low disinfectant residual. For instance, Akuffo et al. (2013) recorded up to 250 CFU/100 mL of FC from water storage tanks in Ghana.

Kampala city in Uganda, a rapidly growing City in the developing world is also faced with the challenge of water quality. Recently, there was an outbreak of typhoid fever in Kampala city (WHO, 2015). The outbreak was linked to the compromised water quality due to reasons including intrusion of contaminants into premise plumbing, mixing of distribution system water with groundwater, or contamination of water during storage in tanks (Murphy et al., 2017).

Cross-contamination in the distribution system and unsafe storage are some of the major sources of water borne diseases (WHO, 2011), but they are mostly overlooked by water professionals. Additionally, most of the storage facilities used in Uganda for domestic water storage are usually located in sites such as roof tops, ceilings, overhead stands and underground. This makes their monitoring, inspection, and maintenance difficult.

Furthermore, it has been reported by EPA (2002) that sanitary conditions such as the presence of sediments, biological growth, and floatable debris/insects in the tank, rodent or bird activity on and around the tank can compromise the quality of water. As such, the quality of water in these storage facilities is questionable since the water utility (National Water and Sewerage Corporation (NWSC)) mandate does not involve monitoring customer's water storage tanks (Water Act, 2000).

In 2015, like in other previous years, NWSC received numerous complaints about contaminated water from its customers, especially those who had domestic storage tanks in Kampala. Over 80% of the water quality complaints raised were of water from storage tanks (NWSC, 2015a). It is therefore important to assess the water quality, tank conditions and contamination levels of domestic water storage tanks of a water utility in a rapidly growing city in the developing world. The study therefore assessed the contamination levels and suggested the best management practices of domestic water storage tanks for NWSC Customers in the Central division of Kampala city.

MATERIALS AND METHODS

Study area

The study was conducted in Kampala District, Kampala capital city, in the Central Division. According to MCHG (2004), Kampala is the Capital city of Uganda that is located in the central region of the country and covers a surface area of 195 square kilometres (Figure 1). The city consists of five Divisions; Central, Kawempe, Makindye, Lubaga and Nakawa.

Study design

A longitudinal assessment of water quality among 372 storage tanks/households in

6 sampled Wards in Kampala District was conducted between March and August 2017. A minimum of 6 samples were collected from each site in both wet (March-May) and dry (June-August) months (UNMA, 2016; World Bank, 2016). Sampling was done weekly, with an average of 17 samples picked each day until 62 samples were obtained from each Ward every month for the dry and wet seasons. March, April and May (18-28 °C; 130-175 mm rainfall) were considered as wet months and June, July and August (16-25 °C; 46-86 mm rainfall) as dry months (UNMA, 2016; World Bank, 2016). This was in order to monitor the impacts due to a change in season on the water in storage tanks.

Population and sampling techniques

The study was conducted in the six Wards of the Central Division of Kampala City, Uganda. Kampala City, a rapidly growing city in a developing country was a good representative of any city in the world (Kulabako et al., 2010). The Central Division (Figure 2) comprises of Central Business District commercial areas, up-scale residential areas, and slums, a combination that is common with most developing country cities in the world. The Central Division also had the most number of NWSC customers with water connections, and had registered the most complaints about questionable quality of water at their premises (NWSC, 2015c; NWSC, 2016). As at June 2016, the Central Division had the highest number (2,570 or 28%) of the water connections in Kampala City. 69% (1,897) of the Central Division connections had domestic water storage tanks (NWSC, 2016).

A preliminary study was conducted to identify buildings/NWSC customers that had a domestic water storage tank of more than two years old in use in each Ward. This period was assumed to be adequate for tank conditions to cause water deterioration, if any, in the storage tanks. Only NWSC customer tanks were considered.

Krejcie and Morgan tables for sample size determination was used to determine the sample size (Krejcie and Morgan, 1970) with p = 0.05; where the probability of committing type I error is less than 5% or p <0.05. There were 1,897 NWSC customer connections in the study area, but the 11,856 water connections in Kampala City Centre were taken as the population size (N), giving 372 connections as the sample size (S) from Krejcie and Morgan tables (320 plus 50 additional connections as a factor of safety). Cluster random sampling was used where the whole geographical population was divided into clusters (Wards). A random sample from each cluster of 62 NWSC customers was performed (Wilson, 2010). This was according to whether the customer had a water storage tank, accessibility and willingness to participate. This sample size was considered statistically significant and representative of NWSC customers in the study area and useful in drawing correct conclusions (Krejcie and Morgan, 1970). At a confidence level of 95% with an error of 0.05, the sample size gave valid and reliable results for a generalized population.

Study Variables

The study considered the following variables (Table 1).

Data collection

Water quality

All samples were tested for physical, chemical and bacteriological properties. Each tank was assessed for various characteristics (tank type, location, age, cleaning frequency in a year, either its covered, cracked or leaking, presence of birds' faecal matter, algal growth and rusty or sludge). This was to determine whether the various characteristics of the tanks had an effect on water quality based on the drinking water Standards (Uganda Standards, 2014) and Guidelines (WHO, 2017). 250 mL Pyrex glass bottles were used for samples of bacteriological parameters and 200 mL plastic bottles were for physicochemical parameters. All containers were prepared as outlined in the NWSC Standard Operating Procedures (NWSC, 2015b).

Sampling, and transportation of samples, was done in accordance with the recommended protocols as outlined by Standard Methods for the Examination of

Water and Wastewater by APHA (2017). Samples were picked from the water storage tanks using a previously sterilized deep sampler. A reference sample of Inflow water from NWSC was also picked alongside (this was not done consistently, but the monthly NWSC water quality results for a study period have been compared to the study findings for statistical comparisons –Table 2). Turbidity, pH, temperature, free and total chlorine were measured onsite as they could change during transportation.

The laboratory experimental work involved determination of physical, chemical and bacteriological parameters of water samples using methods described in the APHA, AWWA and WEF joint publication, "Standard Methods for the Examination of Water and Wastewater" (APHA, 2017).

Turbidity was measured using a handheld turbidimeter (HACH 2100Q with ± 2% of reading plus stray light accuracy), while Free and Total Chlorine were determined using a pocket colorimeter (HACH, Pocket Colorimeter™ II with ± 2 nm wavelength accuracy), DPD and 1% Potassium Iodide (KI) solution respectively. Electrical Conductivity (EC), Temperature and pH were measured using a multi-meter probe (HACH, HQ30D Portable Meter with 0.5 µS/cm, ±0.3 °C and 0.002 pH accuracies respectively). Faecal and Total Coliform counts of the water were determined by membrane filtration with sodium lauryl sulphate broth technique with 47mm diameter, 0.45µm pore size cellulose ester membrane filters incubated at 44 °C and 37 °C for 18 hours for Faecal and Total Coliforms respectively, and results were reported as CFU/100mL (NWSC, 2015b; Rice et al., 2017). For determining the presence of *E. coli* bacteria, *E. coli* agar was used and the same procedure as above was followed with incubation at 37 °C for 18 hours (NWSC, 2015b; Rice et al., 2017).

Association between tank conditions and water quality

A sanitary survey was conducted on each domestic water storage tank to ascertain its physical condition. Seven guiding questions were used to assess sanitary conditions, each carried a maximum risk effect weight of 10.

A *chi*-square test of independence was used to assess the degree of association between study variables while the factors associated with poor quality of water were analysed using multivariate logistic regression model. A p-value of less than 0.05 was considered to be statistically significant in this study.

Data collection instruments

A Data Collection Sheet (DCS) was used to gather information such as; sample point Code, Division, Ward, GPS coordinates and weather conditions, time of sampling, physical, chemical and bacteriological parameters of the water sample.

A Sanitary Inspection Form (SIF) was used to gather information about cleaning frequency, tank age, tank material, and location of the domestic water storage tanks. The SIF also captured the tank conditions of the storage tanks such as; the presence of sediments, biological growth, floatable debris and insects in the tank, rodent or bird activity on and around the tank. For each domestic water storage tank, a set of guiding questions were used to establish tank conditions with a YES and NO response.

Quality/error control

The pre-test of data collection tools on tank conditions was done on a small number of respondents (6 samples from each Ward) for the establishing accuracy of questions and responses, clarity and ease of comprehension, redundancies, omissions and feasibility of implementation. The results of the pre-test helped to refine the data collection instruments to establish their validity and reliability in gathering required information.

Data analysis

All data analyses were done in STATA software version 13.0 (StataCorp, 2013), and ArcGIS software version 10.2.1 was used in geostatistical analysis (ESRI, 2014).

Data was analysed using the Statistics and Data (STATA) analysis package to determine frequencies, percentages, and the relationships between the various variables. The gathered data was coded into themes

before analysis and discussion of the content. A causal analysis concerned with how one variable affects changes in another variable (Kothari, 2004), was used to determine how tank conditions affected water quality in the domestic water storage tanks, one of the research questions. A *chi*-square test of independence was then carried out to assess the degree of association between these variables. Data for electrical conductivity, temperature and total chlorine were not included for analysis as they all met the WHO Guidelines (2017) and Uganda Standards (2014) for drinking water.

Ethical considerations

Permission to conduct research was given by NWSC. Special codes were used to anonymize identity of customers for confidentiality purposes. Customers provided informed consent and their anonymity was observed according to Cohen et al. (2011).

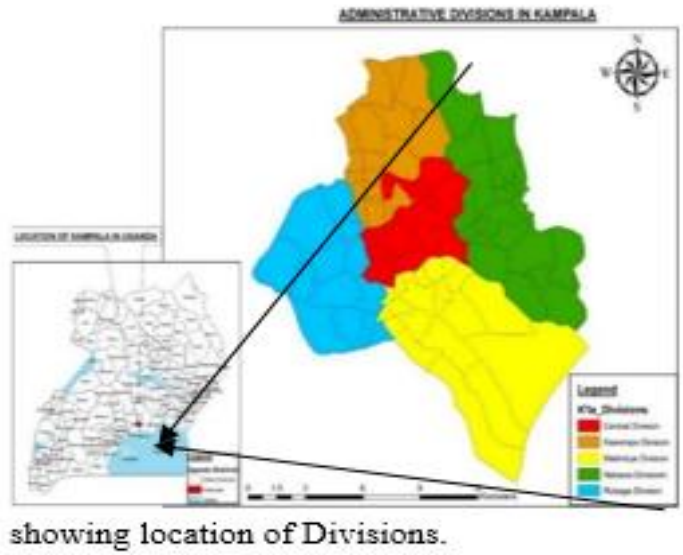

Figure 1: Map of the Study Area in Uganda showing location of Divisions.

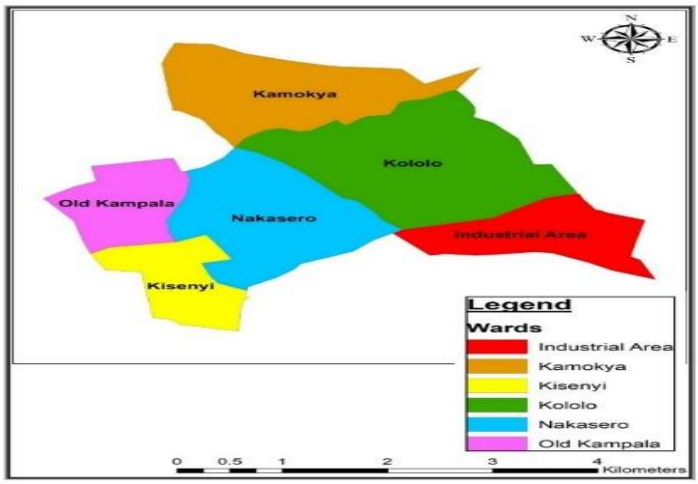

Figure 2: Map of the Study Area in Central Division. Source: Adapted from NWSC (2017).

Table 1: Study Variables.

Variables		Measurement (Unit)	Indicator (Howard and Bartram, 2003; Uganda Standards (US), 2014; WHO, 2017)
Dependent	**Water Quality** (Physical-Chemical and Bacteriological Parameters)	Temperature (°C)	<25
		Electrical Conductivity (µS/cm)	≤1500
		pH (- -)	6.5-8.5
		Turbidity (NTU)	≤5
		Free Chlorine (mg/L)	≥0.2-<0.5
		Total Chlorine (mg/L)	≤5
		Total Coliforms (CFU/100mL)	0
		Faecal Coliforms (CFU/100mL)	0
		Escherichia coli (CFU/100mL)	0
Independent	**Tank Conditions**	Tank Type	Plastic/ Concrete/Metallic
		Algal growth (Presence)	Yes/No
		Rusty (Presence)	Yes/No
		Cleaning frequency in a year (Number)	0-<12
Intervening		Covered (Presence of a lid)	Yes/No
		Cracked Tank	Yes/No
		Age of Tank (Number in years)	≥2
		Location of the Tank	Elevated/Ground/Underground
		Birds' faecal matter (Presence)	Yes/No
		Leaking (Presence)	Yes/No
		Algal growth (Presence)	Yes/No
		Rusty (Presence)	Yes/No
		Inflow water from NWSC pipeline	Meets Uganda Standards and WHO Guidelines for drinking water
		Change in season (In a year)	Wet/Dry

Table 2: Water quality by tank condition of the domestic water storage tanks.

Sanitary Condition (n =372)		Water Quality Conforms to standards				p - value
		Yes		No		
		Number	%	Number	%	
Type of tank	Concrete	23	92	2	8	0.001*
	Metallic	8	44	10	56	
	Plastic	279	85	50	15	
Position of tank	Elevated	257	82	55	18	0.279
	Ground	32	84	6	16	
	Underground	21	94	1	5	
Age of the tank	0 - 5	133	86	21	14	0.019*
	5 - 10	88	88	12	12	
	>10 years	89	75	29	25	
Cleaning frequency	Never	196	77	60	23	0.001*
	Once a year	102	98	2	2	
	More than once	12	100	0	0	
Cracked	No	306	85	54	15	0.001*
	Yes	4	33	8	67	
Leaking	No	303	85	52	15	0.001*
	Yes	7	41	10	59	
Covered	No	4	9	39	91	0.001*
	Yes	306	93	23	**7**	
Presence of algae	No	238	97	9	3	0.001*
	Yes	72	58	53	42	
Rust or Sludge	No	122	97	4	3	0.001*
	Yes	188	76	58	24	

NB: *Significant level, p<0.05. Conforms, Yes or No, to Standards (Uganda Standards, 2014) and Guidelines (WHO, 2017) for drinking water. Samples within the Wet months were considered in generating this composite variable.

RESULTS AND DISCUSSION

In this study, a total of 372 (n=372) samples were picked, with 62 samples from each of the six Wards of commercial, planned residential settlements (Kololo, Nakasero, Old Kampala, Kamwokya) and those with unplanned, industrial settlement patterns (Kisenyi, Industrial Area).

Association between tank conditions and water quality

Tank conditions of the storage tanks

Study findings (Figure 3) revealed that most tanks were made of plastic (88%), elevated (84%), below 5 years old (41%) and not cleaned (69%). A similar study by Aish (2013) showed that plastic tanks are frequently used for domestic water storage. Plastic water tanks are perceived to be durable, safe, and cost-effective and easily available in a wide range of sizes. Most tanks are elevated because domestic water storage tanks are used to maintain the pressure and act as a reservoir during interruptions in supply (EPA, 2002).

The study findings revealed that most of the tanks had rust/sludge (66%), 3% were cracked, 5% were leaking and 12% were not covered while 34% of them had the presence of algal growth. This was a clear indicator that most tanks had not been often monitored and cleaned. WHO (2013) noted that poor handling and management of household water facilities contributed to the contamination of water.

Physical conditions of the water storage tanks and water quality

The study showed that there is an influence of the tank material, presence of algae/ rust/sludge, cleaning frequency, cracked, leaking and uncovered tanks on water quality, whereas the age and position of the tank was not significant (p=0.019 and p=0.279 respectively) (Table 2). Tank characteristics and conditions are affected by the routine management of the tanks and not their age or positions confirming a similar study by Schafer and Mihelcic (2012).

Further, only 9 (3%) of the tanks without algae compared to 53 (42%) of those with algae had water with poor quality, not meeting the Uganda Standards (2014) and WHO Guidelines (2017) for drinking water (Table 2). There was a statistically significant association (p = 0.001) between presence of algae and water quality. Bacteria re-growth is known to impact on disinfectant residual (Duer, 2016), thus the impact of algae on water quality. The study findings further indicated that there is a strong linkage between bacteriological water quality (total coliforms and *E. coli*) and water storage sanitation. This association was also established in a study by Lukubye and Andama (2017).

This study found out that 56% of metallic tanks, 8% of concrete tanks and 15% of plastic tanks had water not conforming to the Uganda Standards (2014) and WHO Guidelines (WHO, 2017) for drinking water. This may be due to the corrosive effect of chlorine on metallic tanks. The US Environmental Protection Agency (EPA, 2002), argues that maintaining water quality in storage facilities is a serious challenge due to factors such sediment accumulation and loss of disinfectant residual.

It was also established by this study that tanks that have never been cleaned 60 (23%) have the highest likelihood of having contaminated water (p = 0.001) because the accumulated sludge affects physical, chemical and bacteriological characteristics of water with an increase in turbidity levels, rapid depreciation of residual chlorine and a favourable breeding environment for algae (Moyo et al., 2004; Schafer and Mihelcic, 2012).

Additionally, 91% of uncovered tanks had water not had conforming to the expected standards (Uganda Standards, 2014) and WHO Guidelines (WHO, 2017) for drinking water. The uncovered tanks provided entry for foreign matter into the water such as birds' faeces that contributed organic matter. A similar study by Johnson et al. (2016) in Lalo Commune, Benin revealed that birds' droppings in water was a major contamination factor to potable water in storage tanks. This was also reported by Schafer and Mihelcic (2012) and Thompson et al. (2003) that cleaning frequency and presence of human or animal faeces were the main

contributing factors for compromised water quality.

Suggested consumer storage tank best management practices (BMPs)

In order to ensure drinking water quality that meets the drinking water standards/guidelines at the consumer point, adequate and appropriate monitoring and maintenance of water storage facilities/tanks is required. Below are extracts of suggested tools and best management practices for proper customer storage tank management developed from the study observations and results.

Monitoring tools

Tables 3, *4, 5 and 6 present the daily, weekly, monthly and quarterly duties respectively by owner, responsible person/technician/entity.*

Inspection protocol

Table 4 *present the inspection p*rotocol.

Risk prediction checklist

Table 5 present the risk prediction checklist.

Study limitations

It was not possible to view clearly inside every elevated storage tank which may have resulted in underreporting likely sanitary conditions of storage tanks.

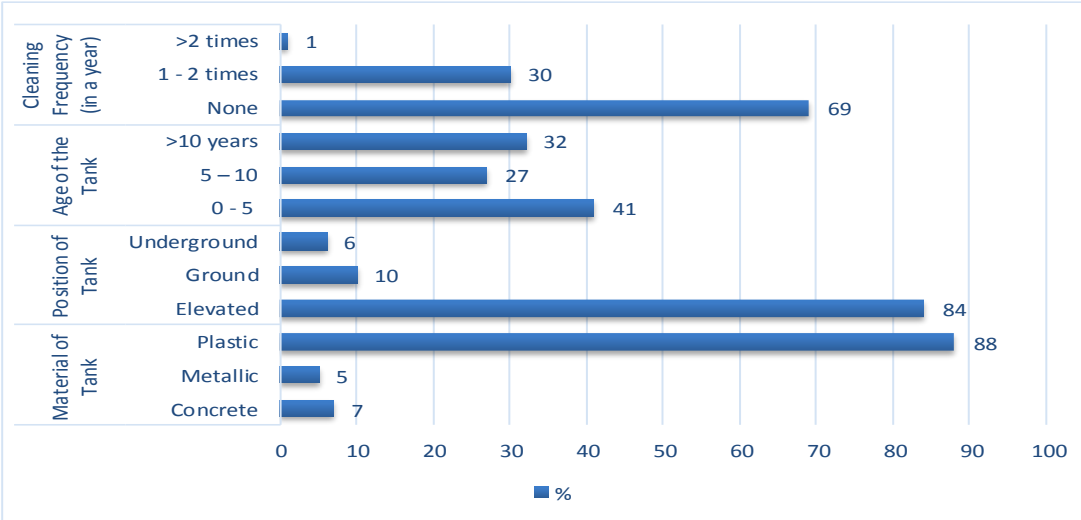

Figure 1: Cleaning Frequency, Location, Material and Age of the Storage Tanks in percentages.

Table 6: Daily Duties (By Owner, Responsible Person).

DAILY CHECKLIST			
Date: ..... Check	Response	Possible Cause	Corrective Action Taken by Owner/Responsible Person
Is the tank overflowing?	Yes ☐ No ☐		
Is the tank leaking?	Yes ☐ No ☐		
Is water level within the required range?	Yes ☐ No ☐		
Are the warning lights in normal operating mode?	Yes ☐ No ☐		

Table 7: Weekly Duties (By Owner, Responsible Person/Technician).

WEEKLY CHECKLIST **Date: .....**				
No	**Defects Check**	**Nature of defect**	**Repairs Done**	**By Who**
1				
2				
3				
Comments:				

Table 8: Monthly Duties (By Owner, Responsible Person/Technician/Entity).

MONTHLY CHECKLIST **Date: .....**					
Water Quality Check					
#	**Water Level (m^3)**	**No of samples**	**Analysis needed**	**Parameters for analysis:**	**Sample Analysis Lab Name**
1				Bacteria (**B**)	.....
2					**Certified for potable water**

Table 9: Quarterly Duties (Owner, Technical/Responsible Person/Entity).

QUARTERLY INSPECTION REPORTING			
Inspection By (Owner, Technical/Responsible Person/Entity):.....		**Inspection Date:**	
Sanitary Inspection Checklist	**Was examination performed?**	**Inspection Results**	
		Unsanitary Condition	**Corrective Action Taken**
Examine all tank openings (if any) such as vents, overflows) if they are properly screened.	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐
Examine for blockage or tears of vents and screens	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐
Examine for any deterioration in the tank walls or	Yes ☐ No ☐	Yes ☐ No ☐	Yes ☐ No ☐

Table 10: Inspection protocol.

GENERAL INFORMATION			
Area:			
Contact Person:	Address:		
Tank ID:			
Tank Location:	Tank Material:		
Tank Age:			
Building Occupancy: □ Multiple Dwelling	□ Commercial	□ Mixed Use	□ Other:

INSPECTION REPORTING		
Was a tank inspection performed? □ Yes □ No	**Inspection By** (Person, Entity/firm): ……	**Inspection Date:** ……

Sanitary Inspection	Was examination	Inspection Results

Table 11: Risk prediction checklist.

GENERAL INFORMATION	
Area:	
Tank Name:	Tank ID:
Tank Location: Tank Material:	
Tank Age:	
Proposed Checking Date:	Actual Checking Date:
Name of Person Checking:	Title of Person Checking:
I certify that this information is complete and accurate:	Date:

OVERALL TANK CONDITION		
Risk Check	**Response**	**Risk Score**
Is the tank covered?	Yes ☐ No ☐	

Conclusion

The study showed that most of the tanks in the study area were plastic (88%), elevated (84%), and below 5 years old (41%). 69% of the domestic water storage tanks were not cleaned, 3% of the tanks were cracked, 5% were leaking, 12% were not covered, 34% had algal growth, and 66% had rust or sludge. There was an impact (p=0.001) of tank conditions on water quality in domestic water storage tanks. Tanks cleaned more than once in a year had all (100%) their samples conforming to Uganda Standards and WHO Guidelines for drinking water. Properly managed tank conditions produced water of good quality. Wards with unplanned and industrial settlements had highest number of tanks with contaminated water levels. The study therefore established that tank conditions of domestic water storage tanks for Customers of a water utility had an effect on the water quality, causing it not to meet the required Uganda Standards and WHO Guidelines for drinking water under certain conditions. Hence, regular multi-level maintenance and routine water quality checks following proposed best management practices should be done.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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Development of optimal pump schedules for improved energy efficiency in water supply systems (case of NWSC)

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ABSTRACT

The water utility in Uganda (NWSC) was under pressure from regulators, environmentalists and board members to reduce energy costs. However, achieving energy efficiency in the water distribution systems of Kampala that is characterized by variable demands and prescribed pressures would be impossible if this utility continued operating on trial and error methods. This research was undertaken in the year 2016-2017 and aimed at exploring how pump schedule optimization could enable NWSC to deal with the challenge of high energy costs and improve water utility performance. In this research, the energy consumption of existing pumps was obtained from historical data, data was diagnosed and based on the diagnostic findings, decision variables were selected and optimal pump schedules were formulated. The formulated schedules were applied to the Gabba Muyenga supply system of National Water and Sewerage Company (Uganda) as a proof of concept. The formulated pump schedules when applied on different pumps classified as models 1, 2 and 3 based on pump flow ratings and motor voltage ratings, results show that scheduling pump operations based on time of the day tariffs enabled NWSC to save about 0.373 Million kWh annually. On the other hand pump scheduling based on pressure, modulation had the potential to reduce water losses enabling NWSC to save 12 m^3/hr equivalent to 0.068 million kWh per year in energy terms without compromising customer service levels and this was only for the established DMA within the case study area and not for the entire NWSC water distribution network. The data presented were obtained through field measurements, statistical analysis and hydraulic design calculations.

Keywords: DMA (District Metered Area), NWSC (National Water and Sewerage Corporation), Gabba Muyenga Supply system, SD (Scheduling Decisions).

INTRODUCTION

The Government of Uganda is promoting energy efficiency in recognition of the benefits among which is energy savings associated with the reduction of electricity consumption for the existing consumers and availing this to meet the incremental demand which would otherwise have to be met by investment. However, reducing energy consumption is one of the global challenges across all sectors and water utilities are not an exception, therefore, water utilities in developing countries have started to investigate the integration of online telemetry and optimal

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control systems to reduce the operating costs. Energy costs for pumping often represent 25-30% of a utility's total operation and maintenance (O&M) costs and also represent the largest proportion of the controllable cost of providing water Savic et al. (1997). In Kampala water, the current total monthly energy consumption for the Gabba Muyenga supply area ranges between 5 million to 5.5 million Kilo Watt Hour (KWH) with the maximum Kilo Volt Ampere (KVA) registered to be in the range of 3500KVA. In 2008, the pumping energy cost accounted for 55% of the total operating expenditure (Mutikanga, 2008), with the increasing global change (population growth, urbanization, climate change & improved living standards), water utilities will even face more difficulties in meeting the energy required to supply water for the increased demand. An increase in demand for energy to move and treat water and wastewater in Kampala is likely to be significant in the next 20 years or so due to stricter health and pollution regulations, which often require additional or more sophisticated treatment that uses more energy. This will progressively increase and affect the corporation's operating margin as well as the ability to and goal of providing funds for service expansion. Therefore, the questions are (1) can the same amount of water be supplied at cheaper energy costs? Or (2) can the same amount of energy be used to supply an increasing demand?

Since energy costs depend on energy usage and the energy rate, to provide a solution to the questions above, (1) pump schedules have to be structured to promote off-peak energy usage with lower rates. However, scheduling of WDS operation in developing countries is such a complex task and consists of applying cost-saving measures whilst aiming at satisfying various constraints on the system. In this study, the most significant savings were made by concentrating the highest power pumping during the night, when electricity is least expensive, and running the variable speed pumps at their maximum efficiency. This led to filling the reservoirs over the night and later emptied during the day, thus reducing the amount of pumping required during peak hours and meeting consumer demand. (2) On the other hand, the need to ensure that reservoirs are maintained at a minimum level for service reliability and the need to minimize wear and tear on pumps due to pump switching meant that identification of suitable optimized pump operation was a complex task that couldn't be solved based on experience and rule of thumb. Moreover, the fact that the water networks had grown organically into spaghetti networks, nonlinear and counterintuitive meant that obtaining an optimal solution was an elusive exercise. As a result, improving energy efficiency through optimal pump scheduling in water supply systems was required.

MATERIALS AND METHODS

The comparative data analysis methodology proposed by Arregui et al. (2013) which rely on existing data and not on costly fieldwork and statistical studies was the basis of the research. Statistical sampling tools (stratified random sampling) and regression analysis techniques were applied to grouped pumps to determine sample sizes and pump operational efficiencies respectively. The research methodology was implemented in four steps in tandem with the stated research objectives, and these included:

(i) Diagnosing the performance of existing booster pumps concerning energy to identify potential for improvement of energy efficiency through pump schedule optimization.
(ii) Formulation of pump optimization schedules for improved energy efficiency.
(iii) Application of formulated schedules on a real case study network and comparison of the impact of the implementation of the proposed pump scheduling routine on energy costs.

Diagnosis of pumps concerning Energy Efficiency

Kampala Water Distribution Supply network consisted of three supply systems namely; Gabba-Muyenga, Gabba-Gunhill and Gabba- Naguru supply system. To diagnose the performance of existing pumps the study focused on the Gabba-Muyenga water supply system simply because it consists of many pumping stations and accounts for about 88% of the total water supplied to the Kampala

metropolitan area. Three different pump models were examined based on volumes pumped (m^3/hr) and this was so because the energy consumed by pumps varies markedly with this parameter (Walski et al., 2003). The pump models formed were (3–300) m^3/hr model 3, (301–800) m^3/hr model 2, and above 801 m^3/hr model 1. The voltage ratings for the respective models were 215V, 400V and 3300V respectively.

Sampling and stratification of pumps

In the sampling of the pumps, asset management data which included delivery heads (m), monthly energy consumptions (kWh) and monthly pumped volumes (m^3) were taken from the utility's database, the pumps were grouped based on water pumped per hour to build more homogenous groups and reduce variability associated with sampling. The sample size was selected according to the research advisors (2006), sample size table recommendations at 95% confidence level considering a 2.5% margin of error for each sub-stratum to have a more reliable statistical judgment derived from sample collection. Analysis of energy use efficiency based on scheduling was based on these sampled pumps to develop optimal schedules for improved energy use.

Analysis of pump data

Carrying out pump operational diagnosis was considered the first critical step in the development of schedules for improved energy use; this was because of the need to quantify the current level of energy use efficiency that would later be used as a benchmark for improvement.

The starting point of the diagnosis was to select samples of pumps for each model considered in this study, to select the samples; a database of pumps' operational records for the years 2012-2015 was obtained from the utility's database. This database consisted of 79 pumps. Of which 17 (21.5%) were model 1 pumps, 12 (15.2%) were model 2 pumps and 50 (63.3%) were model 3 pumps. All pumps considered in this study were fixed speed high-level pumps; it is from these pumps in the database that samples for each model were selected using the equation by *Arreguin-Cortes and Ochoa-Alejo, 1997*. Table 1 shows the number of pumps that were selected and used per model in this study.

The next step was to assess whether pump scheduling impacts the total energy costs (UGX) and specific energy costs (UGX/kWh). From the collected data, the total consumption used at off-peak, shoulder and peak tariff ranges were obtained by summing up the individual pump consumptions in the tariff ranges that fall in the respective categories. This was done separately for each pump strata because each model has got different tariff rates for off-peak, shoulder and peak ranges during the day. Having realized the impact of tariff periods on specific energy costs (UGX/kWh) for each pump model based on historical data, the next step was to use the data to identify the efficiency at which these pumps were operating by considering the specific energy consumption (kWh/m^3). The objective was to identify if any physical operational constraints could be resulting in energy use inefficiencies. The resultant model took the form of the equation.

$Y = \beta_0 + \beta_1 x$ Where Y was the totalized power consumed, X was the totalized water pumped, and $\beta_j (j = 0,1)$ the regression coefficients.

$D = (\beta_1 * 100)$ Equation (4.2) was used to determine the percentage of energy efficiency.

Table 1: Samples considered after screening data.

Pump models	Pumps considered after screening
Model 1	4
Model 2	3
Model 3	11

RESULTS

Based on the time of the day energy use, it was realized that the significant difference in specific energy cost (UGX/kWh) between the periods analyzed was due to lower off-peak energy consumption for the period 06th/11/2012 to 07th/10/2013 compared to the year 7/11/2013 to 08th/10/2014 as detailed in Table 2. Based on these findings it was therefore realized that by rescheduling some of the runnings of model 1 pumps to more off-peak periods, the specific energy cost could be reduced hence improving energy efficiency.

As detailed in Table 3, by Comparing percentages of energy utilization during various tariff periods between model 1 and model 2 for the same periods of analysis, it was also realized that model 1 off-peak energy utilization was less than model 2 off-peak energy utilization and for this reason, the specific energy cost (UGX/kWh) for model 1 pumps were higher than that of model 2 for both periods of analysis.

Also as shown in Table 4, the unit energy cost for model 3 pumps could further be reduced by having more pumps run during the off-peak tariff period if there is adequate storage & supportive system at upstream & downstream sides of the network

Modelling for pump efficiency determination

Model 1 output

Using the operational records for the period 6th-11-2012 to 8th-10-2014 for only model 1 pumps, a regression relationship was developed between power consumed (kWh) and water pumped (m^3). From the results, the specific energy consumption (kWh/m^3) of model 1 high lift pumps detailed in Figure 1 was found to be satisfactory i.e. Energy Efficiency rate of model 1=74.2% for a four combination; however, the goodness of fit of the regression line which is measured using the coefficient of determination (R^2 = 68.1%) was rather low and this is a result of the drop in efficiency as the number of pump combination increased. This was an indication of low output and increased system resistance thus implying that energy costs will increase if more pumps are engaged and the output flow will not necessarily increase.

Model 2 output

Using the operational records for the period 6th-11-2012 to 8th-10-2014 for only model 2 pumps, a regression relationship Figure 2 was developed between power consumed (kWh) and water pumped (m^3). The specific energy consumption (kWh/m^3) of model 2 high lift pumps was high i.e. Energy Efficiency rate of model 2=87.2% for only two pumps in operation. This efficiency rate for model 2 pumps was attributable to the low output of the pumps resulting from a mismatch between the suction and delivery pipe sizes.

Model 3 output

Using the water production and power consumption records for the period 01-12-2014 to 30-12- 2014 for model 3 pumps, a regression relationship Figure 3 was developed between power consumed (kWh) and water pumped (m^3). The results from linear regression relationship could not provide a single uniform efficiency rate for all sampled model 3 pumps, this implied that scheduling based on time of the day tariff and network re-modifications for improved (kWh/m^3) could only apply to individual stations, based on this background pressure controls were allocated in the network by considering the water demand required by users firstly as deterministic and subsequently as probabilistic. These controls were used to trigger pumps on and off.

Impact of scheduling on energy costs and efficiency

To assess the impact of scheduling on model one pumps, the operating costs of the selected pumps based on the Ugandan energy tariff structure was developed as detailed in Table 5, the respective output (m^3) and energy consumptions (kW) for various pump combinations were also computed as shown in Figure 6. To develop an optimized schedule, the operating staff were requested to provide details on how they operated pumps on 28th January 2015 as a benchmark case for the analysis, Table 7 represents the output per day based on the number of operating hours on that day. Using the developed energy optimization tool Figure 5, an optimized scheduled detailed

in Table 8 was developed and this was the appropriate schedule to ensure maximized output at a reduced cost.

It was realized that due to changes in operating hours of different pump combinations there is an additional output of 549 m^3 per day (1%) and a reduction in energy consumption by UGX 59,060 per day. Snapshots of the energy decision support tool are shown in Figure 5.

Impact of model 2 optimal scheduling operations on energy costs

Findings from the diagnosis showed that model 2 pumps were optimally scheduled concerning specific energy costs (UGX/kWh) however the specific energy consumption (kWh/m^3) which is an indicator of system efficiency was high this prompted for detailed efficiency tests. Operational parameters such as delivery head and valve position were monitored to identify the potential for energy conservation measures. From field assessment, it was realized that the delivery pressure of model 2 pumps was controlled to match the rated current of the motor as represented in Figure 4.

Because of the constriction represented in Figure 4, the operating head was 104 m for single operation of pumps and around 112 m for parallel operation of pumps yet the rated head of the pumps was115 m each. Further still, the monitored head after the delivery valve at the pressure vessel was around 92 m representing a pressure loss of around 12 – 23 m depending on the single operation and parallel operation of pumps. It is because of these significant pressure drops that only two pumps were considered for analysis instead of the three pumps that were recommended.

Maintaining the same scheduling protocol because of the low specific energy costs (UGX/kWh) and replacing model 2 pumps with new suitable sized pumps of 95 m head or for the existing pumps changing the delivery pipe size to 600 mm diameter are the recommended solutions to improving energy efficiency the former being preferred because of the cost of implementation.

Impact of model 3 optimal scheduling operations on energy costs

To formulate optimal pump operational protocols, fixed outlet control settings were established, pressure sensors were introduced to control outlet pressure, in automation mode the pump was triggered off any time the system pressure exceeded 56m. The results derived directly from 24-hour simulation runs after pressure reduction is in Table 9. The primary criterion was to ensure the availability of flow at all nodes, throughout the DMA at all times, including the maximum consumption periods. The water and energy saving predictions relied heavily on the accuracy of data before and after the implementation of schedules based on pressure management. Most of the cost parameters were estimated. It is anticipated that the developed schedule acted as a stimulus to promote the use of pressure management strategies as part of the broader energy management policy in water utilities.

Table 2: Model 1 Energy Consumption based on time of the day tariff.

Year	Electricity Consumed (Million kWh)				Amount (UGX, Million)	Cost of Energy per unit (UGX/kWh)
	Shoulder (R1)	Peak (R2)	Off-Peak (R3)	Total		
07/11/2013 to 08/10/2014	5.5 (29%)	4.81 (26%)	8.49 (45%)	18.796	4144.11	220.48
06/11/2012 to 07/10/2013	8.24(48%)	4.63 (27%)	4.14 (24%)	17.006	3949.67	232.25

Table 3: Model 2 Energy Consumption based on time of the day tariff.

Year	Electricity Consumed (Million kWh)				Amount (UGX, Million)	Cost of Energy per unit (UGX/kWh)
	Shoulder (R1)	Peak (R2)	Off-Peak (R3)	Total		
07/11/2013 to 08/10/2014	3.09 (25%)	3.17 (25%)	6.18 (50%)	12.433	2728.10	219.41
06/11/2012 to 07/10/2013	2.17(27%)	2.01 (25%)	3.81 (48%)	7.99	1731.32	216.69

Table 4: Model 3 Energy Consumption based on time of the day tariff.

Station Total	Shoulder Tariff	Off peak tariff	Peak tariff	Fuel	Total Cost (UGX)	Volumes (m3)	SHs/M^3	kWh/ m3	kWh
Station 1	55% (9.9hrs)	23% (1.38hrs)	22% (1.32hrs)	420	19450676	50786	382.99	0.7438	37775
Station 2	49% (8.8hrs)	25% (1.5hrs)	26% (1.6hrs)	700	8462445	20640	410	0.6307	13019
Station 3	54% (9.7hrs)9+	21% (1.26hrs)	25% (1.5hrs)	720	13587938	31670	429.05	0.7483	23699
Station 4	79% (14.22hrs)	11% (0.66hrs)	10% (0.6hrs)	60	2725463	14379	189.54	0.3639	5233
Station 5	44% (7.92 hrs.)	26% (1.56hrs)	30% (1.8hrs)	0	17632847	58657	300.61	0.6364	37331
Station 6	49% (8.82hrs)	23% (1.38hrs)	29% (1.7hrs)	260	7570784	20485	369.58	0.6963	14264
Station 7	48% (8.64hrs)	26% (1.56hrs)	26% (1.6hrs)	80	6517657	22566	288.83	0.5826	13148
Station 8	51% (9.18hrs)	23% (1.38hrs)	26% (1.6hrs)	400	11068286	31136	355.48	0.6616	20600
Station 9	73% (13.14hrs)	10% (0.6hrs)	17% (1.0hrs)	800	4572992	15099	302.87	0.2743	4142
Station 10	76% (13.68hrs)	14% (0.84hrs)	10% (0.6hrs)	0	1555659	4960	313.64	0.6461	3205
Station 11	71% (12.78hrs)	24% (1.44hrs)	5% (0.3hrs)	0	1727369	4724	365.66	0.7356	3475
Total	52% (9.36hrs)	23% (1.38hrs)	25% (1.5hrs)	3440	94872115	275102	3708.248	0.6393	175891

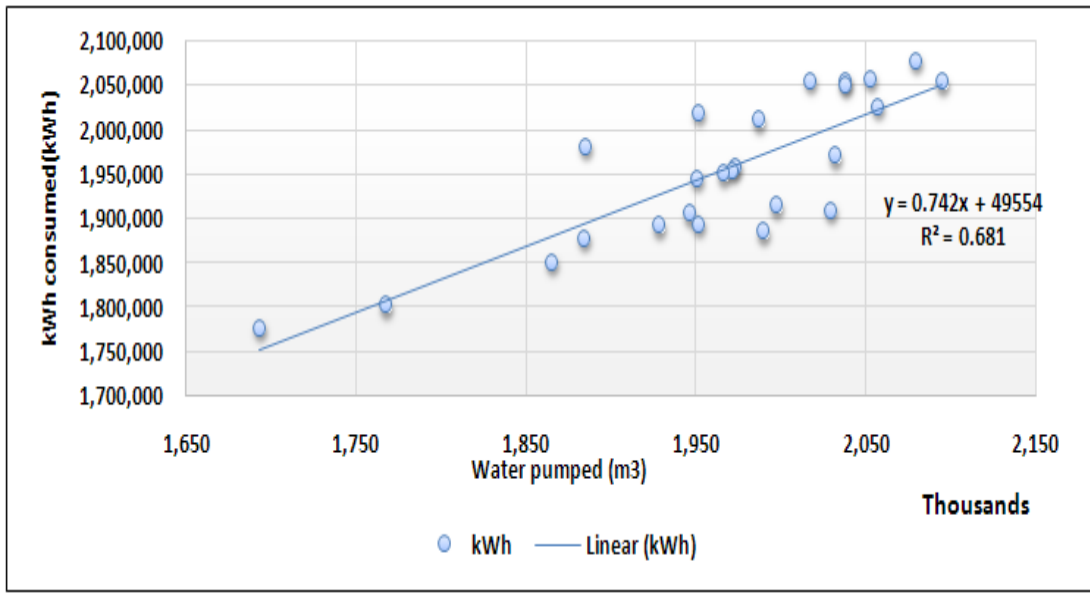


Figure 1: Energy Efficiency rate of model 1.

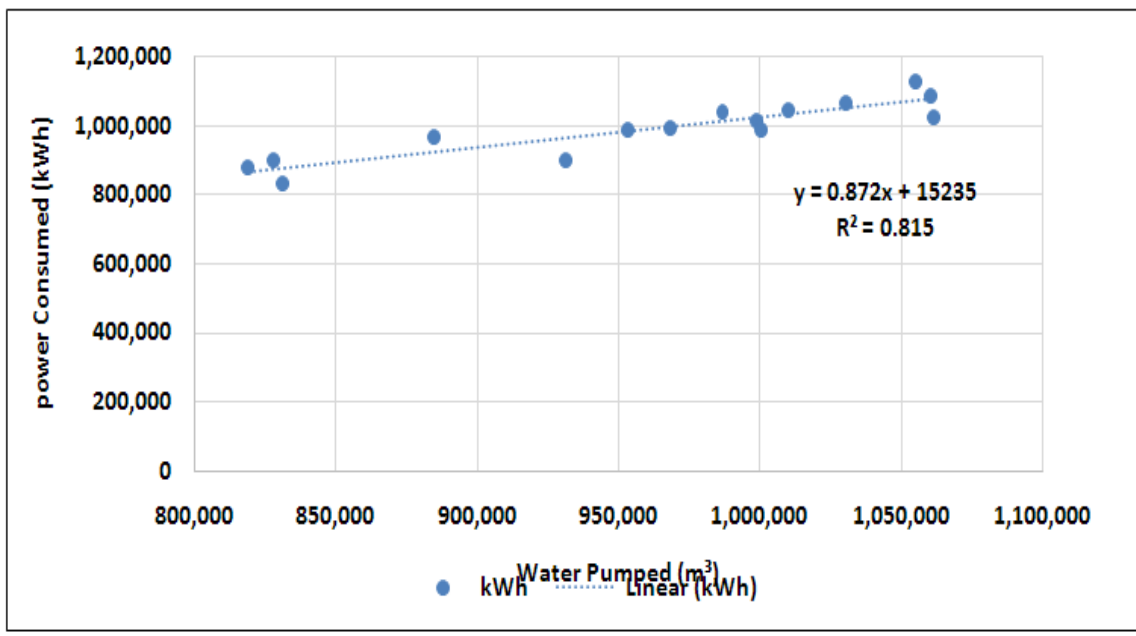


Figure 2: Energy Efficiency rate of model 2.

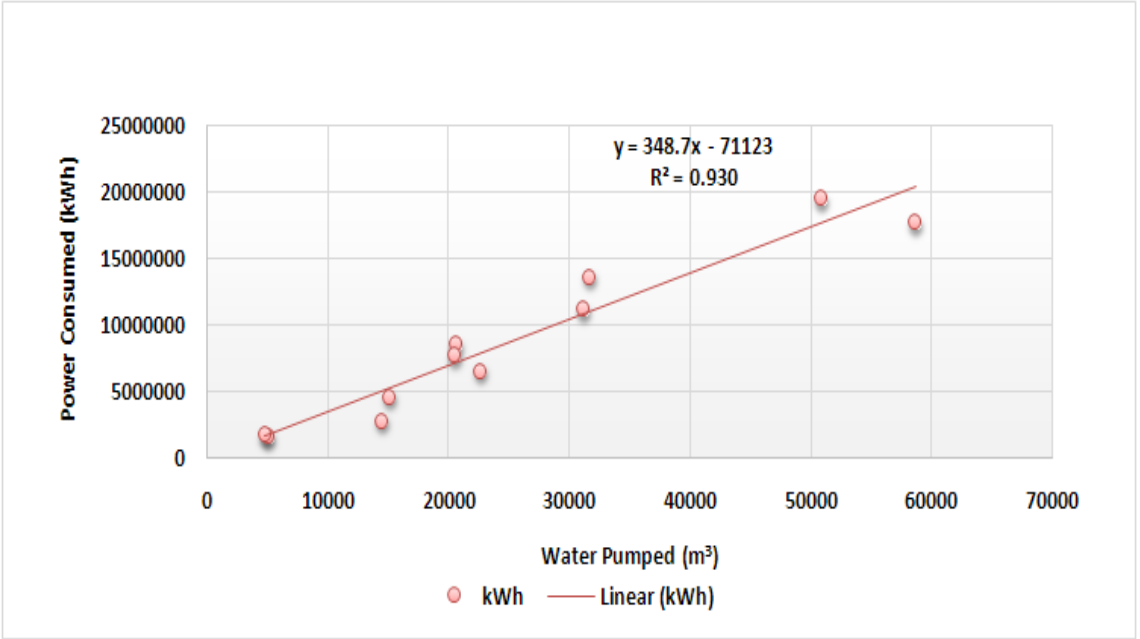


Figure 3: Energy Efficiency rate of model 3.

Table 5: Operating cost of pumps based on tariff structure.

Tariff	**Operating Cost in 000'UGX/hr**		
	Operation of 2 pumps in parallel	Operation of 3 pumps in parallel	Operation of 4 pumps in parallel
Shoulder	214.861	307.549	394.351
Peak	266.151	380.965	488.488
Off-Peak	150.860	215.939	276.885

Table 6: Details of Output and energy per day.

Measured parameters	Operation of 2 pumps in parallel	Operation of 3 pumps in parallel	Operation of 4 pumps in parallel
The output of pumps,m^3/hr	1788	2454	2925
Power consumption, kW	1115	1596	2046

Table 7: Cost and output per day based on number of operating hours (as of 28th January 2015).

Present Scenario				
Tariff	**shoulder**	**Peak**	**Off peak**	**Total**
Operation of 2 pumps in parallel (hrs.)		6		6
Operation of 3 pumps in parallel (hrs.)	11		6	17
Operation of 4 pumps in parallel (hrs.)	1			1
Output per day, m^3	29919	10726	14724	55369
Energy per day, kWh	19602	6690	9576	35868
Total Cost per day, UGX	3777392	1596903	1295633	6669928

Table 8: Optimized schedule (cost and output per day based on number of operating hours).

Developed optimization schedule				
Tariff	**Shoulder**	**Peak**	**Off peak**	**Total**
Operation of 2 pumps in parallel (hrs.)	2	6		8
Operation of 3 pumps in parallel (hrs.)	10			10
Operation of 4 pumps in parallel (hrs.)			6	6
Output per day, m^3	25662	10726	19531	55918
Energy per day, kWh	16594	6690	13424	36708
Total Cost per day, UGX	3197664	1596903	1816301	6610868

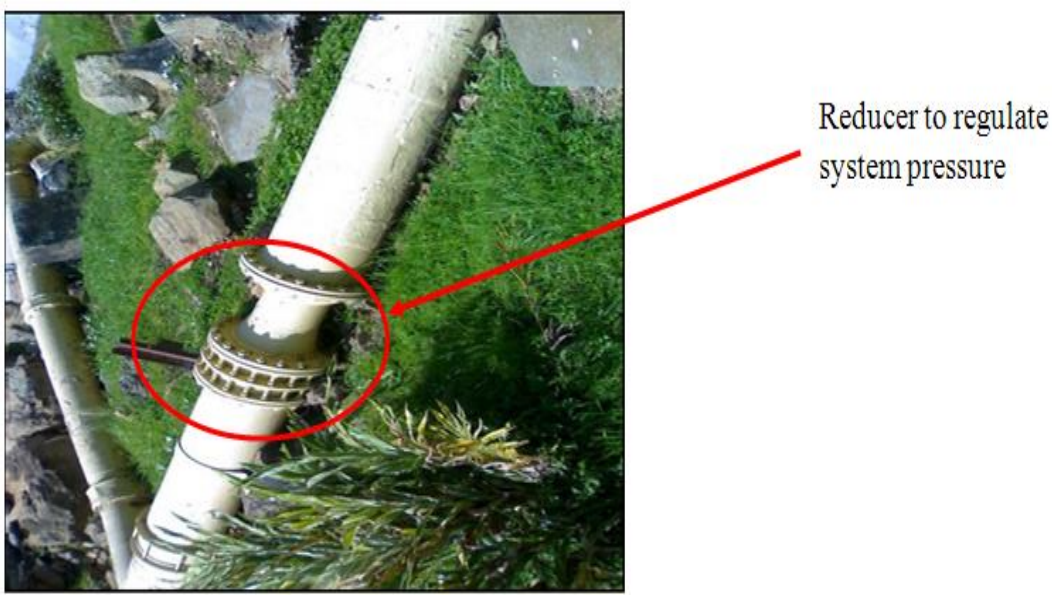
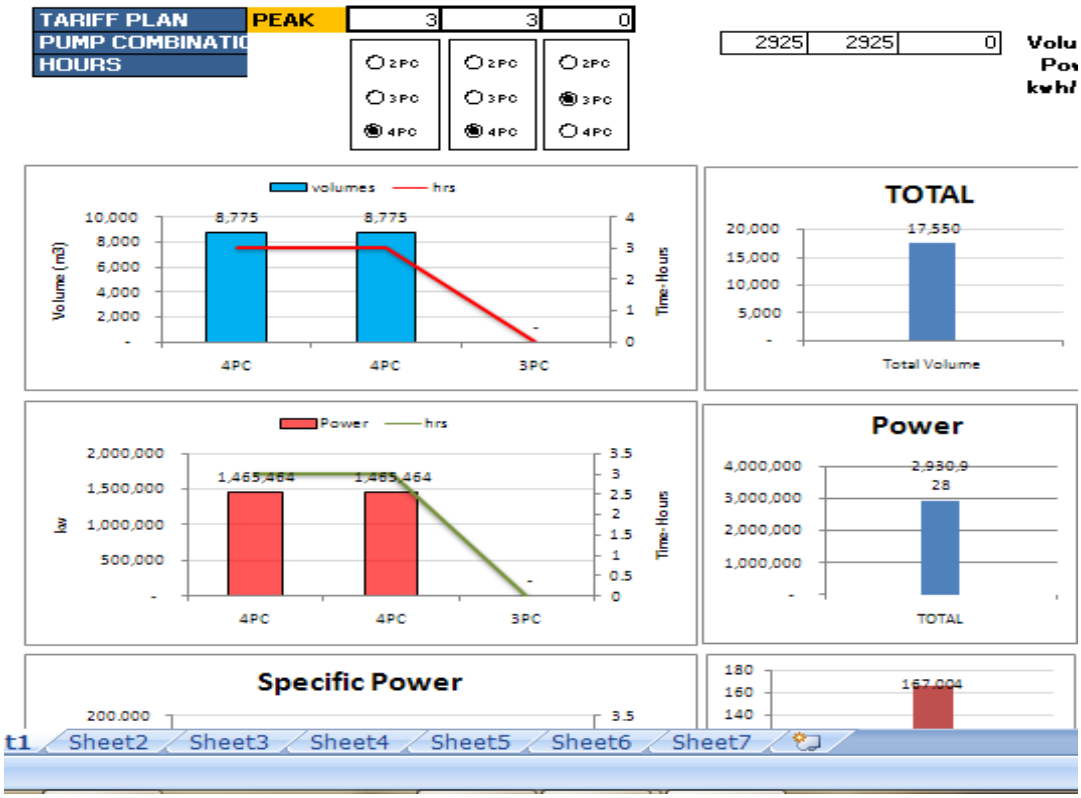


Figure 4: Energy Reducer to regulate system pressure for model 2 pumps.

Table 9: The results derived directly from 24-hour simulation runs after pressure reduction.

Hour	DMA Inflow (m3 /hr) Before PM	DMA Inflow (m3 /hr) After PM	Water savings(m3 /hr)	Energy savings in water Pumpage (kWh)
0-1.	88.704	65.844	22.86	14.0194436
1-2.	89.496	66.42	23.076	14.1519108
2-3.	91.692	66.384	25.308	15.5207384
3-4.	93.276	67.536	25.74	15.7856728
4-5.	93.384	67.572	25.812	215.8298285
5-6.	89.496	67.14	22.356	13.7103535
6-7.	81.072	64.584	16.488	10.1116617
7-8.	59.544	55.26	4.284	2.62726582
8-9.	51.84	50.148	1.692	1.03765961
9-10.	51.624	50.184	1.44	0.88311456
10-11.	53.136	51.408	1.728	1.05973747
11-12.	56.808	52.92	3.888	2.38440931
12-13.	57.672	53.676	3.996	2.4506429
13-14.	62.892	56.088	6.804	4.1727163
14-15.	66.204	57.816	8.388	5.14414231
15-16.	69.984	59.868	10.116	6.20387978
16-17.	67.644	58.428	9.216	5.65193318
17-18.	68.22	58.968	9.252	5.67401105
18-19.	62.856	55.512	7.344	4.50388426
19-20.	60.372	53.964	6.408	3.92985979
20-21.	68.652	59.076	9.576	5.87271182
21-22	77.868	61.056	16.812	10.3103625
22-23	80.208	62.064	18.144	11.1272435
23-24	84.06	63.432	20.628	12.6506161
Daily Mean ($\bar{x}$.)	71.95	59.4	12.564 m³/hr	185kWh
Standard deviation (s)	14.3	5.8		



Recommended and current pump schedule protocol at peak tariff

Table 10: Energy Option details for different pump combinations

Pump Schedule combination at peak period						Two pumps running (Hrs.)	Three pumps running (Hrs.)	Four pump running (Hrs.)	Water pumped (m^3)	Total energy consumed (kW)	Specific energy(kW/m^3)	Total energy cost (USh)	Specific Energy cost (USh/m^3)
0	0	0	0	0	0	6	0	0	10728	6690	0.62360179	1596906	148.854
0	0	0	0	0	1	5	1	0	11394	7171	0.629366333	1711720	150.2299
0	0	0	0	1	1	4	2	0	12060	7652	0.634494196	1826534	151.4539
0	0	0	1	1	1	3	3	0	12726	8133	0.639085337	1941348	152.5497
0	0	1	1	1	1	2	4	0	13392	8614	0.643219833	2056162	153.5366
0	1	1	1	1	1	1	5	0	14058	9095	0.646962584	2170976	154.4299
1	1	1	1	1	1	0	6	0	14724	9576	0.650366748	2285790	155.2425
0	0	0	0	0	2	5	0	1	11865	7621	0.642309313	1819243	153.3285
0	0	0	0	2	2	4	0	2	13002	8552	0.657744962	2041580	157.0205
0	0	0	2	2	2	3	0	3	14139	9483	0.670698069	2263917	160.1186
0	0	2	2	2	2	2	0	4	15276	10414	0.681722964	2486254	162.7556
0	2	2	2	2	2	1	0	5	16413	11345	0.691220374	2708591	165.0272
2	2	2	2	2	2	0	0	6	17550	12276	0.699487179	2930928	167.0044
1	1	1	1	1	2	0	5	1	15195	10026	0.65982231	2393313	157.5066
1	1	1	1	2	2	0	4	2	15666	10476	0.668709307	2500836	159.6346
1	1	1	2	2	2	0	3	3	16137	10926	0.677077524	2608359	161.6384
1	1	2	2	2	2	0	2	4	16608	11376	0.684971098	2715882	163.5285
1	2	2	2	2	2	0	1	5	17079	11826	0.692429299	2823405	165.3144
0	0	0	0	1	2	4	1	1	12531	8102	0.64655654	1934057	154.3418
0	0	0	1	1	2	3	2	1	13197	8583	0.650375085	2048871	155.2528
0	0	1	1	1	2	2	3	1	13863	9064	0.653826733	2163685	156.0762

Figure 5: Snapshots of the energy decision support.

DISCUSSION

Power savings are predominantly from shifting pumping from high day tariffs to lower night tariffs. It is estimated that energy savings for the first twelve months of operating four models 1 pump in parallel were approximately UGX 20.35million. This amounted to approximately 10 per cent of the energy bill and in energy; terms represent a saving of 0.0348Million kWh

I. Assessment and comparison of pumping cost per unit of water i.e. UGX/000'm^3 and kWh/000'm^3 indicate the level of efficiency of the subsystem and system on a whole. In the absence of such monitoring/measuring tools, the operational and maintenance (O&M) personnel are handicapped to further improvement options for energy efficiency.

II. Suitable pump sizing results in significant energy savings, in this study resizing model 2high lift pumps, represented energy-saving benefits of about 0.338 million kWh, In financial terms at UGX 220.7/kWh: UGX 74.6 Million can be realized, however resizing pumps involves incurring investment costs. In this study, an estimated UGX 250 Million for three Pumps was calculated. Simple payback period analysis indicated that the cost could be recovered in about 4 years

III. Significant energy cost savings can be obtained by introducing pressure management, lowering average network pressure in the network by 7 from 63 m to 56 m reduced leakage by about 5 % of its original value. The fixed-outlet pressure settings were considered more appropriate for water utilities in the countries that are just starting to work with pressure modulation systems. They are relatively cheap in terms of investment cost and easy to operate and maintain. It is predicted that further reductions could be realized in future by adopting "intelligent" PM.

Conclusion

It is recommended to optimize operation of pumps utilizing time of the day tariff so as to save the operating cost. It is recommended to implement intelligent pressure management using optimization techniques to maximize pressure reductions without compromising customer service levels. It is recommended to install suitable sized pumps for operations, during this study it was observed that for model 2 pumps the actual head required for pumping was around 90 m whereas the rated pump head was 115 m. Mismatch in head by 25mexisted which resulted for pumps to operate in throttled condition. Therefore, pumps operating with throttled valves should be replaced with suitable sized pumps; this will result in energy savings.

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Improving governance in the water sector through social accountability, communication and transparency

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ABSTRACT

Network for Water and Sanitation (NETWAS, Uganda) in June 2008, with support from the World Bank Institute and in partnership with the Ministry of Water and Environment, Bukalasa Agricultural college which supplies the college and neighbouring homesteads with piped water, Wobulenzi Town Council which signed a contract with Trandit Limited a private company that supplies Wobulenzi core urban and a few peri urban wards, has been implementing a governance project. The aim of this project was to promote better governance in the water sector in Uganda by fostering transparency, social accountability and efficient communication activities. Two social accountability tools known as the Citizen's Report Card (CRC) and the Community Score Card (CSC) have been used. A communication strategy was also developed to ensure better information flow between users and providers and other key stakeholders of the project, the process and the outcomes. This project engaged communities within the Town Council to work in partnership with the service providers to improve the quality of water service delivery. After two years of implementation what is clear is that social accountability works in improving water provision and improving relations among stakeholders.

Keywords: Community score card, citizen report card, service providers, users.

INTRODUCTION

The Program for improving governance in water sector through Social Accountability, Communication and Transparency in Uganda was conceived by the World Bank Institute (WBI) which is the capacity development arm of the World Bank that helps client countries share and apply global and local knowledge to meet their development challenges. The above project was implemented from June 2008 to March 2010. The project launched a citizen's report card (CRC) communication and transparency processes in the District of Luweero, Wobulenzi town council to obtain citizen's experiences on water supply. Two private water service providers operated in Wobulenzi: (i) Trandit Ltd (Trandit), serving urban Wobulenzi and some peri-urban areas; and (ii) Bukalasa College, serving the local agricultural college and its surrounding households. The two providers operated under contracts. Bukalasa provided water as a private operator, whereas Trandit functioned under an output-based aid contract with the MWE (Box 2). Trandit's contract with the MWE granted the service provider a subsidy

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if it installed 200 new connections within five years of the Contract's execution date.

The CRC was used to provide feedback to the private water operator's agencies on the strengths and weaknesses of their work. It was also used to draw attention to the problems highlighted and facilitate cross fertilization of ideas and approaches by identifying good practices. The communities in Wobulenzi were able to monitor and improve the quality of water provision through constructive feedback to water providers using the community score card tool.

Network for Water and Sanitation (NETWAS) Uganda, a national NGO, has been coordinating the initiative on behalf of the wider multi stakeholder. This paper will promote better governance in the water sector in Uganda by fostering transparency, social accountability and efficient communication activities.

MATERIALS AND METHODS

The general approach for the programme was participatory and consultative involving relevant stakeholders at each stage of implementation. The reason for adopting a participatory consultative approach was to build consensus around issues and inculcate ownership of suggestions and recommendations. This program in the water sector in Uganda was implemented through the following components:

Application of Citizen Report Cards (CRC) and Water Quality Test

The CRC tool can be used to understand the degree of transparency in local governance while creating a baseline against which progress in improving transparency can be measured (Maria Gonzalez de Asis et al., 2002). This was applied twice in the lifespan of the project at the beginning and at the end of the programme.

Household Listing

At the beginning of the project, NETWAS randomly sampled 14 villages in Wobulenzi town council. The purpose of the household listing was to obtain a comprehensive updated list of all households in the village without any omission or duplication since the census data was not adequate. The 14 sampled villages all in Wobulenzi town council were listed. The household listers moved from one household to another to be sure all the households were listed in each village. Below is a matrix showing the total number of villages and total number of households in each village and a comparison with the original data set provided.

Baseline Survey

The baseline survey was conducted in Wobulenzi Town Council in Luwero District. A total of 14 LC1s/zones were covered and 487 households interviewed in core and peri-urban areas. The names of the LC1s/zones and the number of households covered in each were as shown in Table 2 on the next page.

A stratified sampling plan used to conduct the baseline. In brief, the households in Wobulenzi Town Council were stratified into two strata; Core –Urban and Peri-Urban. A representative sample was drawn from each of the stratum. The selection of the households for interview was based on a comprehensive listing of households which was undertaken in 2008. A table of random number was used to select the samples (households) for the interviews.

The data collection methods included Questionnaire interviews with households and key in depth key informant's interviews with the members of the Water Boards and service providers. The questionnaire and structured interview guide designed and pre-tested were consequently used.

The quantitative data generated through questionnaire interviews was entered in EPI INFO and was later exported to SPSS for further cleaning and analysis. The qualitative data from key informant interviews with Water Board and service providers was entered in excel worksheet where it was summarized and analysed using thematic procedure and content analysis.

Stakeholder analysis

A comprehensive participatory stakeholder analysis was done to identify the

specific target groups with whom the program would be carried out and to ensure that the diagnosis takes account of local knowledge and understanding, to make the interests of key stakeholders transparent, and to build ownership of the programme. A household listing exercise was carried out to determine the number of households in the project area.

Water quality tests

NETWAS conducted water quality tests in September 2008 and December 2009, coinciding with CRCs. The following measures of water quality were tested:

- pH, which affects the taste and corrosiveness of the water.
- Turbidity, which indicates the cloudiness of the water and affects the risk of infectious disease transmission.
- Electrical conductivity, which affects the taste and freshness of the water.
- Fecal coliform, which indicates recent fecal pollution and the potential risk of contracting infectious diseases.
- Total coliform, which affects the general hygienic quality of the water.

Nine tap stands, four water tanks, and the main outlet of Bukalasa were tested. In Wobulenzi Town Council, a total of four kiosks, two tanks, four tap-stands, and four boreholes were tested. Finally, in Sikanusu zone, one unprotected spring in Wobulenzi (used by a sizeable portion of the population when the flow from tap stands is irregular) was also tested. Water sources were first tested on-site for physical quality using portable electronic meters. Samples were then collected in sterilized glass bottles for laboratory testing supervised by NETWAS. Community focus groups were convened by NETWAS to raise public awareness of the importance of maintaining the cleanliness of water points to avoid contamination, and to demonstrate how to collect, transport, and store drinking water.

Application of Community Score Cards (CSC)

A CSC is a qualitative monitoring tool used for local-level monitoring and performance evaluation of services by communities. The CSC process is a hybrid of the techniques used in CRCs, social audits, and community driven monitoring and evaluation (Ksirker et al., 2009).

The CSC is a tool used to (a) collect feedback from users and service providers of public services (in this case, water) (b) disseminate this information to citizens/users and service providers so they have reliable information about how the community they serve views the quality and efficiency of service delivery (c) both the community and service providers work on a plan to improve service. It also provides the community and the service providers an opportunity to compare service delivery in their community with other communities, or across districts and municipalities or throughout the country. The methodology emphasizes the active dissemination of information in order to create awareness and enhance community participation.

The specific purpose of the CSC in the water sector was to (i) identify priority areas for improvement in the quality of services (ii) generate suggestions for improvement in water services; and (iii) for water users and providers to work jointly to identify and implement specific actions to improve the quality of water services provided at the local level (Figure 1).

Stakeholders

The main stakeholders in the CSC process were: (i) the water users – Direct water users, individual households and institutional (schools, health centers, private businesses), community leaders – LCs, Religious leaders, (ii) water service providers – Kiosks, compound taps, main suppliers (public, private and NGOs), (iii) Duty bearers - Water management boards, District Water department, Town Council, etc. (iv) Potential supporters and donors- World Bank, NGOs, Religious Institutions, Influential citizens, Politicians.

The CSC process covered 7 areas:

(a)_Training and equipping facilitators – Impartial Facilitators with the right attitude towards users and service providers were selected for the training. Two trainings were

held in which 7 NETWAS staff, 5 of Wobulenzi community facilitators, 7 representatives from Wobulenzi Town council, one manager from Trandit, 6 representatives from Bukalasa College and other NETWAS partners such as Buso Foundation (2), Ministry of Water and Environment, World Bank water sector of Uganda, Community Development Facilitation unit of the government, DWD, and Luwero District.

The aim of the training was to "Equip facilitators with skills and knowledge to enable them confidently facilitate the CSC process", Secondly the training was to cultivate the appropriate attitude between facilitators and stakeholder groups, ensure support and active participation of all relevant stakeholders - especially the water board, and to promote ownership and sustainability of the process.

The training covered the following sessions:

(i) **Facilitation skills** for effective facilitation of participatory processes with adult partners: Topics included what motivates and de-motivates adult participants; adult listeners, working with men and women, the roles of a facilitator, listening skills, and some weaknesses of participatory approaches.

(ii) **Preparation for meetings:** These covered two levels: community representatives' selection and invitation, identification and preparation of meeting venue and logistics; and Workshop preparations which covered rehearsing through the process, preparing meeting charts, developing checklists and team roles.

(iii) The CSC process: This session involved walking through the process with detailed illustrations and simulation exercises for the community, service provider and interface meetings.

(iv) **Field practice:** This was carried out in 6 communities served by both Wobulenzi Town council and Bukalasa Agricultural Collage: Sikanusu, Gwaffu, Kigulu, Kitante, Kikasa and Bukalasa Upper West.

(v) **Participants reflection, lessons and emerging issues**: Each day begun with a session for participants to reflect, share lessons and key questions that they still had.

(b) Community meetings – The main purpose of the community meeting was to allow users of the water service to share their experiences, identify priority areas for improvement as well as the roles and contributions they can make towards improving governance, management and delivery of water services. In the meetings because the group was big each representatives of special user groups, each were given room to discuss issues that are most important to them. The focus groups included, women, men, vendors, children, business and local leaders/religious leaders. Each group had its own score card presented during plenary. Communities selected 3 priority areas and 3 programmes should be progressed within 6 months and using available resources. The output of this meeting was a **Community Score Card**.

© *Service providers meetings* – This meeting was held to give service providers the opportunity to discuss and share their views on the quality of services and factors that they think or know affect their effectiveness. They also proposed activities they think can help improve service delivery, management and governance. The main output of this meeting was a Service Providers Self Assessment Card.

(d)Interface meeting – The purpose of the CSC process in the water sector is to promote social accountability, transparency and dialogue between water users and suppliers. The interface meeting did exactly that: bringing together all stakeholders after their independent meetings, to present, negotiate, agree on a joint position, and develop a joint plan of action. The main output of this meeting was a **Joint Action Plan.**

(e) Implementation: NETWAS provided seed money to each community as contribution toward kick starting implementation. Each decided what to use the money for. In this stage, the communities together with the service provider worked on implementing the agreed work plans in the joint action plan.

(f)Reflection and learning meetings –This was Participatory monitoring process to encourage learning and fine-tuning the process to make it more effective. The meetings enabled actors in the action joint plan to take off time to review progress and draw lessons from their own activities. These meetings were held for each of the 6 communities and the activities as spelt out on the charts where reviewed. The group also selected some sites to visit for validation where needed. The group selected sites they wanted to visit. The output of this meeting is a refined joint action plan.

Evaluation: The main purpose of the evaluation component was to carry out a joint "as we go" evaluation of the program. This was done in two parts:

Firstly, an evaluation survey was conducted to monitor changes in quality and performances of providers. Questionnaire interviews were conducted with the households and service providers. These were similar to what was covered in the first survey. The methodology and sample used were similar like in the first survey. Issues on availability and access to water sources, distance, water use, cost, quality of water services and community participation, information and communication aspects were analysed. A second water quality survey was also carried out on the same water sources.

The participatory evaluation was done after implementation of the community score card implementation.

Specifically the methodology included:

- Plenary sessions in the 6 communities to review and establish the status of activities on the ground. All the six communities and representatives from the two service providers (Wobulenzi Town Council and Bukalasa Agricultural College) participated.
- Focus groups to review and score against the progress made, and provide specific perceptions of the various groups, including the service providers. There were largely three groups: men, women and youths. The children were not invited as they were in school. Overall 130 people participated.

(a) Sample household survey to verify and triangulate information generated through focus groups. The evaluation team did not have predetermined questions. The questions were identified based on issues raised during the focus group and plenary discussions. However, in principle most questions were based on the indicators identified during the interface meetings. Homes visited were also randomly selected by the groups. The principle was for each group of 2 -3 persons to interview between 3 -5 homes. The number of homes visited per community depended on the number of participants willing and able to participate in the home visits. Some participants were elderly, some sick and others not able to read and write. Since participants were mostly semi-illiterate, the questions had to be simple, few, focused, and of interest to the meeting. About 188 households were visited: Sikanusu – 24; Gwaffu – 33; Kigulu – 19; Kitante- 53; Kikasa - 30 and Bukalasa Upper West and East.

(b) National Workshop: A national level workshop was held to share experiences of the CSC process with stakeholder in the water sector and to discuss and devise ways of scaling up the approach to other areas of Uganda.

Communication

NETWAS, WBI, and the WorldBank's CommGAP program jointly oversaw the development of a communication strategy for Uganda's water program. The strategy aimed to foster trust among water sector stakeholders and facilitate dialogue and knowledge sharing

regarding the importance of social accountability and transparency. Among the channels of communication developed were:

- Regular meetings with stakeholders, including officials from the MWE, local government authorities, water service providers, and users' associations;
- A bulletin developed by NETWAS in English and Luganda;
- Posters in high-traffic areas;
- A blog to share real-time information with stakeholders;
- A Facebook account to share program information with other donors and water experts;
- A Web site created by WBI to provide easy access to all materials generated by the project, such as surveys questionnaires and results, reports, and evaluations;
- A video produced by NETWAS-WBI;
- Local forums to host presentations on the project, including during the quarterly;
- Action-learning meetings convened b.

Table 1: Listed villages and total number of HH.

No	Village	Total number of households listed	Comparison with census figures 2002
01	Gwafu	074	46
02	Morden	155	162
03	Katale	234	161
04	Kigulu	265	202
05	Bukorwa Central	126	243
06	Upper West	034	55
	Upper East	021	
	North Central	015	
07	Lutamu	150	206
08	Luzzi	351	352
09	Nakadingidi	828	533
10	Kikasa	126	151
11	Katikamu Proper	175	167
12	Kitante	252	235
13	Kikoma	270	
14	Sikanusu	110	83
	14 villages	**3076**	**2596**

Table 2: LC1/zones and number of households covered.

	Core-urban		Peri-urban	
	LC1/ Zone	No. households	LC1/ Zone	No. households
1	Bukolwa Central	36	Katale	33
2	Gwafu	36	Kigulu	34
3	Katikamu	36	Kitante	33
4	Kikasa	36	Luzzi	35
5	Kikoma	36	Modern	33
6	Lutamu	36	Nakadingidi	33
7	Upper West	37	Sikanusu	33
	Total	**253**		**234**

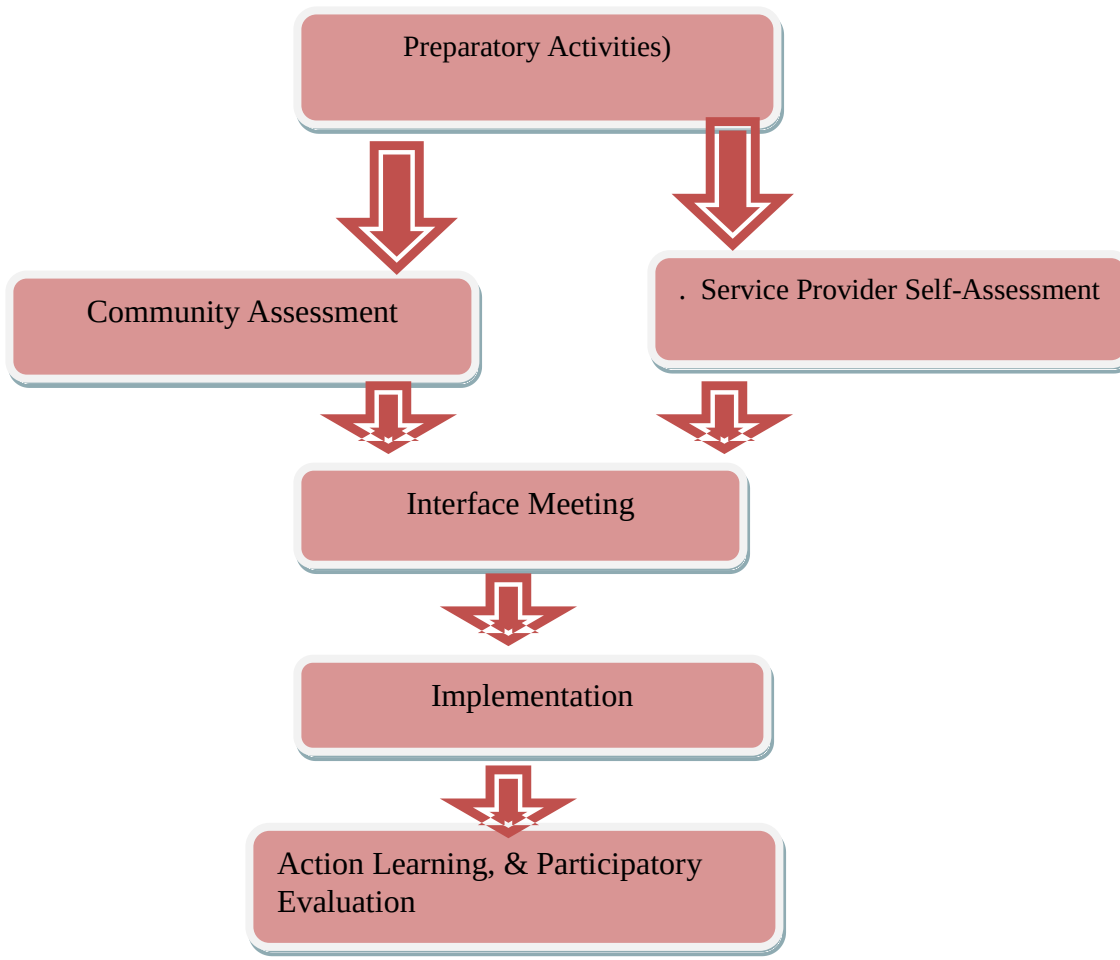

Figure 1: The community Scorecard Process.

RESULTS AND DISCUSSION

Citizen's report card

Comparing the first and second baseline survey, there were notable improvements in some. Citing a few examples;

The general finding was that there was an increase in the percentage of **households with piped water** in the house and as a result, there was a general reduction in the percentage of households using other water sources. This was partly attributed to the OBA service provider (Trandit) who was extending piped water connections to households which did not have at the time of the baseline.

In terms of **location**, the findings show that in Peri-Urban areas, there was an increase in percentage of households with piped water in their houses to 41% from 25% at baseline (August, 2008). However, there was no change in Core-Urban areas and the percentage remained the same (5%). The increase in percentage of households with piped water in their houses may be attributed to repair of the pump by Bukalasa College as a result of the community score card action plan and the additional connections provided by the OBA service provider (Trandit). Table 3 shows the comparison of the results by location.

Conversely, **the reliability of the water supply** by Trandit did not improve much. This was evidenced by the reduction of the percentage of households with piped water in house reporting water flowing 24 hours which reduced to 13% from 21% at the baseline. There was slight increase in the percentage of households that reported water flowing 24 hours at the Kiosks/ Public Stand pipe to 20% from 14% at the baseline. This may be attributed to water system breakdowns and power failures.

- There was no significant change of pH from the along the distribution system. This may be attributed to the boreholes having continuous supply of water and routine maintenance.
- All the results of faecal coliform were satisfactory unlike the previous tests where unsatisfactory results were obtained in the Cylindrical water tank and Sakaza tap-stand in Bukalasa and Kitante B/H. Apart from water from the unprotected spring which was found still contaminated, the rest of the water points had water that was safe for drinking and domestic use. This can be attributed to the cleaning of all the tanks of Bukalasa water supply and their cover tops properly fixed during the community score card implementation.
- Whereas results indicate that there was an improvement in the water quality in the two water supplies, it was observed that people still need a lot of sensitization in the proper transportation and storage of drinking water.
- During the water quality survey, it was also observed that there was no discontinuity in water supplies. Water was constantly flowing and there were no complaints from the community. Therefore, discontinuity which may increase the livelihood of contamination as the risk of back – siphoning into the distribution network is increased when pipes are at lower pressure than the surrounding soils was avoided. Discontinuity was noted in both water supplies during the first survey.

Community score card

While the OBA approach provided the Trandit Ltd with an incentive to improve the service provision by getting paid only after delivering a service, there was no such incentive system for the Bukalasa Agricultural College. However, through the implementation of CRC and CSC users were given a voice to help improve service provision by providing feedback to the private operator and the Ministry of Water based on their own experiences with the service provision of these two water providers.

But perhaps more effective in Wobulenzi was the selection and participation of Water Board (WB) members in the training. Two members Mr. Stephen Sawa Luboowa, the Chairperson and Ms. Sarah Nagujja who have not only been supportive of the process, but have taken over the facilitation and lobbying from within the WB for openness and inclusiveness of users in the water sector activities. They have also been instrumental in securing resource for the meetings that have begun between the WB and communities, and have so far covered 10 out of 20 communities over the 6 months. It should be noted that these were the first community meetings ever held by the WB.

Use of the community score card encouraged service providers to meet with members of the community and give feedback to any issues. Results of the CSC were shared with the community, district/Town council and at national level. NETWAS would facilitate, provide technical advice, supervise and support them technically during the process. A communication strategy to share information with the community as well as with providers and local, Town council and national authorities was implemented (Tables 4 and 5).

The aim of the program was to promote better governance in the water sector, by fostering transparency, social accountability and effective communication/dialogue, with the overall goal of improving services to the users. Progress towards these was discussed at the end of the programme.

Transparency

The working definition of transparency was given as service providers freely sharing with all involved the annual budgets, budget allocations and providing feedback on expenditures. During the Joint Action plan, Transparency between Bukalasa Collage and Users was dropped when the collage explained their status as private suppliers exempts them by law to disclose their incomes and expenditures to the communities. As such transparency was not discussed in Upper West (Collage staff quarters). The case of Wobulenzi Town Council: it became clear to water users through the evaluation meetings that, in principle attending budget meetings was a right for all citizens. The indicator selected to measure progress towards transparency was "Water Board of both Wobulenzi and Bukalasa to hold meetings in the communities" to officially inform the communities about the budgets and work plans, as well as any expenditures (Table 6).

Both Boards (Wobulenzi and Bukalasa) embarked on the meetings to also cover Transparency and Social accountability. Unfortunately for the Wobulenzi Water Board, two of the pilot communities (Kigulu, and Kitante) and partly Kikasa had not been visited by the time of the evaluation as is reflected in the scores and reasons given by these communities.

Bukalasa WB also through the Zonal representatives visited communities primarily to cater for the community priorities of training on sanitation, provide information on the billing system, how to reach the plumbers (by phone) and where the water office of the college was located.

All communities saw NETWAS community meetings as educative. This was because water users for the first time participated in discussing and prioritizing water issues and met some of the WB members. The meetings also provided a safe forum for communities to share their concerns and to be listened to. Table 7 below summarizes the community perspectives on transparency before and at the time of evaluation.

Social Accountability

Social Accountability was defined as "All stakeholders knowing, understanding, performing and being accountable for their roles and responsibilities". This was

envisaged to provide the basis for mutual accountability between water providers and users in relation to their specific responsibilities. Communities identified meetings with the Water Board, in which roles and responsibilities, performance against these are discussed as good indicators for social accountability. This was because the Water Board (Wobulenzi) had not been introduced officially to communities, and communities were confused about the relationships and roles of the various bodies involved with water: Town Council, Water Board, Trandit (private operator), and the Kiosk operators.

The Water Board (Wobulenzi) as a result of the CSC process, embarked on a program to visit all 20 communities in 5 Parishes under the Town council, including Bukalasa College and the communities served by the college. The purpose of the visits was the WB to introduce themselves, inform users about their roles and responsibilities, facilitate the nomination of Water User Committees (WUC) and begin to respond to issues communities wanted to learn about the water services. Ten out of 20 communities were visited before the budget the WB was working with run out. It was unfortunate that three of the pilot communities – Kigulu, Kitante and Kikasa were among those that missed. Table 8 summarizes the community perspectives before and at the time of the evaluation.

Effective communication (dialogue)

Effective communication focused on information flow between Service providers and users. Prior to the CSC process, the formalized mechanism of communication was through the local councils and to a limited extent, during delivery of water bills by Trandit employees. These were not working to the satisfaction of stakeholders. As indicated above, users did not understand the roles of the various bodies and especially as Trandit the private operator was new. Communities served by Wobulenzi Town council made several suggestions to ensure timely and effective communication: Use of the loud speakers - also called *radio Wobulenzi*, public notice boards, written letters/notices, meetings and door to door delivery of information.

At the time of this evaluation, Radio Wobulenzi was actively used, Trandit staff also shared information when distributing bills as well as Kiosk operators, some communities like Gwaffu used written notices and a public notice board provided by CODI (NGO working on transparency- they promote local sharing platforms commonly called "Kimeza"). However, in those communities where the WB meetings had not reached, communities were not yet aware of the new communication mechanisms and many did not respond to radio Wobulenzi for lack of awareness. Table 9 below provides the community perspectives on progress made in the area of communication.

Overall, progress had been made on the part of the Water board on addressing the three issues of governance.

Figures 2 – 4 below show that in Sikanusu and Gwaffu were meetings were held communities' perspectives on performance improved more that 40%, while Kigulu and Kitate there was a drop in the area of social accountability. In the case of communities served by Bukalasa College, a lot of improvement was reflected in the area of communication of about 30%, slight improvement in Social accountability and transparency in Kikasa, while Upper west and East (staff quarters) improvement recorded only under communication. This further confirms the necessity of meetings to share information with users, which had not been a practice of the service providers.

Table 3: Water quality results for the first and second survey.

NO	Name of Tap stand, Tank	Turbidity (NTU)		PH		Conductivity (µs/cm)		TDS (mg/l)		E-Coli (cfu)		T -Coli (cfu)	
		1st Survey	2nd Survey	1st Survey	2nd Survey	1st Survey	2nd Survey	1st Survey	2nd Survey	1st Survey	2nd Survey	1st Survey	2nd Survey
	NON OBA BUKALASA WATER SUPPLY												
1	**Elevated Water Tank**	7.42	1.45	6.69	6.59	172.2	218	81	103	36	0	**160**	0
2	**Mian Source Outlet**	1.45	1.06	5.74	6.40	175.2	230	83	109	0	0	0	0
3	**Cylindrical Water Tank**	5.79	7.18	6.11	6.56	167.9	194.5	79	92	**TNTC**	0	**TNTC**	0
4	**Underground Water Tank**	1.84	1.25	5.87	6.40	181.8	250	86	118	0	0	0	0
5	**Dining Hall Water Tank**	1.29	1.28	6.02	6.69	302	290	143	138	0	0	0	0
6	**Castella Hostel Tap**	0.74	1.23	5.7	6.29	304	291	144	138	0	0	0	0
7	**Paradise Hostel Tap**	0.99	1.27	6.07	6.60	280	295	133	140	0	0	0	0
8	**Washington Hostel Tap**	0.78	1.08	5.94	6.43	164.8	306	78	146	0	0	0	0
9	**Kafu Hostel Tap**	1.35	1.06	6.07	6.42	255	315	121	150	0	0	0	0
10	**Compound Tapstand**	1.05	0.92	5.72	6.15	212	318	100	151	0	0	0	0
11	**Kagera Hostel Tap**	0.85	1.32	6.02	6.29	284	286	135	136	0	0	0	0
12	**Sophie Tap stand**	0.78	–	5.77	–	304	–	144	–	0	–	0	–
13	**Sempembwa Tapstand**	1.19	1.02	5.72	6.46	279	279	132	132	0	0	0	0
14	**Sakaza Tapstand**	1.63	0.72	6.41	6.64	174.4	197	82	93	**156**	0	**TNTC**	0
15	**Dining Hall Tap**	1.07	1.38	6.13	6.67	302	289	143	137	0	0	0	0
	OBA WOBULENZI TOWN COUNCIL WATER SUPPLY												
16	**Sump (Tank)**	0.86	2.23	6.01	6.58	313	346	149	164	0	0	16	0

17 **Kisawe Kiosk B**	0.77	1.14	6.49	6.89	310	359	147	171	0	0	8	0
18 **Wobulenzi Abattoir Tap**	1.46	5.3	6.70	7.24	304	321	144	152	8	0	20	0
19 **Kitante A. Kiosk**	0.96	1.24	6.46	6.99	313	357	149	169	4	0	26	0
20 **Reservoir Tank**	11.3	1.78	6.56	6.98	323	362	153	172	6	0	12	0
21 **Semaganda Tap stand**	0.82	1.99	6.53	7.00	311	359	148	171	2	0	**112**	0
22 **Nabowa Florence Tapstand**	1.04	1.24	6.27	7.06	316	359	150	170	0	0	**160**	0
23 **Mrs. Betty Nakajubi Tapstand**	0.83	1.42	6.28	7.02	313	359	149	171	4	0	**188**	0
24 **Sikanusi Tapstand**	1.03	1.48	6.40	7.03	309	358	147	170	0	0	**216**	0
MR. KATONGOLE EXPEDITO KIOSK												
25	0.96	6.62	5.47	6.03	482	561	230	268	0	0	0	0
	Turbidity		**PH**		**Conductivity**		**TDS**		**E-Coli**		**T-Coli**	
UNPROTECTED SPRING												
26	65.8	68.8	5.63	6.40	155.6	219	74	104	**TNTC**	**TNTC**	**TNTC**	**TNTC**
INSTALLED BOREHOLES												
27 **Kitante B/H**	21.0	8.65	6.03	6.51	346	381	164	181	6	0	48	0
28 **Mohammed Matovu B/H**	0.92	–	6.01	–	242	–	114	–	0	–	0	–
29 **Luyima B/H**	1.39	9.05	4.96	5.46	294	341	139	162	0	0	0	0
30 **Bukorwa B/H**	1.79	–	5.84	–	161.5	–	76	–	0	–	0	–
31 **Gwafu B/H**	11.3	2.05	5.80	6.36	224	229	106	108	0	0	0	0
32 **Kikoma B/H**	1.78	2.06	5.21	6.01	99.2	126.6	47	60	0	0	0	0

Table 4: Community score card for Sikanusu.

Areas for improvement	Desired changes	Scores	Reasons for the score	Proposed activities
Inadequate water supply	Adequate water supply	5%	Water supply is so low	Apply for more boreholes to be constructed • Nganda Khalid
High cost of water	Reduced water prices	10%	Low income of the community	Hold discussions with service providers • Councilor Kasirye James
Low quality of water	Good quality water	40%	Poor quality water	Ask for a water quality specialist to test the water
Preferential treatment of adults over children at water points	Equality and fairness at water points	0%	There is no equality	Local council should to discuss with vendors on the issue of children • Mwanje Fred
Transparency	Service providers should inform community on upcoming activities and water plans	0%	Service providers do not inform community of events and plans.	Clear introduction of service provider and their roles and duties to the community • Seruwagi Kasim
Social accountability	Accountability to the water users	0%	there	
Dialogue	Well-structured channels of two way communication	0%	There is no communication between service providers and the community	Create avenues of communication like loudspeaker to notify community of progress and changes in water schedule and activities • Hamuza kizito

Table 5: Service Providers self-assessment card.

Areas for improvement	Desired changes	Scores 0-100	Reasons for the score	Proposed activities
System machines are old and some pumps are non-functioning	New and functioning machines	40%	Frequent breakdown of machines	To ask for new pumps from the ministry.
Unstable power supply and hiking price of fuel	Uninterrupted power supply	35%	Power supply is very inconsistent	Increase on budget allowance for preparedness when power is off
Poor payment of water users	Good and timely payment	40%	High percentage of defaulters	To ask water users to pay on time
Transparency	Openness	60%	Most information is communicated	To be transparent in all activities
Social accountability	Timely reporting to the water board	45%	Roles and responsibilities are not clear.	Reporting and accounting of all responsibilities
Dialogue	Frequent dialogue with water users	48%	Limited communication and dialogue between water users and service providers	Create avenues of communication with water users

Table 6: Joint action plan of Kikasa and Bukalasa.

Areas to be improved	Desired change	Evidence of progress	Scores out of 100	Reason for the scores	Proposed activity	Tasked person	deadline	Person to monitor
Water pipes not enough	increased coverage in piped water supply in Kikasa	Increase in water extension	15%	Water pass on main roads Small pipes Some area has no pipes	Community to ask water while paying	LC1 Zone leader	4 month 6 month	**Sekibengo edward**
No bore hole in Kikasa	When bore hole is excavated	Started getting water from it	0%	There is none	Ask a borehole/water from luwero	LC1 asks through town council to district	2 month	**Sekibengo edward**
To increase on the number of pumps	water has is increased	When getting water in plenty	35%	Water pumps working are few When students are back water is reduced	Repair pumps	Bukalasa water board	4 month	**Kalungi edward**
Communication	When providers work with users	Giving information to people	20%	Zone leaders are not seen They are seen when bringing bills	Electing another zone leader Getting phone numbers of service providers	Water board kalungi Edward	2 month now	**LC1**
Social accountability	Tell people board members	When getting information from board members	20%	Some are being seen working	Visit water users Call meetings	Zone leaders Zone leaders	2 month 2 months	**Sempebwa gideon**
Transparency	When knowing expenditures and plans	When meetings are organized	0%	Water board did not know it was their responsibility	When transparent in activities Calling meetings	Water board Water board	2month 2 month	**Sempebwa Gideon** **Sempebwa gideon**

Table 7: Transparency scores and reasons for the scores.

Communities	Initiation score	Reason for the score	Ev. Score	Reason for the score
Served by Wobulenzi Town council				
Sikanusu	10%	There was no transparency	50%	There was some level of information sharing by local leaders but Trandit and WB not yet shared the budget issues
Gwaffu	8%	Users had never been informed about work plans and budgets	68%	WB called the meeting but the weakness was on the users attendance
Kigulu	0%	No meetings on water services had been held	0%	No meeting held to inform users about the budget or work plans
Kitante	0%	No meetings had been held	0%	- do -
Served by Bukalasa Agricultural College				
Kikasa	0%	WB did not consider it as their responsibility	23%	Plumbers come when called and people were informed of the debt by the service provider and reason for increasing the tariffs
Upper west and East	- N/A	WB did not consider it as their responsibility	- N/A	- N/A

Table 8: Social Accountability scores and reasons for the scores.

Communities	Initiation score	Reason for the score	Eval. Score	Reason for the score
Served by Wobulenzi Town council				
Sikanusu	0%	None at all	70%	Water board took the responsibility and held a meeting in Sikanusu. Trandit workers got uniforms with name tags as requested by the community
Gwaffu	10%	People neither knew the water service provider representatives nor their roles	78%	The WB and LC created awareness. The WUC worked but there was still need for the TC to inform people about their roles. The water providers came and promised to come back.
Kigulu	0%	There were a lot of complaints	4%	Men gave 10%- because NETWAS meetings provided information on roles and responsibilities but the WB/TC had not come officially. Women 0%-People have not been trained Youth gave 2%- kiosk attendants played their roles but complaints still existed
Kitante	20%	Trandit workers were seen working	4%	- do -

Served by Bukalasa Agricultural College				
Kikasa	20%		43%	They knew the water office and their Chairman had liaised with Bukalasa WB
Upper west and East	50%	-	50%	Had not changed due to failure to organize meetings

Table 9: Communication scores and reasons for the scores.

Communities	Initiation score	Reason for the score	Eval. score	Reason for the score
Served by Wobulenzi Town council				
Sikanusu	25%	There was no communication mechanism	70	Trandit talked to people and used of Radio Wobulenzi to deliver information
Gwaffu	10%	Some information came through the councilors most times late. A few people were informed	75%	Information was timely; but the information person had no means of transport or airtime which delayed delivery a bit. Communication was fast, they were called to the meeting in writing, and the information person moved house to house
Kigulu	0%	No meetings or training	7%	Communication was not good. The loud speakers did not reach Kigulu, they got some news during NETWAS meetings but not from the water providers. Meetings had not taken place.
Kitante	0%	No meetings or training	7%	There was the use of the loud speaker but there had been no meeting
Served by Bukalasa Agricultural College				
Kikasa	20	Zone leaders are not seen They are seen when bringing bills	54%	Had the telephone contacts of the service provider's technicians and when called they responded. Little communication, they had yet to met
Upper west and East	50%	The water users got to know water board members from the NETWAS meeting and increased the score by 25% The service providers had been seen working but not known.	78%	Can be contacted and reached any time: phone and a bicycle. The water office had a sign post and all knew it. Everything proposed to improve communication was covered and working well especially Plumbers.

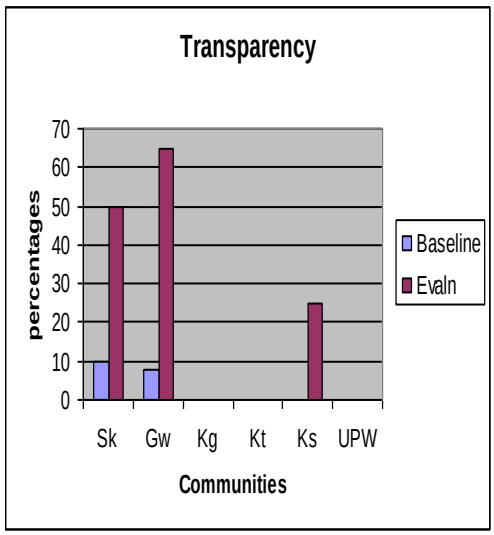

Figure 1: Transparency.

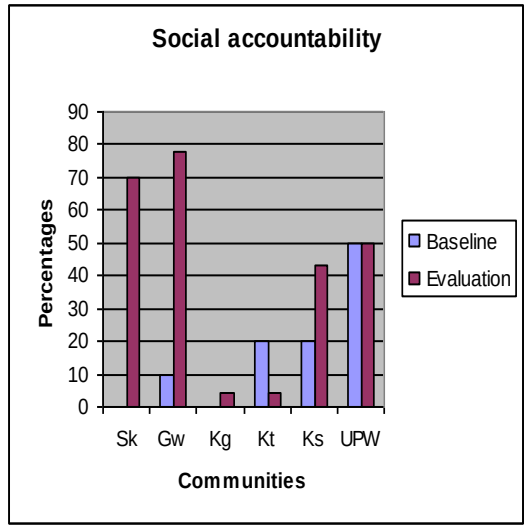

Figure 2: Social Accountability.

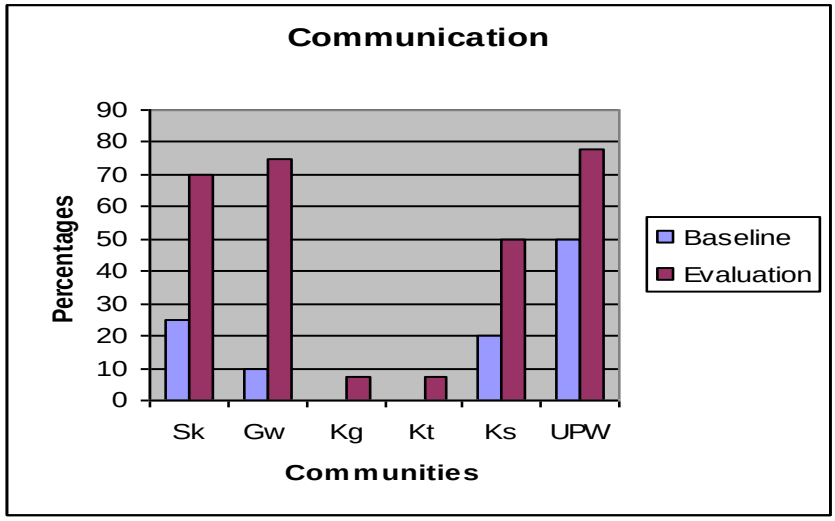

Figure 3: Communication.

Key: SK = Sikanusu, Gw = Gwaffu, Kg = Kigulu, Kt = Kitante, Ks = Kikasa, UPW = Upper West.

Conclusion

The main conclusions were :

The CSC process had been effective in bridging the gap between water service providers and users. It was a learning process that provided a safe haven for stakeholder to open up and share their concerns, fears, grievances, etc., and yet remained committed to working together towards set goals. But perhaps most effective was the equipping of key members from both WBs with the skills to facilitate the CSC process, and the background principles to allow them understand, fine-tune and work with the process. The Chairman and the youth representative of the Wobulenzi Water board and one Zonal leader from Bukalasa emerged as key pillars in the process.

The success of the project depended on the concerted effort of all Team members and

stakeholders in Uganda. The commitment of the service providers was paramount in implementation of the project. There was progress in social accountability but both WBs had more work to do to ensure that Water users understood the roles of all stakeholders involved and how to approach and work with them. As part of the commitment of the Water board and on the way forward, both WBs committed themselves to regularizing the meetings and trainings in the communities. The District was expecting a grant in this financial year 2009/10 from which the WB Wobulenzi expected to receive the money needed to take the meetings forward.

There was evidence that improvement in the area of governance improves service delivery. The right priorities usually emerge when you engage with the stakeholders. Also involving users in the needs and solution identification helps in targeting interventions. Communities can actually be trusted with targeted resources to address key priority needs. They can also openly account for the money.

The results indicate that some progress was made but the actual sharing of plans, budgets and expenditures did not happen. Both the communities and WBs agreed that meetings had to continue, specifically to inform and provide updates to people concerning work plans, budgets and expenditures.

The issue of effective communication at the time was limited to loud speakers especially used by Trandit to communicate changes the water supply and remind users to pay their bills. Views from the field revealed that many pockets in the communities even those near to central town did not hear the loud speaker. The quarterly meetings proposed by the WB should also serve as medium for information dissemination, sharing about budget processes, priority setting, social accountability and targeted training. There is also need to take the communication issue back to the communities to agree on a complementary means to the loud speaker.

The three priority areas selected by each community were areas of service delivery that they wanted to be addressed. The process helped clarify that priorities selected when addressed there should be progress within 6 months and using available resources. The purpose was to help stakeholders consider carefully the aspects of resources and the time it would take to see change. In this regard, NETWAS did not mention the seed money until after the communities had identified what they wanted done. The seed money was to kick start implementation and challenge service providers to release resources towards the Joint Action Plans. In view of the above, both WBs made substantial progress especially in the area of renovating, replacing, servicing and maintaining the water systems. Both spent over USD 2000 to do this, which they had not budgeted for but did so in response to the needs raised by communities.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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Sawdust as a filtering media in sludge drying beds

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ABSTRACT

Conventional wastewater treatment is a common method of domestic wastewater treatment in Sub Saharan Africa. Lubigi wastewater treatment plant (LSTP) in Kampala – Uganda is a unique wastewater treatment system combining treatment of on-site faecal sludge and domestic wastewater. High solids content of on-site faecal sludge mean large volumes of the same, thus limited sludge drying space. This means need to optimize sludge drying bed use (improving the sludge drying efficiency) by reducing their drying times. This study investigated use of wood sawdust as a filtering layer in the faecal sludge drying process. Comparison of performance between sand, fine and coarse sawdust as a filtering media was conducted at LSTP. Sludge shrinkage depth (cm) and moisture content (%) were key parameters used to analyze and determine the most ideal media for sludge dewatering. The study was conducted during both wet and dry seasons to determine the impact of seasonal changes. Dry season results showed a drastic decrease in the sludge depth (shrinkage) for all the three media types after a period of 8 days followed by a gradual decrease in sludge depth up to 28 days. This implies that effective dewatering happens for the first 8 days, which goes on for the rest of the remaining days. Overall, the best performing media was fine sawdust, coarse sawdust and lastly sand. Independent two sample t-tests assuming equal variances show that there is a significant difference between the mean sludge depth of sand and fine sawdust $t(df) = 56$, $P<0.05$). There was no significant difference in the mean sludge shrinkage depth of fine sawdust and coarse sawdust. Similar results were obtained during the wet season. Comparisons of similar media types during the dry and wet seasons shows that the mean sludge shrinkage for the dry season were significantly lower than that of the wet season ($P<0.05$). This implies that seasonal changes significantly affect the sludge dewatering. In terms of moisture content (MC), the results for dry season showed that fresh fine and fresh coarse wood sawdust achieved MC of 28% and 31% respectively after 28 days. Sand produced faecal sludge with a higher MC of 49% after 28 days. Similar results of the performance of the three types of media was observed during the wet season. In conclusion, fine sawdust performs better than coarse sawdust and sand media in faecal sludge dewatering. Sludge dewatering is affected by seasonal changes.

Keywords: Coarse sawdust, fine sawdust, moisture content, sand, Sludge shrinkage.

INTRODUCTION

Demographic trends world over indicate increase in population. This has translated into an ever-increasing pressure on the available resources which without a doubt has led to an increase in volumes of waste generated. Wastewater with its component of feacal sludge is one of the wastes generated in

large quantities. This means challenges as far as its management is concerned, which translates into both an environmental pollution and public health threat. These large sludge quantities, if not well managed well, call for vast storage space. Such space is not readily available making the accumulating sludge a public nuisance. To properly dispose it off, strict regulations must be adhered to, to meet environmental standards (Andreoli et al., 2007).

Treatment techniques will vary from plant to plant depending on the raw sewage quality received (Yeqing et al., 2013). These may involve characterisation, stabilisation, dewatering, thermal processing, agricultural reuse (for that whose content of organic matter and nutrients is high and thus beneficial) and or its eventual disposal (Metcalf and Eddy, 2004).

One of the techniques used in sludge management is the unplanted drying beds as case is at LSTP. This employs natural drying techniques of evaporation and percolation, driven by the area's temperature and humidity (Strande et al., 2014). From the above it is clear that large Sludge volumes are generated which require innovative mass and volume reduction treatment techniques.

Ordinarily, sand acts as a filtering media for which this research studied sawdust as its potential replacement with gravel maintained as the draining medium. Sawdust, a by-product of the sawing processes has various agricultural uses (mulching, animal bedding, and soil conditioner), construction and as an energy source (Forest laboratory services, 1969).

According to Kufour (2010), sawdust has exhibited abilities to act as a sludge conditioner in the dewatering process on sand sludge drying beds. This resulted in reduction in the sludge dewatering times for different sludge to sawdust mixed ratios. The sludge drying period of about 2 months taken to dewater the sludge at LSTP is longer than the design period of 1- 1.5 months. This is despite the beds having plastic roofing sheets to enhance the dewatering process. The need to reduce this long drying period coupled with sawdust availability (from the prior mentioned sawing processes), presented the opportunity to beneficially dispose it off and informed the decision and need to conduct this research.

The importance of sludge management under the environmental management of solid waste, emphasising waste minimisation and increased reuse/recycling as strategies is clearly outlined in Agenda 21 (Andreoli et al., 2007). From this conference, innovative sustainable treatment and disposal methods in the management of sludge were deemed necessary.

With the feacal sludge source majorly being the human gut, presence of pathogens with potential to pose a public health risk (cause disease), or be hazardous/toxic due to presence of/interaction with organic and inorganic contaminants is a must. All these factors deem it environmentally harmful (McGhee, 1991), for which, its treatment and proper handling cannot be underestimated. Goal 6 of the globally set Sustainable Development Goals (SDGs) earmarks sludge management as a means of availing sustainable yet manageable water and sanitation for all. The impact of this would have a direct bearing on goal 12 targeting waste recycling through sustainable consumption and production patterns.

Article 3 of the Bamako convention stipulates banning of the importation of hazardous wastes to Africa, aided by their management through transboundary movement controls. It further emphasizes proper treatment measures as a means to minimize their generation. This would lead to a healthier environment through reduced pollution. Presence of pathogenic as well as other environmentally contaminating constituents in the sludge, renders it as a hazardous waste, for which this convention predominantly addresses itself.

Mathney and Jennifer (2011), according to U.S. Environmental Protection Agency (EPA), defines sewage sludge as the solid, semi-solid, or liquid residue formed after domestic sewage treatment. This residue can comprise the beneficial by-product referred to as bio-solids or suspended solids or liquids requiring treatment after removal from the

liquid stream before disposal (Jenkins and Nolasco, 2015).

Faecal sludge (FS) is obtained from onsite sanitation technologies, with the transportation means being cesspool emptier trucks, aquavacs, etc. and not through sewer lines. It takes on the form of raw or partially digested, slurry or semisolids, and formed after the faecal sanitation chain (storage, collection, transportation and treatment) of combinations of excreta and black water, with or without greywater (Strande et al., 2014), as shown in Figure 2 below. Examples of onsite sanitation technologies include pit latrines, sewered public ablution blocks, septic tanks, aqua privies, and dry toilets (onsite sanitation appurtenances). It doesn't have a uniform composition, nor is it of the same quantity and concentration. The sludge comprises of a solid and liquid fraction as in studies by Garg and Neeraj (2009), Yeqing et al. (2013) and Jenkins and Nolasco (2015).

Five groups of pathogenic organisms are majorly known, namely; bacteria, fungi, viruses, protozoa and helminths. These are mostly found in faecal matter of animal and humans which means that they are present in human systems. The treatment process concentrates most of these pathogens initially present in the incoming wastewater into the sludge. Therefore, how this sludge is handled is of utmost importance (Andreoli et al., 2007).

Reduction of sludge volume and alteration of its properties prior to its transport, disposal and or use are the main objectives of treating it, for which several technologies are employed. Some of these technologies for which the sludge is treated before it is disposed off include but not excluded to digestion, thickening, stabilisation, drying and de-watering. During these processes, excess water and heavy metals are removed as well as killing off the pathogens.

It employs physical processes such as evaporation, evapotranspiration, filtration, gravity, surface charge attraction, centrifugal force and pressure (Strande et al., 2014). As a process, it reduces the moisture content and volume of the sludge, which increases its solid content. This enables considerable amounts of sludge to be treated/dried, transported and hence disposed of.

With the reduced dried sludge volumes (cake), means transportation of a product with a more relevant solids content, otherwise impossible in its liquid form. By this, through pathogen reduction, stabilization of organic matter and nutrients, and the safe end use or disposal of treatment end products, the objectives of ensuring environmental protection and public health safety are achieved (Strande et al., 2014). Key targets of odour and putrescible control, are achieved by this method which is undertaken before most disposal methods (Metcalf and eddy, 2004). Several dewatering techniques exist, either mechanical or natural, but all being physical processes.

These involve natural processes of evaporation and percolation which include lagoon and drying beds which may be planted or unplanted. The natural dewatering method used was one of the Conventional sand drying beds, which is the most used sludge drying technique worldwide. Several factors affect and therefore are key in informing their design and usage. Among these are weather conditions, sludge characteristics, land values, closeness of the residents to the site, as well as conditioning aid use (US EPA, 1974). These beds can be open or covered.

The general drying bed lay out usually consists of a rectangular tank, of masonry or concrete walls and a concrete floor, with the details as elaborated by Wang et al. (1986). The natural process of evaporation and filtration are the main drivers of dewatering and drying of the sludge in the sand drying beds. As a multi-phase process dewatering consists of the liquid, plastic and solid phase. For much of the dewatering period, the water easily percolates through the draining bed (liquid phase) up to the moment when the sludge changes into a thick pasty mass, the plastic phase (Andreoli et al., 2007). This is further aided by the additional exposure of the sludge area through the developed cracks in it.

Good weather and the sludge condition can enable to obtain a cake of 40-45% solids in 2-6 weeks (Wang et al., 1986). It however,

must be noted that drying beds, besides achieving dewatering, do not aid stabilisation, nor pathogen removal, although biodegradation may occur to some extent (Strande et al., 2014). As a result, presence of any pollutants within the sludge would remain in it and or the resultant leachate.

According to Manga et al. (2016) research in Uganda, it was realised that it 100% helminth eggs removal efficiency from the percolate was attained meaning that the dewatered solids retain them. As such further treatment of the dewatered dry sludge is required before its use. Total solid (TS) content of at least 25% is fit for removal regardless of the different sludge treatment technologies.

Also referred to as wood dust, is among the wood processing by products besides chippings, slabs, off cuts and shavings (Tiough, 2016). It is a tiny – sized powdery wood waste in saw milling and wood industries with their particle size largely dependent on the wood type, saw teeth and purpose for which it is to be used (Maharani et al., 2010). Such industries are quite numerous in Uganda from which varying shape and sizes of sawdust can be obtained. What endears the sawdust for its use are its absorptive, abrasive, bulky and fibrous, nonconductive and granular properties (Forest product laboratory, 1969), for which challenges as far as its disposal as a waste are negated. This study investigated use of wood sawdust as a filtering layer in the faecal sludge drying process.

MATERIALS AND METHODS

This involved setting up model beds of 1 m^3 volume capacity with 1 m^2 effective drying area covered with tarpaulin structure. The study was carried out in the wet and dry seasons.

Three of the beds were used for the first cycle (dry season) while five were used in the second cycle (wet season).

In first cycle, all model beds comprised of course and fine aggregates, but differing in filtering layers (sand, course sawdust and fine sawdust); while in second cycle, besides the known media, also reused course and fine sawdust were included as filtering layers.

Bed construction consisted of a raised plinth wall approximately 1 m from the ground surface. The drying beds contained a supporting layer of gravel (fine and coarse) with a depth of 30 cm and sizes ranging from 5-10 mm and 10-19 mm. This was placed on the under drains which consisted of a PVC pipe. The sand-sawdust mixture serving as a filtering media, was placed on the gravel at a depth of 20 cm. The sand was washed and dirt free, having an effective size of 0.2-0.6 mm with a uniformity coefficient of 2.833. Sludge was pumped into each bed to a height of 30 cm. Each of the beds was constructed in triplicate and arranged in a randomized block design.

The change in depth of the sludge layer was measured after every 24 hours, using a 2m long tape measure to determine reduction in depth of sludge due to filtration and evaporation. Samples from the bed were collected with an interval of 7 days for monitoring moisture content and initial total solids. This was done until the desired moisture content of the cake at which harvesting occurs was achieved.

Phase changes of the sludge in the beds were monitored i.e. liquid, plastic and solid phase. Sludge changed from liquid to plastic phase when the percolation stopped. A change from plastic to solid phase was realized when cracks formed on the surface of the sludge. These which were deep to an extent that the filtering media could be seen.

The total number of days taken for complete dewatering was noted and recorded. Dewatering was considered complete when the solid phase was reached, moisture content for dried solid was reached (30%-40%) and the percolate from the drying bed stopped. At this point, the dewatered sludge could be easily removed with a spade. Two dewatering cycles were conducted and monitored for a period of 1 month each.

Moisture content determination

The moisture content of the sludge was determined using the gravimetric method. This is done to determine the variation of the moisture content of the sludge before and after drying and was done in a laboratory. It is

expressed by weight as the ratio of the mass of water present to the dry weight of the sludge sample. The materials used included: a drying oven, analytical balance, aluminium weigh tins, Auger or tool to collect sample and a Crucible.

Moisture content is the mass fraction determined as the loss on mass after the specified drying process. It is expressed as a Percentage or in milligrams.

Calculation

The percentage moisture content (MC) is expressed as below:

Moisture content (%) = (Mw-Md)/ Mw*100

Mw= mass of wet sample

Md= mass of dry sample

The procedure involved:

Placing the crucible in an oven for 30 minutes to remove all moisture, weighing the crucible, and recording its weight.

Placing a sample of about 10g in the crucible and record this weight as (wet sludge + crucible).

Placing the sample in the oven at 105^{o}C for at least 7 hours.

Weighing the sample, and recording this weight as weight of (dry sludge + crucible).

Return the sample to the oven and dry several times between intervals of 30-60 minutes, and determine the weight of (dry sludge +crucible).

Repeat above step until there is no difference between any two consecutive measurements of the weight of (dry sludge and crucible).

Figure 1: Sludge being dried in one of the unplanted covered sludge drying beds at LSTP, Kampala, Uganda.

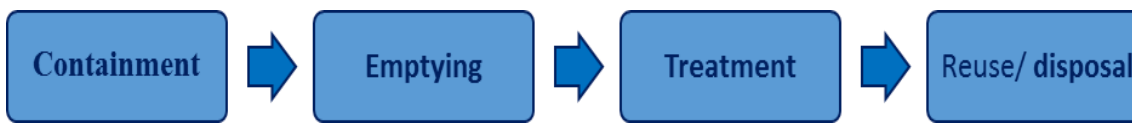

Figure 2: Faecal sludge management chain.

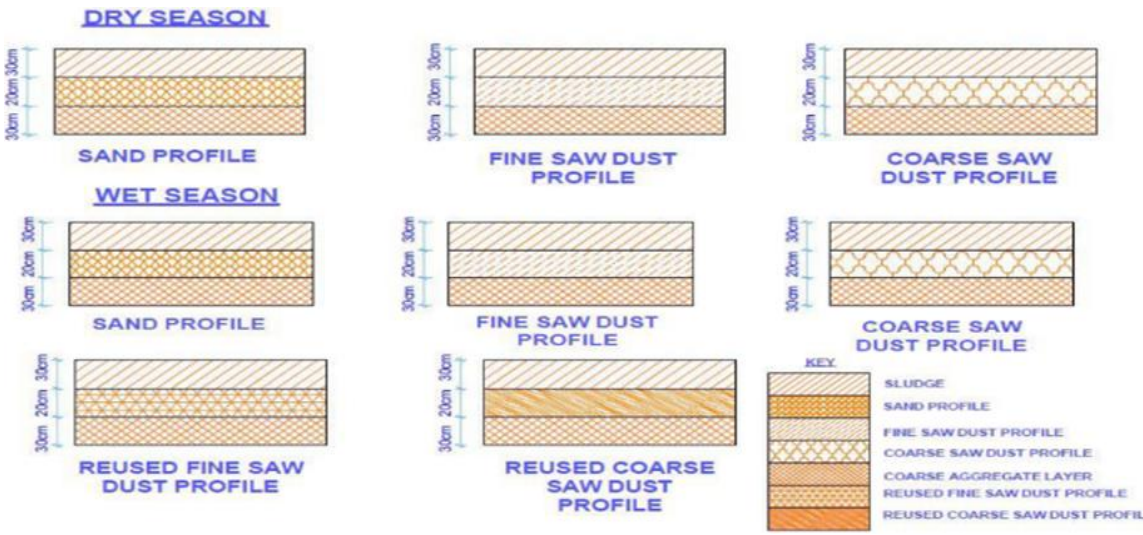

Figure 3: Layout of different filtering profiles of model drying beds.

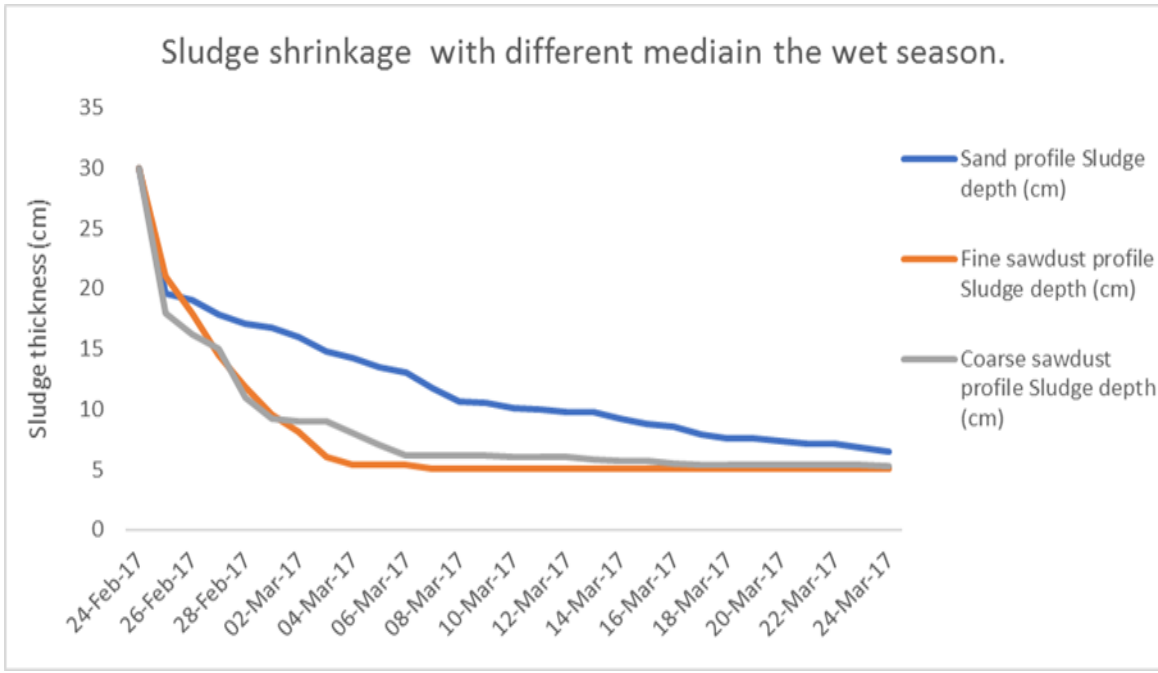

Figure 4: Graph showing trend of sludge dewatering process in the different filtering bed profiles (Wet season).

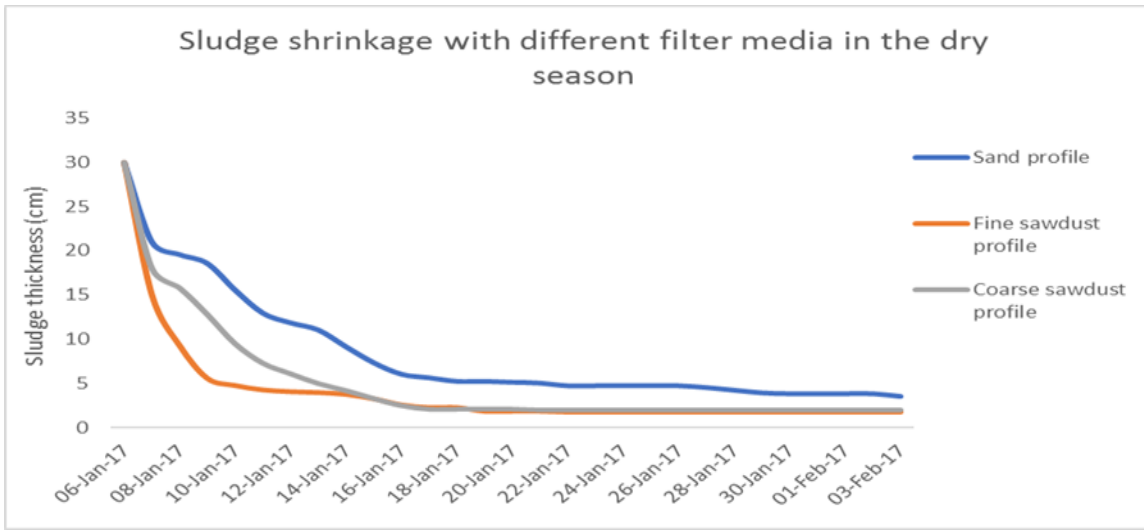

Figure 5: Graph showing trend of sludge dewatering process in the different filtering bed profiles (Dry season).

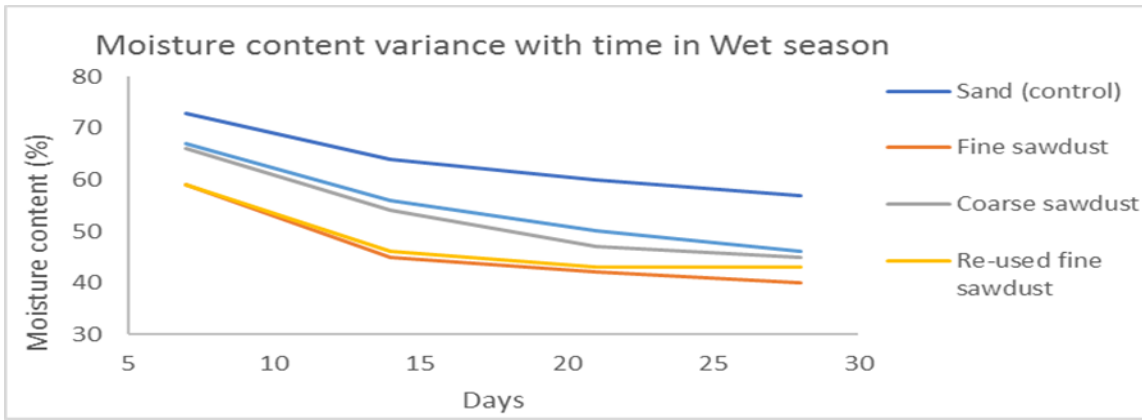

Figure 6: Graph of moisture content values for sludge (Wet season).

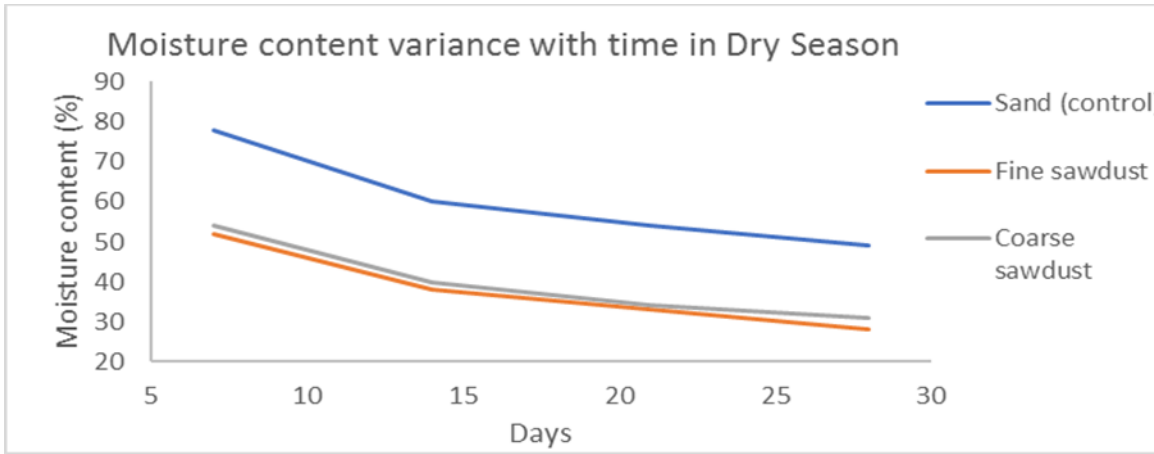

Figure 6: Graph of moisture content values for sludge (Dry season).

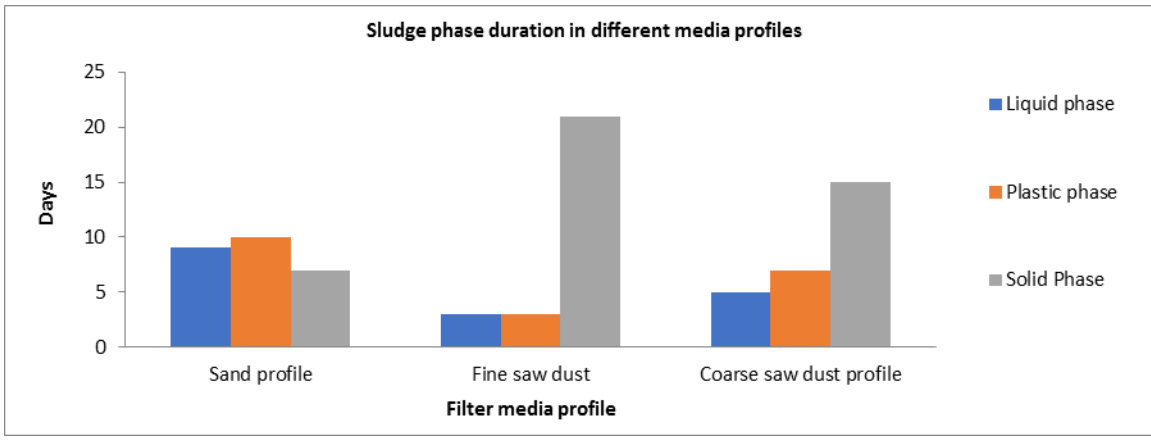

Figure 8: Sludge phase duration in different filtering profiles (dry season).

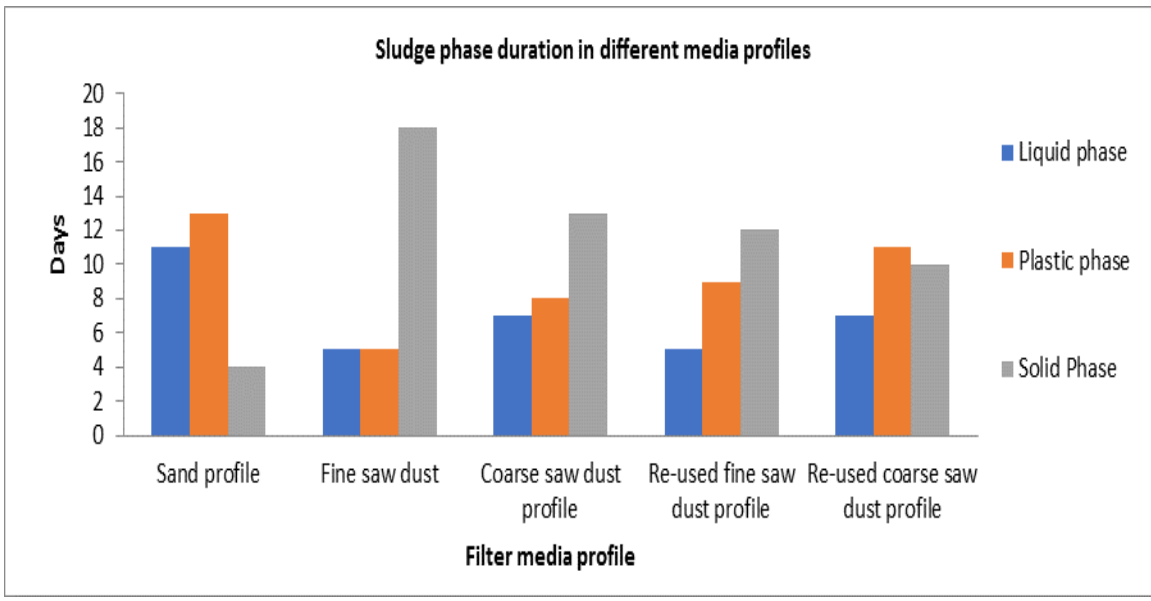

Figure 9: Sludge phase duration in different filtering profiles (dry season).

RESULTS AND DISCUSSION

Results for the dry season show that there was a drastic decrease in sludge depth (shrinkage) for all three media types after a period of 8 days followed by a gradual decrease in sludge depth up to 28 days. The mean sludge depth of sand, coarse sawdust and fine sawdust after 8 days were 14.9±7 cm, 10±8.3 cm and 7.9±8.2 cm respectively. This implies that effective dewatering happens for the first 8 days with the best performing media being fine sawdust, coarse sawdust and lastly sand. Sludge depth of sand, coarse sawdust and fine sawdust after 28 days of study were 8.5±6.6 cm, 5.2±6.5 cm and 4.2±5.7 cm respectively. Independent two sample t-tests assuming equal variances shows that there is a significant difference between the mean sludge depth of sand and fine sawdust $t(df) = 56$, $p<0.05$). There was no significant difference in the mean sludge shrinkage depth of fine sawdust and coarse sawdust. Similar results were obtained

during the wet season. Comparisons of similar media types during the dry and wet seasons show that the mean sludge shrinkage for the dry season were significantly lower than that of the wet season ($p<0.05$). This implies that seasonal changes significantly affect the sludge dewatering.

In terms of moisture content (MC), the results for dry season showed that fresh fine and fresh coarse wood sawdust achieved MC of 28% and 31% respectively after 28 days. Sand produced faecal sludge with a higher MC of 49% after 28 days. Similar results for the performance of the three different media types were observed during the wet season.

Conclusion

In conclusion, fine sawdust performs better than coarse sawdust and sand media in faecal sludge dewatering, and should be adopted as a filter media in sludge drying beds within sludge treatment plants as a suitable replacement of sand. Sludge dewatering is affected by seasonal changes.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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Enhancing waterborne toilets to reduce water usage in schools: experience from Kampala, Uganda

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ABSTRACT

Over 620 million children worldwide lacked a basic sanitation service at their school and 12% of schools have facilities that are not usable. In Kampala's public primary school, the pupil to stance area stands at 57:1 as compared to the required 40:1 by the public health regulation of 2000. A number of waterborne toilets have been constructed in schools to change the pupil to stance ratio from 118:1 to 57:1 in the period 2012- 2018. However, the administrators of schools have denied 07% of the toilets in schools to be accessed by pupils in an effort to control water bills. Administrators prefer pupils to use pit latrines to waterborne toilets because they use less water. This acerbates the inadequacy of access to sanitation in schools in Kampala. The objective of this work was to develop a waterborne sanitation facility that meets the school administrators' preferences features of VIP latrine with water usage of less than 10 liters of water to flush the toilet. Kampala Capital City Authority (KCCA) has constructed water based toilets referred to as 'channel flush' toilets in public schools to reduce water usage. The channel flush toilet uses a channel as a receiving chamber for faecal matter which is flushed intermittently to the septic tank or bio-digester. Each toilet block is flushed four times a day with each flushing time using 60 liters of water. With the channel flush toilet, schools use about 4 liters per child per day on flushing toilets leading to a 90% water usage reduction. Emptying has been reduced from 30 cubic meters to 5 cubic meters per year. The toilet is recommended to be used in schools and public places such as markets and taxi parks.

Keywords: Waterborne toilets, VIP latrine, ventilated pit latrine, schools, Kampala Capital City Authority, Uganda.

INTRODUCTION

Goal six of the Sustainable Development Goals (SDGs) requires the world to achieve universal access to adequate and equitable sanitation and hygiene for all by the year 2030 (UN, 2018). This can be realized through putting up infrastructure, operating and maintaining them across both the waste water and the faecal sludge management chains. To date, 892 million people still practise open defecation and 4.5 billion people do not access safely managed sanitation services where excreta is safely disposed of *in situ* or treated offsite (UN, 2018). Currently, over 620 million children worldwide lacked a basic sanitation service at their school and 12%

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of schools have facilities that are not usable (WHO/UNICEF, 2018). Poor water, sanitation and hygiene (WASH) conditions have been reported to reduce educational outcomes in school going children by contributing to absenteeism and impaired cognitive abilities (Cronk et al., 2015). Worldwide over 440 million school days are missed annually by children due to WASH-related illnesses (Hullalli et al., 2017).

In Kampala, the Capital City of Uganda, schools are required by law to only use waterborne toilet (MLHUD, 2011). About 20% of the toilet facilities in Kampala public schools meet this requirement (KCCA and WAU, 2018) with the ventilated improved Pit (VIP) latrines being the most popular and preferred technology covering 57% of all toilet in public schools (Kimbugwe et al., 2018). Kampala Capital City Authority, the entity managing the city for the central government, has invested in waterborne toilets in primary schools shifting the pupil to stance ratio from 118:1 in 2012 to the current 57:1 (Kimbugwe et al., 2018). However, children are denied access to 7% of the waterborne toilet stances in school. This acerbates the inadequacy of access to sanitation in schools in Kampala. The objective was to innovatively modify the waterborne toilet to have features of a ventilated pit latrine and minimize water usage. The ventilated pit latrine is preferred over the waterborne toilet because of low operations costs and low water usage.

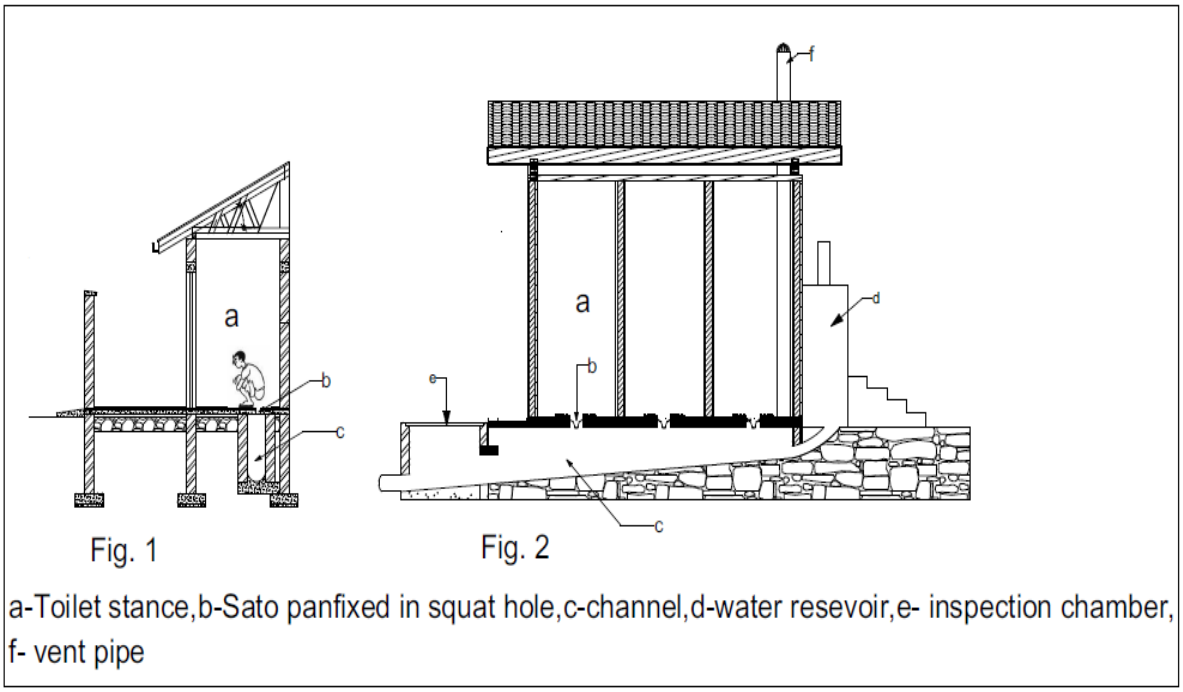
MATERIALS AND METHODS

Enhancement of waterborne toilet to channel flush toilet

The features of the VIP latrines and those of waterborne toilets were compared and contrasted in line with the problem of water usage. Common features were maintained and the differences considered for modification. All features of the superstructure of the VIP latrine were maintained in the new design which led to elimination of cisterns for the case of waterborne toilets. The substructure of the VIP latrine was adjusted by incorporating a channel in the substructure instead of having a pit. The drop hole for the case of VIP latrine and toilet bowels for the case of waterborne toilets were replaced by a sato-pan. A sato-pan is a plastic mold that fits into a concrete base over a squat hole with a self-sealing trap door that shuts our flies and unpleasant smell. The sato-pan, direct the feces in the channel which is directly below them as shown on Figure 1. The channel is constructed using concrete with a slope of 12% to 15% and the surfaces finished smooth with cement sand mortar. The channel depth is 1.5 m above floor level with bifurcations at each point that is directly below the squat hole. Bifurcations are put in the channel to retain some water that keeps the channel wet always. The channel connects to a reservoir at the upper end and to the inspection chamber at the lower end. The inspection chamber then connects to the septic tank as shown on the Figure 2. The modified waterborne toile is referred to as ‘channel flush toilet’. In Kampala, the cost of constructing a channel flush toilet is equivalent to that of a waterborne toilet.

Using the channel flush toilet

The channel flush toilet is used as a pour flush waterborne toilet with a flushing quantity of one liter to clean the sato-pan. The sato-pan opens upon receiving the weight of the feces and closes the flap upon releasing it into the channel underneath the floor slab. After three hours of use, 60 liter of water are flushed from the reservoir running through the channel down to the inspection chamber. The flowing water cleans the channel of all feces taking it into the septic tank or the digester. The foul stench escaped through the vent pipe inserted on the channel.



Figures 1 and 2: Samples of toilets.

RESULTS AND DISCUSION

Using a 'channel flush' toilet in Kampala

KCCA has constructed 12 toilet blocks each with 14 stances that uses this technology. These toilet blocks are used by public schools having an average population of 1000 pupils with an estimated water usage on waterborne toilets of about 30 liters per child per day. With the channel flush toilet, schools use about 4 liters per child per day on flushing toilets leading to a 90% water usage reduction.

Sato-pans prevent flies to harbor in the toilets by closing the drop hole with a flap after solid have fallen in the channel. There is no foul stench due to the fact that vents pipes are connected to the channel to suck out the bad odor. Secondly, the waste is not given long time to sit in the channel while rotting. Flushing is always done every after 3 to 4 hours. The challenge of the channel surface drying when the toilet is not in use for a long period is solved by wetting the channel with soapy water. This is normally experienced on resumption of schools after holidays.

The toilet are as clean as waterborne toilets with very low maintenance costs. The technology is recommended for public and institution sanitation where bid numbers of user are common. Such institutions include schools, markets and taxi parks. These institutions require a lot of water for flushing. It is common in Kampala to find soak away pits of such institutions failing due to the high volumes of water received per day which cannot be accommodated by the soils through infiltration. This technology also reduces on the emptying frequency for the toilets.

Conclusion

The public schools where channel flush toilets have been constructed, feacal sludge emptying has been reduced by 80% (from 30 Cubic meter to 5 cubic meters per year). The toilet is recommended to be used in schools and public places such as markets and taxi parks. More research needs to be done to optimize water usage and channel flow properties.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All the authors participated in this work and contributed to the writing of the final manuscript.

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Faecal sludge briquettes production as a viable business in Kampala: a case study of a partnership between Water for People and National Water and Sewerage Corporation

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ABSTRACT

Production of faecal sludge (FS) briquettes is not a new technology and is often used in the sanitation value chain as part of resource recovery efforts. Water for People in its mandate to develop appropriate and sustainable sanitation technologies sought to optimize the process of faecal sludge based briquette production. This was done by testing the different compositions of faecal sludge (100%, 80%, 60%, 50% and 40%) with other materials such as wood charcoal dust, agricultural waste and market waste to come up with a briquette that could compete favorably with charcoal and traditional briquettes on the market. The testing phase indicated that such briquette was at a composition of 40% faecal sludge and 60% charcoal dust and adequately provided the fuel properties required as well being safe from any pathogens or emissions. A briquette production facility was set up in collaboration with National Water and Sewerage Corporation, Uganda at their treatment plant in Lubigi and has to-date produced more than 10 tonnes of briquettes and sold more than 3 tonnes since its inception. Further research is being carried out in production process efficiency and use of other raw materials such as agricultural waste and market waste to offset the wood charcoal.

Keywords: Briquettes production, faecal sludge, reuse, Kampala, Water for People, National Water and Sewerage Corporation.

INTRODUCTION

For many years in Africa, faecal sludge has remained regarded as a hazardous material, given little attention about energy recovery from the bio solids (Semiyaga et al., 2015).The most common reuse option has concentrated on direct application of bio solids onto garden- risk of pathogens

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especially for vegetables eaten raw (Jimenez et al., 2009; BIOHAZ, 2014; Dickin et al., 2016). One product of faecal sludge that is most likely to be free of pathogens is the briquettes (Atwijukye et al., 2018; Andriessen et al., 2019). The pathogens are killed during the carbonization or pyrolysis process that requires high temperatures (Cao and Pawlowski, 2012; Jin et al., 2016). Faecal sludge briquettes can be used to replace the wooden charcoal briquettes hence reducing pressure on the forests in search for charcoal (Ward et al., 2014; Nantambi et al., 2016; Karahalios et al., 2018). Faecal sludge products are normally challenged by community attitudes due to various beliefs and taboos around faeces handling (Strenstrom, 2004; NETWAS, 2011). Faecal sludge briquettes are a good reuse option because they burn longer than wood charcoal and are more cost effective, making them a much cheaper option as a fuel source.

Following the success of faecal sludge briquette production in Kole district as a viable business with SAWA SAWA under a project supported by UNICEF Finland, Water For People embarked on a setup of a briquette production facility in Kampala since it has the biggest charcoal market. This was done in partnership with National Water and Sewerage Corporation, the national utility responsible for treatment of sewerage. The objectives of this project is to identifying the most suitable sludge to use for briquette productionin water, testing of physical and emission properties of different compositions of sludge combinations to come up with a briquette that can compete favorably on the market, setup of a briquette production facility and market testing of faecal sludge briquettes.

MATERIALS AND METHODS

As part of Water for People's efforts to ensure market driven approaches in sanitation, we planned to scale-up the production of briquettes from faecal sludge as an alternative fuel source with the setting up of a production plant in Kampala. Faecal sludge briquettes are not new to the market and while a lot of research has been carried out on the physical and fuel properties (Kiwana and Naluwaaga, 2016), there was need to optimize the process for large scale production. In this process, we tested briquettes made from two types of faecal sludge that is top scum and bottom settled sludge with different composition as follows; 100%, 80%, 60%, 50% and 40% with wood charcoal dust. The production of these test briquettes was done in collaboration with Sustainable Energy Answers Company Limited and Canaan Pioneering Innovations Development Agency, one of the existing briquette manufactures in Uganda.

The two types of FS are collected from National Water and Sewerage Corporation's (NWSC) Treatment Plant in Lubigi that is top scum (collected and scooped from the top of the sedimentation tank) and bottom settled sludge (collected from the bottom of the tank). The parameters tested for include: fuel properties test; calorific value, ash content, moisture content, volatile matter and fixed carbon, Water Boiling Test (WBT), emission test; CO, CO_2, PM2.5 (that is particulate matter having a diameter of less than 2.5 micrometers), black soot, oxides of Sulphur, Nitrogen and Phosphorus organic pollutants (Joseph et al., 2012). These parameters were tested by the Centre for Research in Energy and Energy Conservation laboratories in Makerere University and Central Government laboratories.

A briquette production plant focussed on producing stick and honeycomb faecal sludge briquettes with a faecal sludge/wood charcoal dust compositon of 40%/60% was intially set up in Nyanama and has since been moved to National Water and Sewerage Corporation Treatment Plant in Lubigi following the MOU signed between the two entities with facilities on the site such as production machinery, a solar dryer, greenhouse and carbonizer unit. The production unit currently has a staff of 6 people with a target of 3 tonnes of faecal sludge briquettes produced per week by the end of December 2019.

A market assessment study was carried out by Whitten & Roy Partnership to evaluate the market potential within Uganda for a

partially fecal sludge-based eco-briquette. In addition, recommendations for production, value chain participation, marketing and sales were sought. Following this assessment, Water For People embarked on small sales to test the market and gain insight into consumer perception of the product as well as develop business models that would build this into a viable business.

RESULTS AND DISCUSSION

Faecal sludge briquettes are technically viable as a cooking fuel when blended with other char from agro-waste, market waste or char dust. However, they cannot be used as 100% faecal sludge given the low calorific value. Top sludge is more suitable for use in faecal sludge briquettes as it is lighter and has less inorganic matter (Table 1). Briquettes with higher percentage of charcoal dust have better fuel properties hence the briquette with 40% FS ; 60% CD compares well and this was our starting combination. The briquettes proved to be durable, having a shorter lighting time, taking shorter time to boil water although burning out faster. Organic emissions such as PCBs, Furans and Dioxins were at non-detectable levels with SO_2, SO_3 levels detected below 5% and this reduced with reduction in faecal sludge composition, NO_2 levels at below 1% reducing with decreasing faecal sludge compositon and P_2O_5 levels at below 10% reducing with decreasing faecal sludge content.

Fuel briquettes made from 40% faecal sludge performed comparably well to wood charcoal with a calorific value of 24,000 KJ/kg (Figure 1) and close-in range fixed carbon and volatile matter to wood charcoal (Figure 2). The faecal sludge briquettes still have a lot more ash than wood charcoal however this improves its properties to burn longer with clay as a filler material and some clients have indicated that the ash can still be used as a soil amendment. The faecal sludge briquettes and wood charcoal used the same time to boil 5 litres of water (Figure 3) which is an indicator that they can be used effectively as a fuel source.

The briquette production facility started production in October 2018 and has to-date produced more than 10 tonnes of faecal sludge briquettes with the highest weekly production at 2.7 tonnes and averaging weekly at 1.5 tonnes (Figure 4a and b). The biggestbottleneck in the production process has been the carbonization process which has a low efficiency of approximately 30% and this greatly affects the volume of briquettes that can be produced.

The market assessment report by Whitten &Roy Partnership indicated that the market is large. The potential market for eco-briquettes using faecal sludge as a component ingredient is large enough to accommodate any volume that could be produced in the near-term if not long-term. Both business and consumer markets appear willing to adopt the product. Thus, the primary concerns lie with operational issues such as production and distribution, as well as marketing and sales details. Despite the potential demand being significant, selling product will still require building brand awareness through marketing to convert sales prospects into actual buyers. For some consumers, both marketing and sales will need to address habit change due to the unique characteristics of using fecal sludge-based briquettes. There is limited faecal sludge available at the quality and accessibility levels required. Therefore, Water for People should focus on one key B2B market (chicken farmers) and one key B2C market (middle-class consumers purchasing in supermarkets) to start.

With the informal sales carried out by Water For People, more than 3 tonnes (Figure 5 a and b) of briquettes have been sold with an indication of repeat and new clients monthly. Water For People has teamed up with a distributor Sheercare Cleaning Services (U) Limited who have managed to sell about 1 tonne of briquettes. This was to test the dyanmics of the distributorship model as a way of increasing sales. It has presented challenges with most clients preferring to buy the briquettes at the source production unit and not willing to pay more at the distributor regardless of the transport cost implication

Table 1: Physical Fuel Properties and Emission Test Results for FS Briquettes (Using Top Sludge) with Charcoal Dust.

Briquette Composition	**100%FS**	**80%FS 20%CD**	**60%FS 40%CD**	**50%FS 50%CD**	**40%FS 60%CD**
Weight of Briquettes (kg)	4.57	1.30	1.60	1.38	1.47
Moisture Content (%)	10.08	6.28	6.50	6.54	6.74
Calorific Value (kJ/kg)	5,875.50	9,628.50	17,747.50	23,823.76	24,495.37
Analytical Ash Content (%)	60.73	57.01	46.44	43.22	18.58
Fixed Carbon (%)	11.22	18.90	30.40	31.28	39.94
Volatile Matter (%)	17.96	17.81	16.65	18.96	19.83
Water Boiling Test	192 minutes	34.5 minutes	39 minutes	34 minutes	
CO emissions-g/MJ	180.01	42.75	32.75	36.76	
CO2 emissions-g/MJ	491.29	533.44	552.84	555.09	
PM 2.5 emissions-mg/MJ	39.06	2,848.99	1,236.70	1,411.41	
Sulphur emissions (SO3)-%	4.13	4.11	4.09	3.45	3.28
Nitrogen emissions (NO2)-%	0.96	0.72	0.76	0.81	0.66
Phosphorus emissions (P2O5)-%	9.11	8.16	8.42	8.30	7.09
Organic Emissions (Furans, Dioxins, PCBs)-g	Not Detectable	Not Detectable	Not Detectable	Not Detectable	Not Detectable

Table 2: Physical fuel properties and emission test results for FS briquettes (Using Bottom Sludge) with Charcoal Dust.

Briquette Composition	100%FS	80%FS 20%CD	60%FS 40%CD	50%FS50%CD	40%FS 60%CD
Weight of Briquettes (kg)	4.57	1.58	1.61	1.63	1.37
Moisture Content (%)	14.40	5.08	5.06	6.00	5.67
Calorific Value (kJ/kg)				12,037.21	18,281.80
Analytical Ash Content (%)	58.91	53.61	50.54	41.19	39.93
Fixed Carbon (%)	11.23	19.30	25.23	29.36	34.93
Volatile Matter (%)	15.45	22.00	19.17	23.44	19.47
Water Boiling Test	Briquettes fail to light	80 minutes	37 minutes	50 minutes	43 minutes
CO emissions-g/MJ	Briquettes fail to light	54.01	33.09	47.91	41.75
CO2 emissions-g/MJ	Briquettes fail to light	749.47	490.91	614.38	1380.51
PM 2.5 emissions-mg/MJ	Briquettes fail to light	1937.39	1238.35	1380.51	1209.73

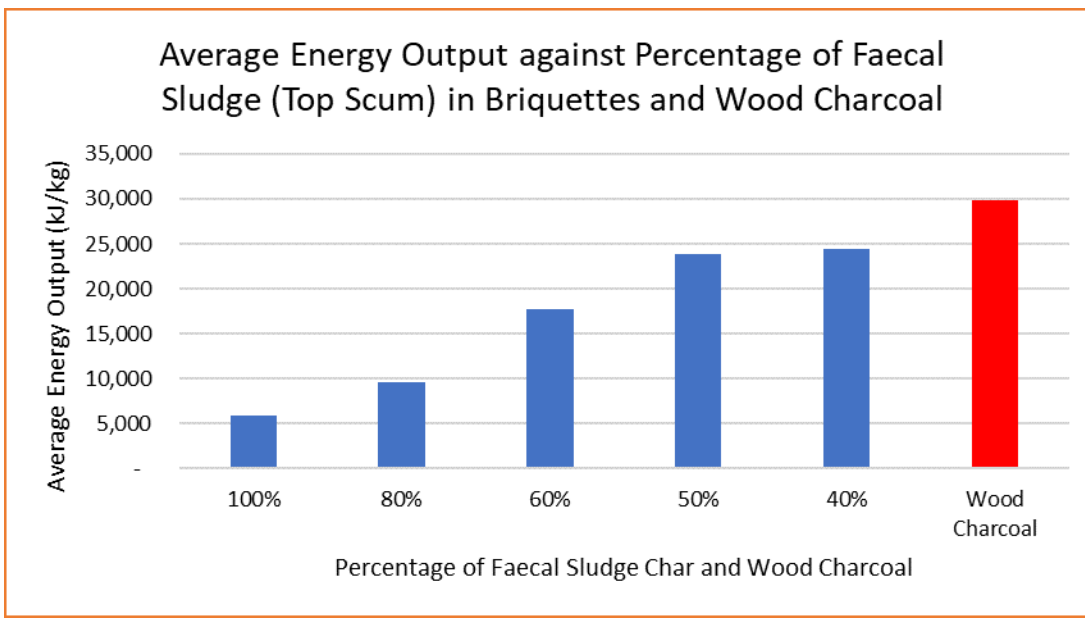


Figure 1: Average energy output in faecal sludge briquettes and wood charcoal.

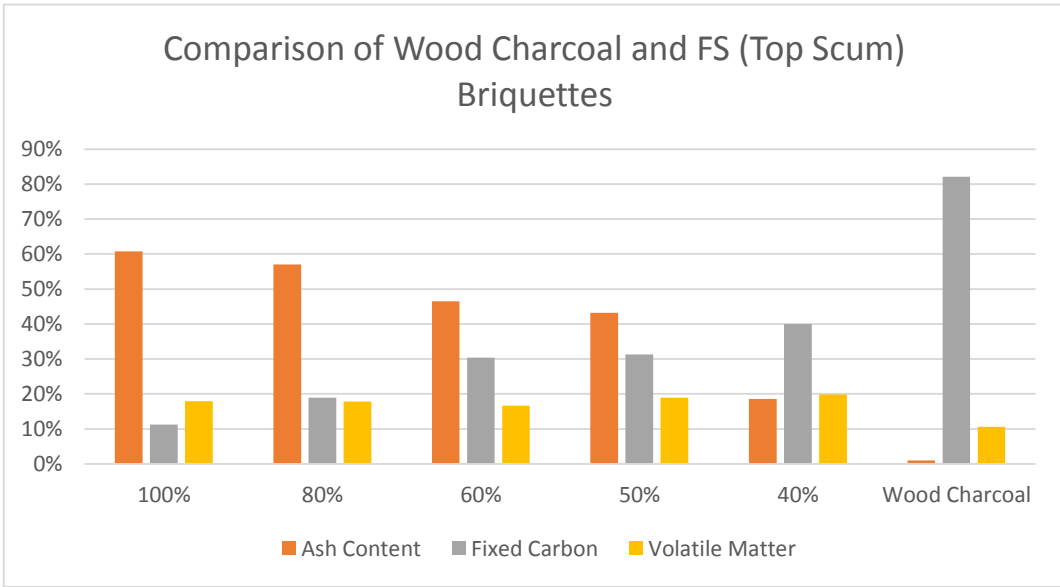


Figure 2: Ash content, fixed carbon and volatile matter percentages for faecal sludge briquettes and Wood Charcoal.

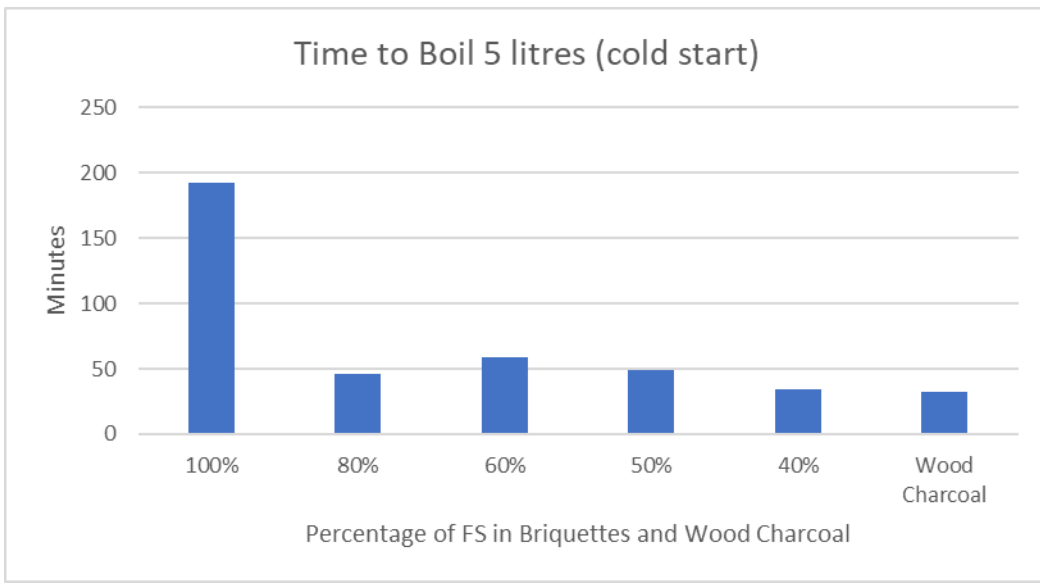
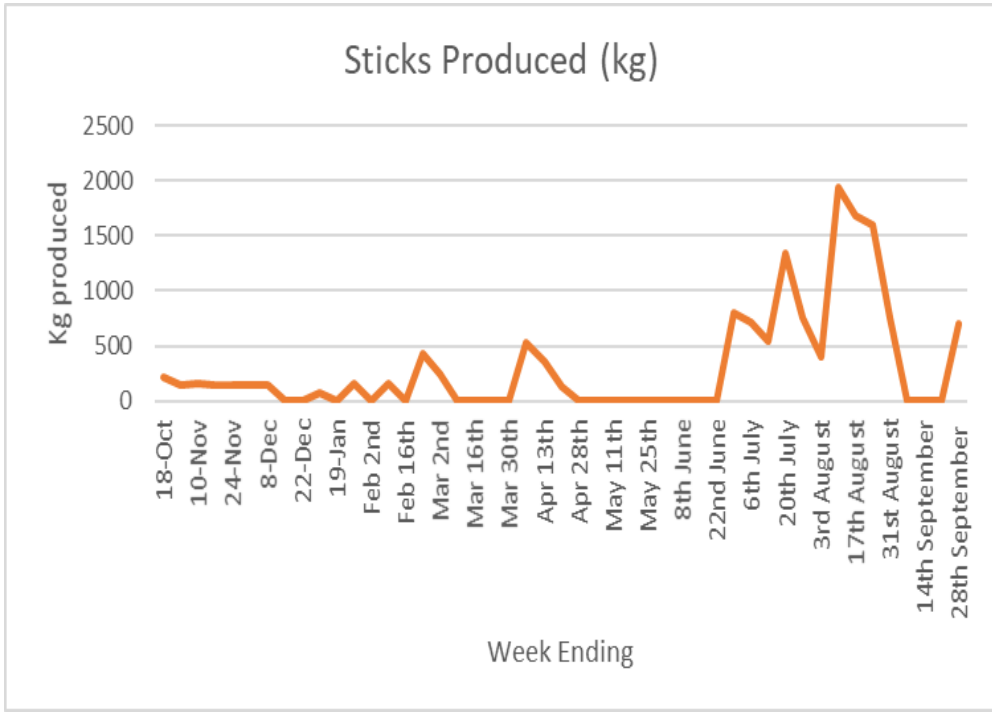


Figure 3: Comparison between faecal sludge briquettes and wood charcoal in time taken to boil 5 litres of water.



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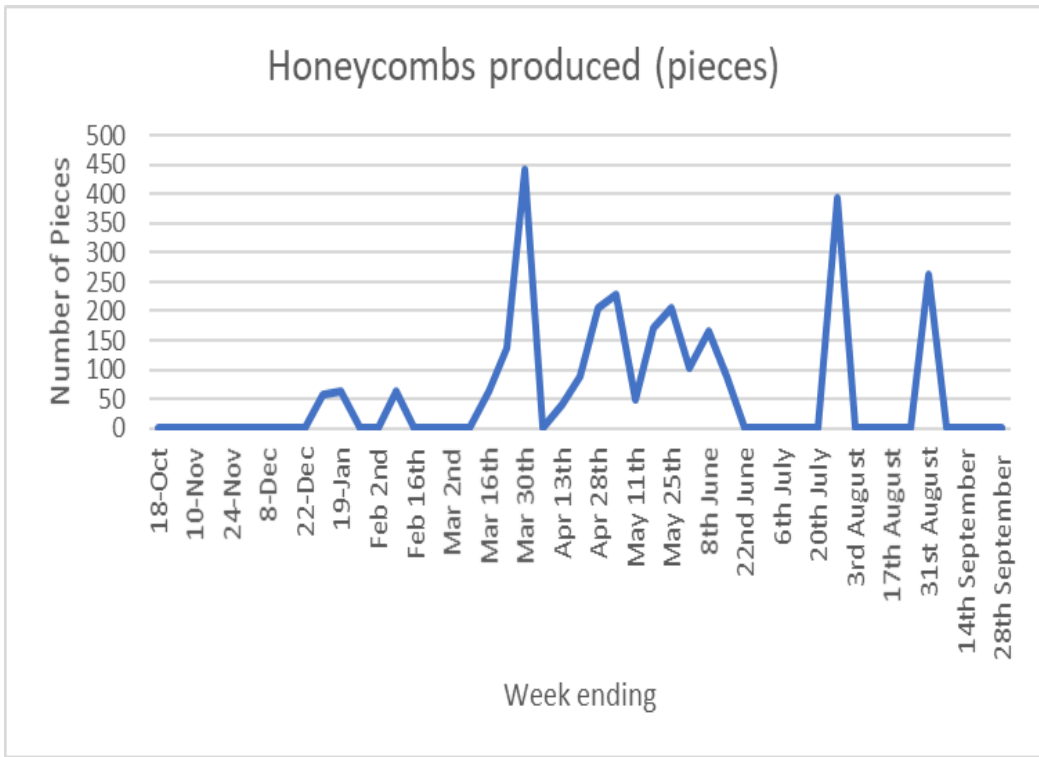

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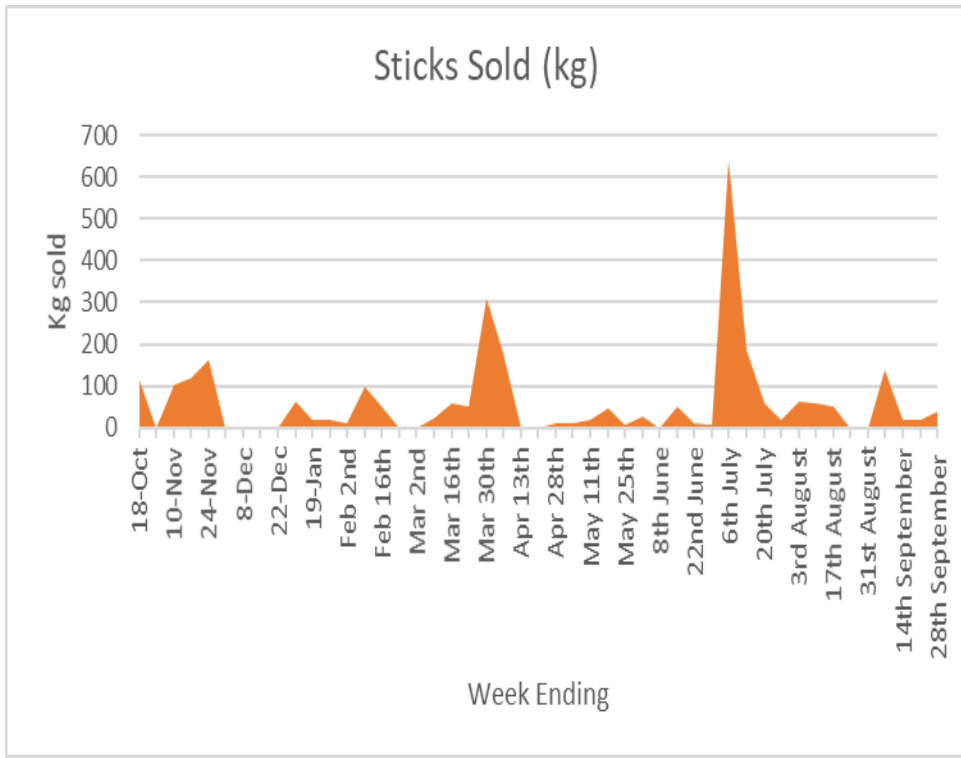
Figure 4 a and b: Faecal sludge production trend from October 2018 to September 2019.



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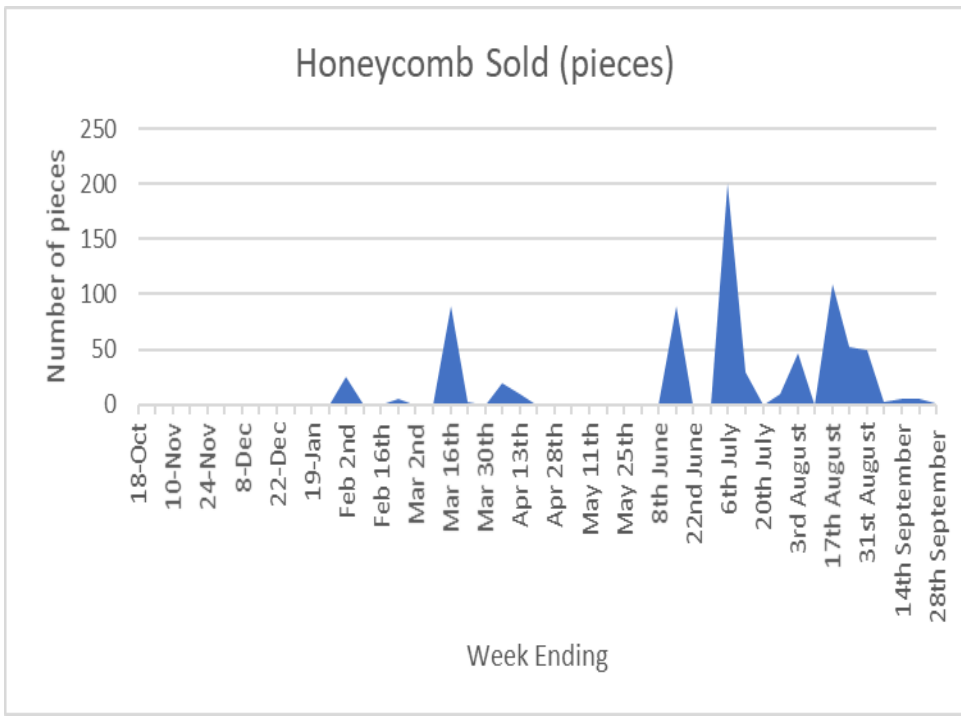

b)

Figure 5 a and b: Faecal sludge production trend from October 2018 to September 2019.

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Conclusion

Previous tests and current research has proved that FS briquettes with 40% FS are most viable to compete with charcoal and charcoal dust briquettes. New information has shown the most viable sludge to use is the top scum given that it does not have a lot of sand that is picked up in the bottom sludge from the drying beds. Setting up of a briquette production plant in Kampala has informed the project on the availability of local fabricators in the market and the strives being taken in automation of the briquette production process. At the start, assumptions were made that sludge and charcoal dust are a waste product and therefore would be available free of charge or in the very least at a minimal cost. We have, however, since learnt that the sale of FS feeds into the income stream of the treatment plant and charcoal dust is very much in demand, hence reducing the profit margins of the entire venture. Today, there is no clearly defined supply chain for the raw materials and this needs to be developed in future. There is also a need for further research into reducing the percentage of charcoal dust in the briquette with other materials such as agricultural and market waste. The other major lesson has been understanding the production process of faecal sludge briquettes, especially the efficiency of certain processes like carbonization. Further research is needed in the production process engineering for optimization as well as meeting the current market demand.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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Barriers to inclusion in the WASH sector: insights from Uganda

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ABSTRACT

In the WASH SDG Programme, Gender Equity and Social Inclusion (GESI) is a transversal topic in the different phases of the programme. As such, there was a GESI assessment done in 2018 during the inception phase of the programme to identify who is left behind and which barriers the socially excluded groups are often facing. From this assessment, our assumptions and expectations on barriers to inclusion were challenged by the relationships and differences we found in the field. In order to make sure "no one is left behind" it is vital to research why and how certain groups are excluded. We have to know the root causes of exclusion to reach inclusion and have to be context specific. There could be different types of barriers hindering socially excluded groups (e.g. social/cultural, economic, technical, political and technological) and these need to be well understood in order to address and remove them. WASH (*Eau, ASsainissement et Hygiène*) programmes need to go beyond inviting marginalised groups to participate in meetings. Attending a meeting does not naturally translate into the voices of the marginalized being heard or will not contribute to removing the barriers that hinder social inclusion. Incorporation of GESI into the WASH programme cycle can help addressing gender and inclusion differences and change these relations over time.

Keywords: Barriers, GESI, inclusion, LNOB SDGs.

INTRODUCTION

The Sustainable Development Goals (SDG) report of 2018 highlighted that majority of the world's population still lacks safe WASH (*Eau, ASsainissement et Hygiène*) services. In 2015, 844 million and 2.3 billion people lacked even a basic service for water and sanitation. (UN, 2018) Sub Saharan Africa still contributes more than half of this disparity with 34% using basic water services, 28% using basic sanitation services and 15% using basic hygiene services respectively.

In Uganda, the policy on WASH has improved. WASH indicators have predominantly increased over the last decade. However, there is still a lack of improved services and demand on the ground within the communities. National estimates indicate that 30% of population still depends on surface water sources such as streams. Where there is a source there is a 15% likelihood that the water

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source is non-functional. 20% of the population was reported to lack access to decent sanitation facilities and more 70% of the population is without a handwashing facility (MWE, 2019).

The 2030 Agenda and SDG 6 promise to extend services to those unserved populations across the world through the leave no one behind commitment (UN, 2015). To deliver this development agenda, governments and development agencies have to understand who is left behind, what barriers exist and how do the dynamics of exclusion affect WASH needs. It is only by tackling these issues that inclusive WASH interventions can be designed and implemented.

Social Inclusion is widely defined as the process by which efforts are made to ensure equal opportunities for all, regardless of their background, so that those marginalized can achieve their full potential in life. The World Bank Group expands this definition to encompass improving the opportunities, ability and dignity of the disadvantaged (The World Bank, 2019). Whereas exclusion is the barrier that impedes social inclusion through partial or wholly excluding individuals on grounds of social identities including age, sex, culture/ethnicity, religion, language, physical and economic disadvantages. Exclusion could manifest as a lack of voice or recognition (Ahrari et al., 2018). Barriers to social inclusion can be categorized as social, economic, political, physical or environmental factors. These may appear directly or indirectly and take place at different levels- either at a global scale, within countries or between the urban and the rural populations. (White et al., 2016)

The WASH SDG programme (2017-2022) is implemented in seven countries by a consortium consisting of the WASH Alliance International (WAI), Plan Netherlands and SNV. The programme aims at improving WASH situation for all. It is built on three core strategic objectives, namely: (1) increasing demand for improved WASH facilities and practices; (2) improving the quality of service provision; and (3) improving governance of the sector. Gender and Social Inclusion (GESI) is an area of specific attention in each of the three strategic objectives as well as Climate Vulnerability and Resilience (CVR). Funded by the Dutch Ministry of Foreign Affairs, the 5-year programme will run from July 2017 to September 2022.

The WASH SDG Programme in Uganda consists of the Uganda WASH Alliance sub- programme and Uganda Kamuli Buyende and Nebbi sub-programme. The WASH SDG Programme in Uganda aims at sustainably deliver access to, and use of, safe drinking water for at least 86,400 people; and improve access to, and use of, sanitation and improve hygiene behaviours for at least 279,400 and 150,700 people respectively.

The Uganda WASH Alliance sub-programme is being implemented in Agago district in Northern Uganda, as part of Agago sub-catchment. Simavi is leading the Uganda WASH Alliance sub-programme. The Uganda WASH Alliance sub-programme is implemented mainly by the local partners. These include: Agency for Sustainable Rural Transformation (AFSRT), Amref Health Africa- Uganda, Health through Water and Sanitation (HEWASA), Joint Effort to Save the Environment (JESE), RAIN Uganda, Network for Water and Sanitation Uganda (NETWAS Uganda) and Water and Sanitation Entrepreneurs Association (WASEU), and supported by the Dutch WAI partners: Simavi, Amref, Akvo, RAIN, RUAF, IRC and Practica.

GESI has been a key focus area from the start. As it was a key topic during the baseline, a GESI assessment was done in the inception phase to understand the GESI issues in Agago and take this along in programme development. The baseline assessment designed and conducted by Simavi found a negative relation between access to and use of WASH services and marginalized groups. This entails that; there are certain barriers that prevent communities from establishing inclusive WASH services and WASH governance. The findings that came out of the assessment question previously made assumptions on exclusion and are therefore of great value. This paper aimed at discussing the

main GESI findings and how these are implemented in the WASH SDG programme.

MATERIALS AND METHODS

In order to ensure that the WASH SDG Programme is addressing GESI, different methods have been used in different phase of the programme cycle:

- *GESI-informed programme design:* a GESI assessment was done, based on document review, interviews, questionnaires, and focus group discussions. Assessments focused on: marginalisation within the household; between households and of community. The assessments also reviewed public administration and legal and policy barriers/enablers.
- *GESI-focused implementation and management:* Support was provided to both GESI- specific activities that are targeted directly at women and/or socially excluded people as well as the mainstreaming of these issues into broader activities. Programme organisation structures, budgets, staff, capacity building and establishment of programme modalities were also addressed for GESI related activities.
- *Monitoring, evaluation and learning for GESI:* In monitoring and evaluation, data is included with disaggregation for gender and socially excluded groups. The WASH SDG Consortium is developing a systematic learning programme on the experience of implementing a GESI focused WASH programme, including learning between country programmes. Therefore, an example from Indonesia can be adapted by other subprogrammes through the learning programme and *vice versa*.

Looking at the Uganda WASH Alliance sub-programme in Agago, a GESI assessment was conducted in order to assess who is left behind in Agago district. The following GESI research questions were asked:

- Who is left behind from access to WASH services?
- Who controls the resources and takes the decisions?
- What are the barriers for inclusion?
- How are the WASH practices different for different (marginalized) groups?

The GESI assessment was done based on primary and secondary data sources. A cross sectional study design was used to undertake the qualitative assessment (Ofumbi, 2018). Furthermore, data from the baseline study was used. The baseline study consisted of a household survey; 913 respondents, including a water quality assessment. Through this household survey the WASH practices following the JMP ladders were clarified. These findings were then disaggregated for different wealth quintiles (based on the Poverty Probability Index (PPI) for Uganda (IPA, 2015)), urban/rural settings and gender. Additionally, interviews with key informants and stakeholder were conducted, followed by a GESI Assessment where the special position of marginalized groups was assessed. The collection of this data contributes to the research of exclusion in WASH service provision and the design and implementation of the programme.

RESULTS AND DISCUSSION

A total number of 913 respondents have been included in this household survey. The main focus was on female members of the household and that can be seen in the gender distribution of all respondents: 83% female and 17% male. The average household size within the sample is seven household members. In 74% of the households there are children under five. 87% of the households there are children between five and 17 years old. Most households are headed by a male member (71%), showing that the intervention area represents a traditional structure in terms of power in the household (patriarchy). Most of the heads of the households are able to read and write (73%) and most households have finished primary education (44%), secondary education (22%) or no education (23%). Almost all households in the sample are Christian, and 95% of all households are from the Acholi tribe, showing a homogenous society in general. Agriculture is the main

source of income for 95% of the households. 20% of households reported to have a person with disability. In the majority of cases this is a physical disability. Other types of disability like lack of vision, hearing and/or mental problems are also present. This shows the importance for the programme to focus on the inclusion of people living with a disability in the programme (Simavi, 2018).

Figure 1 shows the correlation between the JMP service ladders on Water, Sanitation and Hygiene and wealth. More households within the lowest wealth quintiles are using lower service levels of water, are practicing open defecation and do not practice handwashing. Majority of the households >60% were accessing a limited service level. More than >80% were using unimproved sanitation and >90% didn't have hand hygiene facilities to their disposal. Looking at different wealth groups the baseline findings show that there is a difference between sanitation and drinking water. Safe drinking water is better accessible throughout different wealth groups. This is because drinking water is generally organized on community level. With regards to sanitation the difference between wealth groups are much more diverse. This is related to the fact that sanitation is often organized on household level. This shows that there should be a different approach for reaching marginalized groups in different elements of WASH.

The GESI assessment found different barriers to social inclusion in Agago. In terms of social and cultural barriers, stereotyping and prejudice against women and other marginalized groups limit their participation in WASH decision making at household and community level. Furthermore, there is discrimination and stigma for certain socially excluded groups.

There are two main barriers to economic inclusion of women. One, limited control and decision- making power of women over household and community investments and resources. Two, women carry the burden of most of the unpaid work. On the other hand, women were the main recipients of loans from saving and or credit groups, which combined with their limited decision making power can lead to their exposure to violence within/outside the family. At the same time, the existing WASH businesses are not focusing on rural areas or on the needs to women and other socially excluded groups (e.g. people living with a disability and the elderly).

In terms of technological barriers, the Local Government in Agago has limited capacity in terms of knowledge, skills and financial resources to mainstream social inclusion. Looking at political barriers, most policies, laws, strategies, plans and guidelines on social inclusion are sound in Uganda, but are not fully implemented. Looking at technological barriers, some WASH technology options/ designs like pit latrines and boreholes are non-inclusive to the People living with Disability and elderly.

Implications for implementation

From the baseline study and GESI assessment, the WASH SDG Programme started implementation of the programme on 1st of July 2018. The programme is promoting a GESI- sensitive approach, for instance in making sure women and socially excluded groups have equal opportunities to access and influence WASH related decision making and use improved WASH services. A GESI-focused WASH programme requires adjustments to hygiene behaviour change communication, sanitation demand creation (e.g. CLTS), supply chain development (e.g. sanitation marketing approaches) and WASH governance.

Increase demand for improved WASH facilities and practices

A GESI approach within the WASH SDG programme places increased emphasis on participatory methods and tools to create demand for improved WASH facilities and practices. Existing methods and tools are being adapted to support a more GESI transformative process as well as more equal outcomes. The WASH SDG programme will engage with young people, adolescent girls and/or boys to influence harmful gender stereotypes. In 10 households from three selected villages in

Omot sub-county, the WASH SDG Programme is piloting household level gender action planning (GAP). This activity is conducted to understand existing gender inequalities at household level and re-defining women's and men's gender roles and relations through guidance on gender mainstreaming at household level. In all 10 households a gender responsive and transformative action plan that clearly recognizes the women and children's contribution to household resources was developed. We will continue to follow up on the implementation of these plans and there after role out GAP to other villages. From this GAP exercise it's noted that the issue of ownership of household resources particularly land and money is a reserve of men yet women have the greatest contribution. It's important that under the WASH SDG programme we should have a deliberate gender mainstreaming and awareness campaigns in order to recognize and increase effective women's participation in production and use of household resources. This entails empowering both women and men.

Improve the design and implementation of service provision

Partners are adapting the design of toilets and handwashing facilities to ensure they meet the need of elderly people, women, children and people with disabilities. In Agago, women are under-represented in formal WASH technical roles such as toilet construction or pit emptying as well as service delivery for instance as WASH entrepreneurs. In response, sub-programmes are training female entrepreneurs to help them to compete with male counterparts. Masons and WASH entrepreneurs are also being trained on the WASH products suitable for people with particular needs. Through mentoring and the use of role models, women are encouraged to become entrepreneurs.

Improve governance of the sector

Partners are supporting government institutions and community committees and leaders to better plan and budget for WASH services. The partners are building the capacity of government and traditional leadership on gender transformative and inclusive WASH approaches to ensure ownership of activities. In Uganda, the WASH Alliance is working with District local government in Agago to introduce bylaws related to GESI. One success is that the local government is taking the GESI issue seriously. The local government has issued a by-law to prevent alcohol abuse, as they see a link between alcohol abuse and gender-based violence (e.g. 37 women were murdered by their husbands in Agago district in 2018).

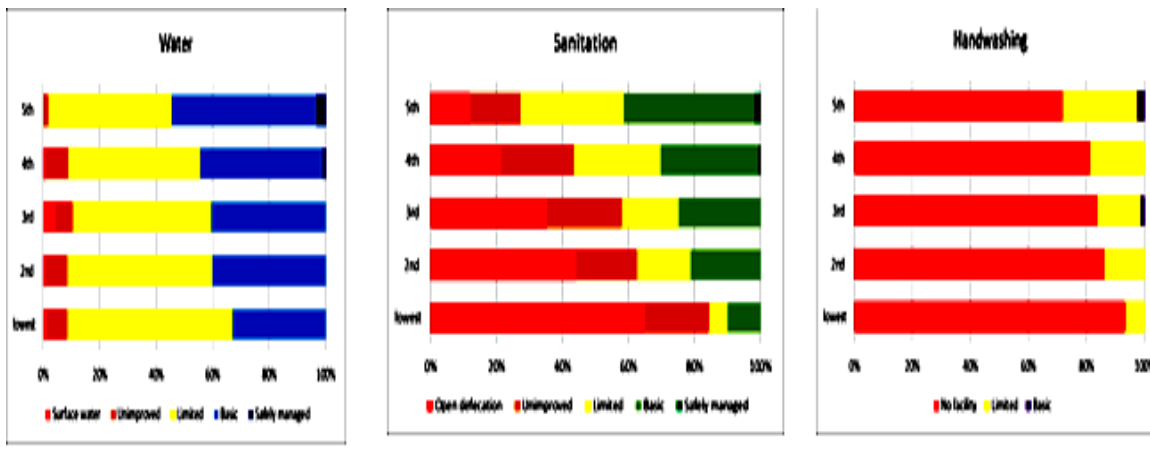

Figure 1: results on the water, sanitation and hygiene ladder per wealth quantiles.

Conclusion

Gender stereotyping, patriarchal system, limited female mobility outside the house, discriminatory beliefs and stigma's against minorities, women's lack of decision making power, gender based violence and lack of knowledge by men and boys on gender equality were among the major barriers faced by women and other socially excluded groups. The study shows the importance to be specific in identifying the barriers to inclusion and drivers of exclusion in each context and for each topic. The integration of GESI from the start into the WASH SDG programme in Uganda has forged the way to ensure the programme is better able and equipped to contribute towards equality in terms of access to and use of WASH services. It will also contribute to greater equality in society beyond WASH by ensuring the implementation of the "do no harm" principle; and ultimately to the realization of the ambition of leaving no one behind in 2030. Recommendations for WASH programmes that aimed at "leaving no one behind": Design for GESI from the start – make it central to the Theory of Change. Incorporation of GESI into the WASH programme cycle can help address gender and inclusion differences and change these relations over time; GESI programmes must be evidence based – do assessments and use tried and tested approaches - but also make space for innovation; Transformative change requires learning organizations for personal and professional change and inclusion of all relevant stakeholders in the process.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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Household-level Fluoride reduction from drinking water using crushed fired clay – proof of concept

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ABSTRACT

Residents of Bunyangabu District in Uganda have reportedly suffered from cases of dental fluorosis due to consumption of water with high levels of Fluoride from Ntabago Stream. A household-level sand filter incorporating crushed fired clay as an adsorbent was designed for a household to reduce the Fluoride concentration in their drinking water from the natural raw water levels (2-3 mgF/L) to permissible, healthy levels (0.5-1.0 mg/L). Pieces of fired clay bricks were crushed, and particles of 150 µm to 300 µm in size were selectively obtained by sieving. Stream water was filtered through replicate model layered filter columns of the prepared clay, sand (fine sand of 150 µm-2 mm; coarse sand of 2-5 mm), and gravel (6-15 mm). It was found out that fired clay layers of 2.5 and 5 cm thick reduce the concentration of Fluoride in water by up to 74%, to less than 1.0 mg/L. This was deduced by evaluating Fluoride concentration in both the clay and water before and after filtration, using the SPADNS Colorimetric method. Use of crushed fired clay for reduction in Fluoride concentration in drinking water is the focus of this paper. Additional work will optimise filter design to improve overall water quality.

Keywords: Defluoridation, filter column, household-level water treatment.

INTRODUCTION

Fluoride is found in all natural waters at varying concentrations (Djossou et al., 2015; Hisseien et al., 2015). Seawater generally contains about 1.0 mg/L, while rivers and lakes mostly exhibit concentrations of less than 0.5 mg/L. In groundwater however, low and high concentration of Fluorides can occur, depending on the nature of the rocks and the occurrence of Fluoride-bearing rocks (Djossou et al., 2015). Many of the lakes of the African Rift Valley especially the soda lakes, have extremely high Fluoride concentration.

Geographical areas around the world that have concentrations of Fluoride include Syria, Jordan, Egypt, Libya, Algeria and Morocco. It also includes the rift valley area in Africa from Sudan through Kenya to Tanzania and Malawi. Another geographical area extends from Turkey through Iraq, Iran and Afghanistan to India, northern Thailand and China. The most affected areas by Fluoride include India, China and Rift Valley

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countries in Africa (Demelash et al., 2019; Mosonik, 2015).

In Uganda, 6.45% of the water sources exceed the standard value of Fluoride in drinking water. The maximum value of Fluoride in these waters is reported to be 3.31 mg/L and the most affected areas include volcanic areas of Elgon, Mbale, Moroto and the Rift Valley of western Uganda (Malago et al., 2017).

Preliminary tests carried out in October 2018 on water from Ntabago Stream in Western Uganda showed concentrations of Fluoride between 2 mg/L to 3 mg/L, which has led to fluorosis and discolouration of teeth for the residents consuming the water (Figure 1). According to the Ugandan Standard (UNBS, 2008), this range is greater than the permissible levels (0.5 mg/L to 1.0 mg/L for potable treated water, and 1.5 mg/L for potable untreated water). This has made the water unsafe for human consumption due to high concentration of Fluoride in water (Das and Mondal, 2016).

The National Water and Sewerage Corporation (NWSC) has provided piped water, but because of the cost attached, the residents prefer free water from this stream to piped water, which makes them susceptible to health risks associated with Fluoride contamination (Table 1). 34% of the population in Rwimi Town Council have access to safe and clean water (MWE, 2018). This implies that the bigger percentage (66%) of the population have no access to safe and clean water. The focus of this study is mainly on the potential for defluoridation of water from Ntabago Stream to permissible levels using crushed fired clay as an adsorbent.

Crushed fired clay was chosen as it is readily available to households in Uganda where small scale industries involved in firing of clay bricks for construction, firing of pottery, and charcoal stove linings are common. Other adsorbents have been studied for fluoride reduction including bone char, ceramics, and oxides (Djousse Kanouo et al., 2020; Yadav et al., 2018; Habuda-Stanić et al., 2014; Madhukar et al., 2014; Loganathan et al., 2013), but these may not be available at household level.

Figure 1 Affected residents of the study area showing teeth discolouration.

Table 1: Health impacts of Fluoride in drinking water.

Fluoride (mg/L)	Health Impact
< 0.5	Dental caries
0.5–1.5	Optimum dental health, works against dental caries
1.5–3	Dental fluorosis, blackening and pitting of enamel and teeth from long-term exposure, mottled enamel, Roentgenographic bone changes, polydipsia
3–8	Skeletal fluorosis, damages foetus, increase in F-concentration in milk, infant mortality due to calcification of blood vessels, lack of intelligence quotient in children, osteosclerosis, renal diseases, elevated serum alkaline phosphatase, stiffness of knees and hips, increased bone mineral density, bone and joint pains.
10–100	Gastroenteritis, skin irritation, deformation of bones and other skeletal abnormalities, thyroid changes, growth retardation, kidney damage, crippling fluorosis.

Compiled from Madhukar et al. (2014)

MATERIALS AND METHODS

Raw water quality

Grab samples of stream water were collected from three locations along the Ntabago Stream (Figure 2) for raw water Fluoride concentration analysis.

Defluoridation model filters

Model filters were prepared for defluoridation filter test runs as follows:

Pieces of fired clay bricks were crushed and sieved to obtain the particles that pass through a 300 µm sieve and are retained on a 75 µm sieve. After sieving, the clay was washed to eliminate very fine particles (dust of less than 75 µm). Clays reportedly have a Fluoride adsorption capacity of 84-95 mg/g; and over 85% adsorption for clays with high Al and Fe content. Heat treatment (firing) increases adsorption capacity (Madhukar et al., 2014).

Sand was washed using clean water until clean water from it was observed. The sand was sun dried for two days, and fine sand and coarse sand portions were obtained after sieving. Coarse sand and fine sand of 2 mm to 5 mm, and 150 µm to 2 mm, respectively, were used.

The gravel to be used was thoroughly washed with clean water to eliminate dust and then sun dried, after which gravel of size 6 mm to 15 mm obtained by sieving.

The model filter layers were arranged with the gravel at the bottom, followed by coarse sand, then fine sand, and crushed fired clay at the top. The gravel and sand layers had a constant thicknesses (5 cm) while the crushed fired clay had varying layer thickness (2.5 cm, 5 cm, 7.5 cm) in each of the three model filters.

A 3 mgF/L solution comprised of distilled water and Sodium Fluoride (NaF) was prepared for the model filter test runs. After stock preparation, the solution was analyzed to confirm the concentration of Fluoride ions using SPADNS Colorimetric Method (APHA/AWWA/WEF, 1999). 750 mL of the 3 mgF/L solution was passed through the model filter in each test run, and the filtrate was analysed for Fluoride concentration.

The SPADNS Colorimetric Method was used to determine the concentration of fluoride in the water before and after filtration. This Method is based on the reaction between fluoride and a zirconium-dye

and relies on the fact that when Fluoride reacts with certain zirconium dyes, a colourless complex anion and a dye are formed. The complex, which is proportional to the fluoride concentration, tends to bleach the dye which therefore becomes progressively lighter as the Fluoride concentration increases. In the case of the Fluoride ion reaction with Zr-SPADNS (sodium 2-(parasulphophenylazo-)-1,8-dihydroxy-3,6-naphthalene disulphonate), the resulting coloured complex is measured in a spectrophotometer at 570 nm (APHA/AWWA/WEF, 1999; HP, 2000).

To determine the clay-adsorbed portion of Fluoride, the clay was removed from the filter and a homogenized sample washed using 250 mL of 1 M of hydrochloric acid for 1-hour in order to extract Fluoride ions in a solution. The acid enabled the detaching of the Fluoride ions from clay particles into the washing solution (Moon et al., 2015).

After one hour, the suspension was filtered using a 0.45 µm micropore filter and the filtrate was then analysed for Fluoride concentration according to the SPADNS Colorimetric Method as described above.

Adsorption capacity and effect of adsorbent layer thickness

Fluoride reduction with tests with model filters were carried to determined layer thickness of the adsorbent and the initial Fluoride ion concentration in the solution was determined at ambient temperature (~25 °C). The Fluoride concentration in the filtrate and fired crushed clay from the filter was determined using SPADNS Colorimetric Method. Three model filter setup experiments were used, and three test runs carried out on each.

The effect of the adsorbent layer was investigated by varying the crushed fired clay layer thicknesses, and spiking the water to be filtered with 3 mgF/L. The fired clay thickness in the filters was varied from between 2 cm to 10 cm (2.5 cm, 5 cm, and 7.5 cm). The concentrations of Fluoride in the filtrate were determined after each test (Motora and Tesema, 2017). The concentration of Fluoride retained in the clay layer was determined in one of the three test runs.

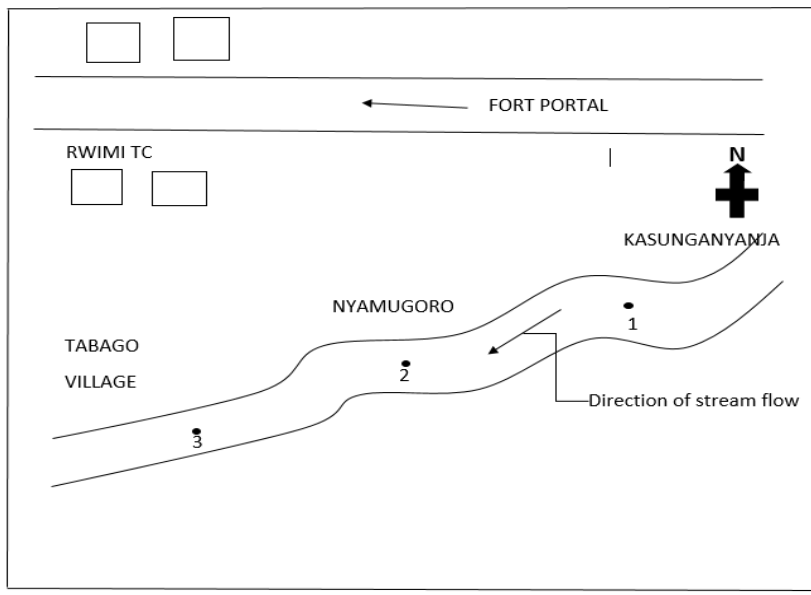

Figure 2: A sketch map showing location of sampling points along Ntabago Stream.

RESULTS

Defluoridation test runs

The 2.5 cm and 5 cm crushed fired clay layer filters were able to reduce to the Fluoride concentration in the filtered water by 71% and 74% respectively to within the optimum range for dental health (0.5-1.5 mgF/L), which meets the Uganda National Standard maximum limit of 1.5 mgF/L (Figure 3). Other studies with fired clay show similar reduction levels (Mottora and Tesema, 2017).

The 7.5 cm clay layer filter reduced the Fluoride levels by 95% to below 0.5 mgF/L (Figure 3), which is a risk factor for dental caries. Reduction in the clay-free control was about 10%. Therefore, the 5 cm clay layer filter was chosen as a conservative option for further study.

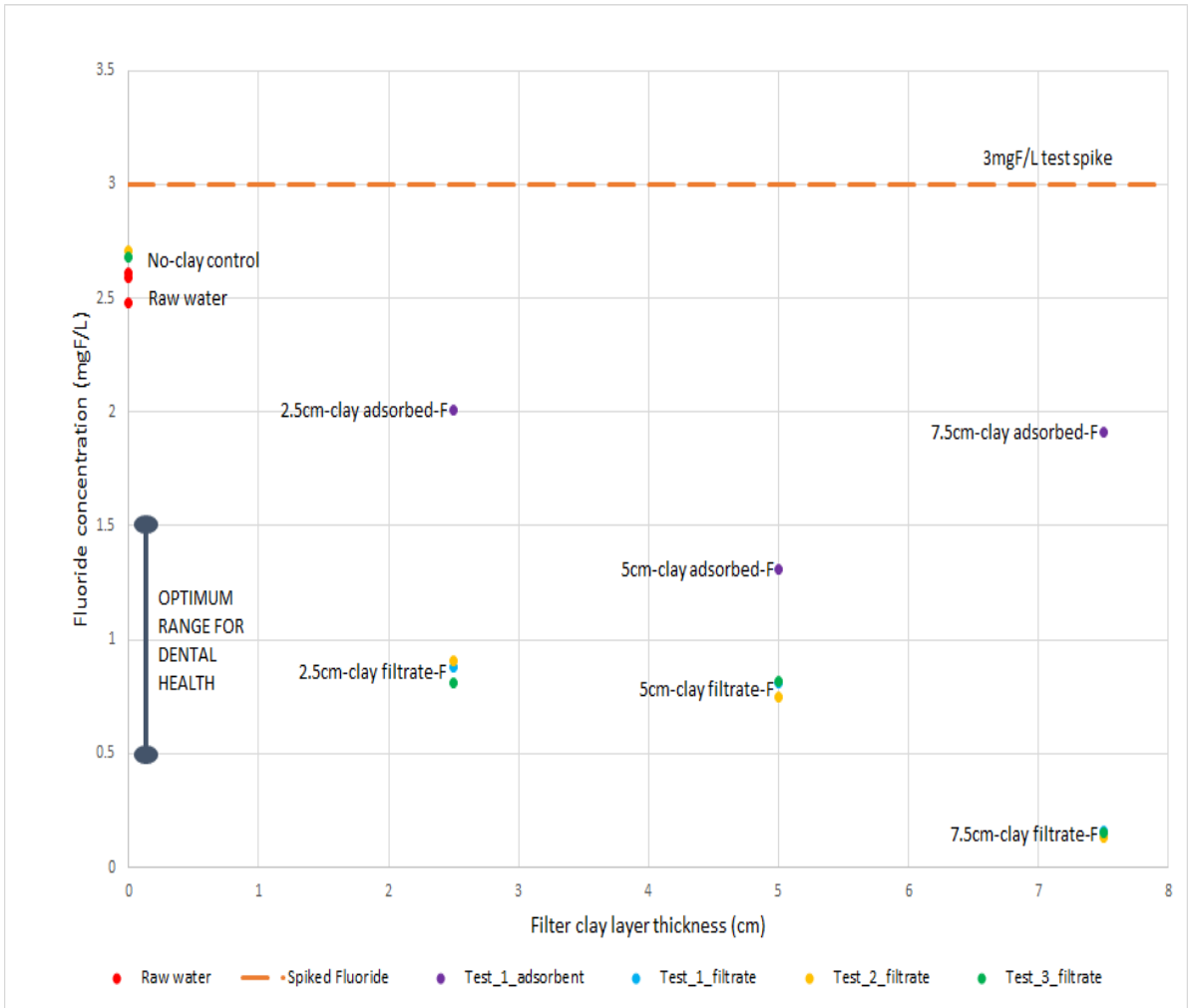

Figure 3: Defluoridation test runs show reduction of Fluoride to within and below the optimum range for dental health in filtrate from model filters with a crushed fired clay layer receiving water spiked with 3 mgF/L.

DISCUSSION

With the 7.5 cm clay layer, 95% of the Fluoride could be accounted for in the filtered water and HCl acid-washed clay, which compares favourably with the findings of Moon et al., (2015). However, with the 5 cm and 7.5 cm clay layers only about 70% of the spiked Fluoride was accounted for at the end of the test run. It is therefore important to carry out more tests to account for the remaining 30% in order to understand the defluoridation process better, and to determine how long the clay layer can remain effective before needing to be replaced.

Filtered water quality

Raw water quality improvement in other parameters of interest was therefore checked with a 5 cm clay layer test filter (Table 2).

While the 5 cm clay layer model filter reduces Fluoride levels to optimum, and improves other physicochemical parameters (Electrical Conductivity), it produces water which needs still improvement in Apparent colour, Turbidity and Total Suspended Solids levels (Table 2). Further optimization of the sand filter layer thickness is needed for overall physicochemical and biological water quality improvement for household level drinking water treatment. An adaptation of the HACCP (Hazard Analysis Critical Control Point) methodology outlined by Gokpeya et al. (2019) for household level clay water filters shall form the basis for this assessment.

Table 2: Raw water quality before and after filtration.

Parameters	Units	Initial quality	Filtrate quality	Uganda National Standards for potable water	Filtered water compliance
pH		7.11	7.32	6.5 – 8.5	OK
Electrical Conductivity	µS/cm	980	348	≤ 1500	OK
Colour (apparent)	PtCo	207	**74**	≤ 15	**High**
Turbidity	NTU	39	**9**	≤ 5.0	**High**
Total Suspended Solids	mg/L	44	**9**	0.0	**High**

Conclusion

Ntabago Stream has between 2-3 mg F/L, which is above the National Standard and above the optimum range for dental health (0.5-1.5 mgF/L). A crushed fired clay layer of 5 cm thickness in a model filter was adequate for reducing Fluoride by 74% to the permissible levels. The filter system was also effective at reducing water Turbidity, Electrical Conductivity, Apparent colour and Suspended Solids.

Further studies will be done on optimization of the defluoridation model filter and process. This would aid in determining the contact time for optimum Fluoride reduction, the period after which the adsorption sites are fully saturated, potential for adsorbent regeneration, maintenance best practice for the filter system, and the filter layer requirements for achieving overall safe drinking water quality at household level.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors contributed to the conception and design, and analysis. EW was the principal investigator. BN and BK contributed to material preparation and data collection. EW led the manuscript writing and made revisions.

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Transboundary water governance and water conflicts in the Lake Victoria Basin: an adaptive and integrative management approach

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ABSTRACT

Lake Victoria Basin is a transboundary natural resource shared by five East African Community countries. The Basin experiences unsustainable water resource utilization and management which creates conflicts among the users. This objective of this study was to examine the contribution of transboundary water governance systems in managing the water conflicts in the Basin. Qualitative data were collected through interviews and focused group discussions where respondents were clustered and purposively selected while quantitative data were collected through questionnaires and analyzed using SPSS. Lake Victoria Basin Governance Performance Composite Index was also used to assess the effectiveness of governance systems in the Basin. The study findings revealed that: transboundary water governance systems with participation, integration, legal frameworks, collaboration, equity and adaptability, all with $P < 0.05$ negatively and significantly influence the causes of conflicts and water management challenges; integration (20%) and equity (19%) contribute highly to the model; and both adaptive and integrative water governance systems are less effective with a score of 34% and 35% respectively. The study concludes that the current management systems require an adaptive and integrative governance system. The study recommends harmonization of regional laws and policies governing the Basin and involvement of local communities in decision making.

Keywords: Adaptive governance, collaboration, integrative governance, mechanisms, water conflicts.

INTRODUCTION

Transboundary watersheds are the water resources which cross two or more countries and they include rivers, lakes and aquifers. Over 276 international watersheds worldwide transcend through different national boundaries covering almost half of the earth's land surface (UN Water, 2013; Choudhury and Islam, 2015; UNESCO, 2013; and UNECE, 2015). The transboundary water resources are essential for socio-economic developments for the riparian countries however; they have continued to be endangered by a multiplicity of complexities and crises (Earle and Neal, 2017; Paisley and Henshaw, 2013). A large number of authors and international organizations point out that "the water crisis of the 21st century is, in many ways, a crisis of governance". They argue that the crisis is rooted in power, poverty, poor resource utilization and management and unequitable distribution but not the physical water resources availability (UN-Water, 2013; Jacobsen et al., 2013; World Bank, 2013; De-

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Stefano et al., 2014; OECD, 2015; Akhmouch et al., 2017).

The rich ecosystems in the watersheds have attracted a diversity of people who live and derive their livelihood in the shared water Basins. Over 40% of the world's population depends on these international watersheds for agriculture, fishing, transport, hydropower generation, wildlife, and mining and among others (Jägerskog, 2013; OECD, 2015). The significance of the water resources, notwithstanding, the rapid population growth accompanied by unregulated human activities on the transboundary water resources have threatened the sustainability of the resources. A combination of social, economic and ecological issues have continued to be a major challenge in the management of shared water resources causing high demand for water resources leading to an increased competition resulting into conflicts over the utilization of the scarce resources (Munia et al., 2016; Moore, 2013). Rojas and Iza (2011) argue that to mitigate the consequences of human activities on the water resources requires an effective and efficient management system for sustainable and equitable utilization of the water resources.

Despite the Lake Victoria Basin's economic potential, the Basin is under threat by a host of social, economic, political and environmental challenges which affect the sustainable utilization and management of the water resources in the Basin. Among the major issues are: half of its population is living in absolute poverty (living on income less than a dollar per day) and mainly relies on subsistence production. Poverty is further aggravated by the rapid population growth and the high level of illiteracy in the Basin (LVBC, 2015). Again due to the high population, the land is highly fragmented and the women, who are the productive group, have less access to productive land for cultivating. Relatedly, there is a lot of migration to the Basin which has seen high rate of refugees' influx to the Basin and this has exacerbated insecurity and unemployment (Were, 2016; LVBC, 2015; Ogello et al., 2013).

Similarly, the rapid population growth has intensely put pressure on these natural resources through human activities such as over fishing, pollution, poor methods of agriculture which is the main cause of degradation. In the Basin, there are poor and inadequate healthy services where HIV/AIDS is rampant and the mortality rate is too high where mostly a big number of people die due to water bone diseases such as Bilharzia, Tuberculosis, Cholera and Malaria (LVBC, 2011; LVBC, 2015). In addition, according to GWP-EAC (2015) and AU-IBAR (2016), the Basin is faced with governance challenges that need immediate intervention and they include un-harmonized laws and regulatory standards; low compliance to joint water resource laws and regulations and inadequate enforcement.

The other management issues that threaten the Basin are: inadequate institutional and human capacities to formulate and implement programs; limited effective involvement of stakeholders in the management process; inadequate governance mechanisms that have limited provisions for enforcement; lack of awareness and ownership at community level and limited information about transboundary ecosystem management among others (UNECA, 2016; Were et al., 2013; Lalika et al., 2015). In addition, the pollution from the unplanned urbanization in form of chemicals, waste water, sewage and rubbish discharge into the lake especially from the major towns of Jinja, Mwanza, Kisumu and Kampala-Entebbe has continuously affected the lake (Ogello et al., 2013; LVBC, 2011). Furthermore, the high level of degradation in the Basin both in the lake and the catchment has caused conflicts over the water resource usage (UNECA, 2016; AU-IBAR, 2016; GWP-EAC, 2015).

As observed by Bigas (2012), the poor state of the shared transboundary ecosystems is a manifestation of the lack of effective governance for the sustainable utilisation and management of the world's water resources. To address these challenges and to ensure equitable and sustainable utilization and management of transboundary water resources, there is a need for good governance and

management across all levels of governing institutions and engagement of all stakeholders in riparian countries (Akamani and Wilson, 2011).

Despite the establishment of LVBC and LVFO as EAC institutions by the EAC treaty through the LVB Protocol to manage the resources of Lake Victoria, the Basin has continued to experience water conflicts and other social, economic and political challenges which many scholars have attributed to poor governance system in the Basin (AU-IBAR, 2016; De- Stefano et al., 2014; OECD, 2015; Akhmouch et al., 2017).

The management challenges notwithstanding, Atieno (2014); LVBC (2011); Were, (2016) note that the Lake Victoria transboundary waters are susceptible to both intra and inter-conflicts arising from poor utilization and competition for the scarce water resources. Okurut and Weggoro (2011) suggest that water conflicts which emanate from management challenges could be addressed by effective water governance through institutional frameworks which can ensure proper utilization and management of resources. The objective of this study was to examine the effectiveness of transboundary water governance practices in managing the water conflicts and other social, economic and political challenges in the Lake Victoria Basin.

MATERIALS AND METHODS

Lake Victoria Basin

Lake Victoria Basin has a catchment area of 194,200 km (Table 1) that stretches further to two additional countries (Figure 1); Rwanda and Burundi in various proportions: Tanzania (44%), Kenya (22%), Uganda (16%), Rwanda (11%) and Burundi (7%) (Mwiturubani, 2010; UNECA, 2016). The dimensions of Lake Victoria stretch 400 km from North to South and 240 km from West to East. It strides the equator between latitude 00^0, 30'N and 3, 12'S and from West to East between longitude 31o37' and 34o53E (Ogello et al., 2013; Mabikke, 2014). It is situated on an altitude of 1,134 meters above sea level which gives it unique features that are different from other similar lakes.

The study applied mixed methods approach where a combination of both qualitative and quantitative approaches to examine the governance and management systems of the Lake Victoria Basin were used. The researcher opted to use mixed method because of its usefulness as highlighted by Strauss and Corbin (1990), which includes the validation of findings through triangulation and a deeper, broader and more illustrative description of phenomena. This approach enables the use of both qualitative and quantitative data collection and analysis techniques in answering research questions. Each approach synergizes the other to be more effective and it provides a full understanding of the research problem. Creswell and Clark (2011) observe that: "The major premise behind the use of mixed methods is that a combination of quantitative and qualitative approaches provides added perspective and a more comprehensive understanding of the research problem being studied than either approach alone can provide." Furthermore, mixed methods helped during data collection to close the gaps of illiterate respondents who could not work well with questionnaires but instead with interviews.

This study examines the governance of Lake Victoria transboundary water resources to conflicts management and since the lake crosses different countries, Cluster random sampling and purposive were used. Cluster random sampling was opted because the population under this study is dispersed across a wide geographical region that involves crossing the borders. This technique allows for the division of the study population into clusters such as regions and provinces (Saunder et al., 2009). The population under the study included the local community leaders of the villages within the Lake Victoria basin. These villages were clustered basing on the geographical location into small groups for the purposes of easy collection of data and interviewing the participants. The researcher also used purposive sampling; a technique that involves a process of selecting a sample based on experience or knowledge of the group (Saha, 2008). By this procedure, only the organizations that are involved in the

management of Lake Victoria Basin and the communities within the Basin were considered. Also, only the respondents who were more knowledgeable in the area of study were contacted to fill the questionnaires.

Statistical analysis

The Quantitative raw data collected, particularly in surveys, was processed before subjected to any useful analysis. This process included correcting errors in the data (editing), coding the data and storing it in appropriate form. Data was first entered into SPSS and thereafter cleaned. SPSS was used for filling missing values, data aggregation, factor analysis and also testing parametric assumptions. SPSS was also used to run the descriptive statistics, analyze sample characteristics and run the coefficients and the regressions. The regression models were run to identify the variables that have an impact on the topic of interest and how they influence each other. The hypotheses were tested using regression analysis. The Lake Victoria Basin Governance Performance Composite Index (LVBGCI) was also used to assess the performance and effectiveness of governance systems in the basin.

Table 1: Morphometric Data for Lake Victoria Basin.

Country	Lake surface area		Catchment area		Lake shoreline length	
	Km2	%	Km2	%	Km2	%
Kenya	4,128	6	42,724	22	550	16
Uganda	29,584	43	31,072	16	1,750	51
Tanzania	35,088	51	85,448	44	1,150	33
Burundi	0	0	13,594	7	0	0
Rwanda	0	0	21,362	11	0	0
Total	**68,870**	**100**	**194,200**	**100**	**3,450**	**100**

Source: Lake Victoria Basin, Adopted from LVBC, 2007.

Figure 1: Lake Victoria Basin.

RESULTS

Effectiveness of integrative water governance systems in the LVB

To this end, integrative water governance indicators of stakeholder participation and engagement, integration and legal frameworks/rule of law were examined as suggested by Cookey et al. (2016) in their study on the assessment of water governance performance of Songkhla Lake Basin in Thailand. The quantitative approach using the Lake Victoria Basin Governance Performance Composite Index (LVBGPI) was used to assess the status performance or effectiveness of governance mechanisms.

Results depicted in Figure 2 reveal that the aggregated score of IWG systems on the LVB based on the three indicators of stakeholder participation and engagement, integration and legal frameworks/rule of law was 35% which is below the average mark of 50%. Individually, all the performance indicators of IWG performed below 50% where integration scored 38.0% indicating low levels of integration in the LVB, stakeholder participation and engagement scored 32.0% indicating low levels of stakeholders' involvement and participation either directly or through legitimate representatives in the activities and management of the LVB while rule of law/ legal frameworks scored 35.0% indicating poor performance or inadequate application of the rule of law and other legal frameworks.

Effectiveness of adaptive water governance mechanisms in the LVB

As advised by Cookey et al. (2016), the adaptive water governance as second arm of water governance was assessed using the LVBGPI based on three indicators of adaptability, equity and ethical and collaboration. Each of the indicators was assessed separately to establish the level of its effectiveness in the governance of LVB and later all the three were aggregated together to find the overall score in regard to the level of adaptiveness in the governance of LVB as shown in portrayed in Figure 3.

The aggregated score of the AWG systems in the LVB based on the indicators of adaptability, equity and ethical and collaboration was 34%. All the three indicators scored below the average score of 50% where adaptability scored 33.0% indicating low degree of institutional response, openness to socio-ecological changes and to incidence of a disaster, equity and ethical had the lowest mark of 32% signifying poor performance of equity and ethical principles in the governance of LVB and collaboration scored 36% indicating low levels of collaboration.

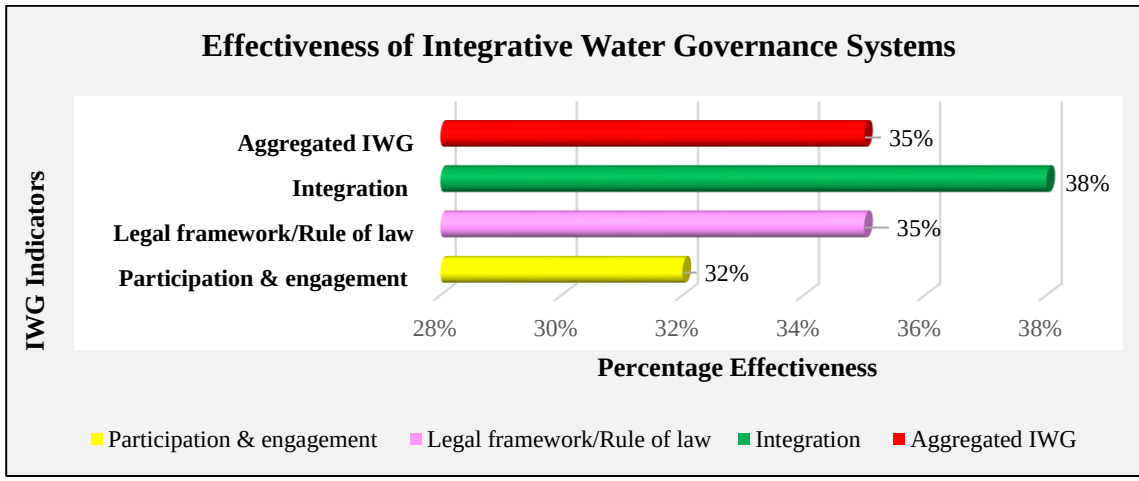

Figure 2: LVB Governance Performance Composite Index for IWG.

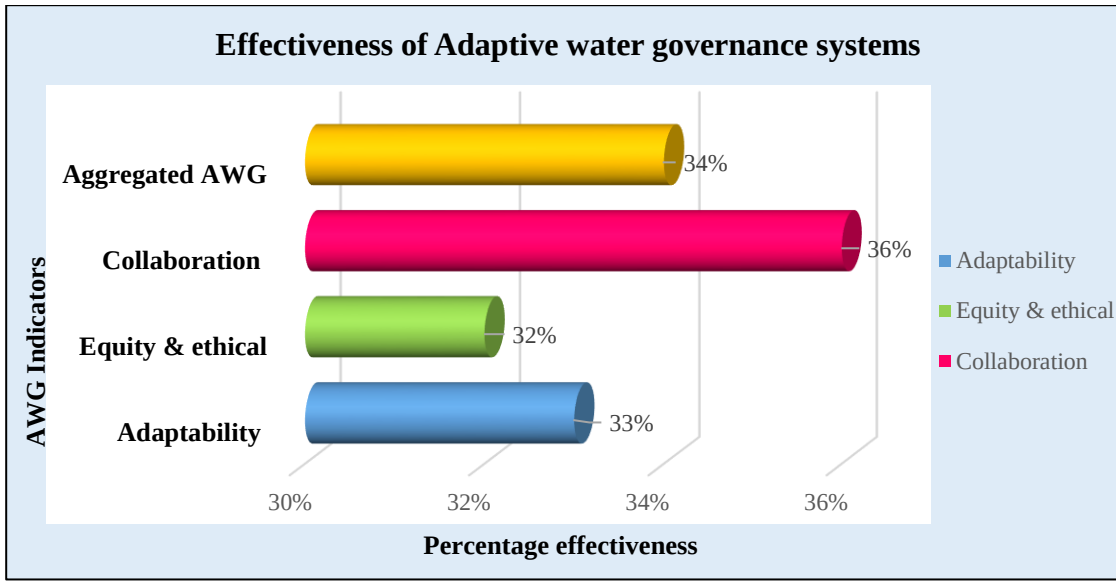

Figure 3: LVB Governance Performance Composite Index of AWG.

DISCUSSION

The results revealed that the integrative water governance systems on the LVB based on the three indicators of stakeholder participation and engagement, integration and legal frameworks/rule of law were found to be ineffective with an aggregated score of 35% which is below the average score of 50%.

Regarding integration, the results means that there is poor policy coherency and consistency between the riparian countries, the different governing organizations, agencies and other organizations involved in the basin which are not satisfactorily interacting and working together for the sustainability of the resources. Lack of policy and development plan harmonisation and coherency between the sectors' ministries and agencies in the management of the Basin may be responsible for low level of integration which is causing management challenges. Lalika et al. (2015) concur with the findings where they recognized that lack of harmonization and integration of management systems of different institutions related to water-shed management, normally results in unsustainable use of water resources and resource use conflicts. Secondly, this result portrays the inadequacy of vertical and horizontal interaction, coordination and communication between the stakeholders and organizations both within the partner states and across other riparian countries. For this, there is a need for strengthening vertical and horizontal integration among the national governing institutions (Resource Management Systems) and between human and natural systems. The national governing institutions are structurally and policy wise fragmented and they administer and enforce their individual sector policies, laws and regulations differently which affects the coordination that leads to water use conflicts. Our finding is in line with the finding of Vasquez (2017) which found that managing natural resources such as soils, fauna, plants and human beings in a fragmented way leads to resource conflicts. Therefore, the study recommends the integration, coordination and interaction of both formal and informal institutions for the harmonisation of sector policies, provisions and development plans.

The poor performance on participation and stakeholder engagement reveals that stakeholders are not effectively participating throughout the water policy chain from decision making to the implementation process which may lead to misunderstanding between water user interest parties. This finding is in agreement with AU-IBAR (2016) which noted that inadequate involvement of stakeholders in

the activities and programmes undertaken in the Basin creates a governance gap that can cause conflicts; the stakeholders are merely consulted to rubberstamp decisions instead of participating. The results portray the inability of stakeholders to influence and share control over the development initiatives and management decisions that affect them in the LVB. It further means that probably stakeholders have limited freedom to express their concerns and that; the governance institutions put little effort to communicate to all stakeholders at all the levels from community level to regional levels and give feedback in time. In this case, the Basin managers miss out to capture valuable information from indigenous local inhabitants who probably would help them in decision making and resolving water conflicts.

This position was also echoed by Megdal et al. (2017) who argued that the inefficiencies in the communication and coordination among the governing institutions is a manifestation of lack of stakeholder participation in the governance of water resources .Given the realisation that human systems (cultures, preferences, norms, beliefs) affect the natural systems (the resources functions and services such as fishing, agriculture and forestry among others) and the resource management systems (institutions, management instruments and policies among others), the study further suggests that the Basin managers should understand the human dimensions and ensure the integration of the stakeholders especially the water resources users and local communities in the management of the LVB and more especially in decisions making process.

The low performance on the rule of law in the governance of water resources implies that there is low compliance and adherence to different aspects of regulatory procedures in the governance processes of the LVB. Once the laws and regulations are not complied with, this leads to confrontations between water resource users and managers. This finding is consistent with Cookey et al. (2016) which established that poor adherence to legal instruments exposes the risks of inadequate protection against the effects of wrong actions in the Basin which is a source of water use conflicts. This result further indicates the low capacity of the governing institutions to produce and share relevant information in time, the ineffective implementation and enforcement of laws, policies and regulations in the LVB. Secondly this score below average mark could be the manifestation that the governing institutions have low capacity to monitor, evaluate and supervise sufficiently the basin's projects, programs and actions of the riparian countries. The study finding is further supported by GWP-EAC (2015) which reported that although the Lake Victoria Partner States put in place the required policies and legal framework, the level of implementation and compliance is still very low.

The study observed that although, the protocol for sustainable development of the LVB mandates the LVBC to facilitate, harmonise and coordinate all activities and oversee the LVB on behalf of the partner states, the LVBC is not legally empowered to enforce any law. This is because at its birth, it was established through the protocol which is weak and it is like gentleman's agreement with policy statements which are silent on how to enforce the laws and guidelines and it does not guide on what to do to the defaulters of the laws and guidelines. For this, and as it was provided for in the 1999 EAC treaty, the study recommends that EAC through EALA should empower LVBC by coming up with an act of parliament giving the LVBC powers and authority to monitor, supervise and enforce laws and regulations for effective governance of the LVB.

The results of Adaptive Water Governance mechanisms in LVB which indicated an aggregated score of 34%, just slightly below the IWG systems, mean that the level of adaptiveness in the governance of LVB was very low. Regarding adaptability, the result implies that the social actors in the LVB have low ability to work together to enhance the capacity of the socio-ecological systems to cope with intermittent shocks. They also indicate that LVB has low capacity to absorb disturbance and still maintain the functioning of the ecosystem which signals that the LVB management systems are not robust enough to manage the changing pressures, threats, opportunities and risks. This implies that the low level of adaptiveness in the management of

Lake Victoria is partially responsible for the causes of water conflicts and the prevalence of other socio-economic, political and institutional challenges. Adaptive governance integrates information from stakeholders such as from local communities which normally have relevant information that can help to address the uncertainties however, in the Lake Victoria Basin, the capturing and sharing of information and synergistic linkages between stakeholders and organisation is inadequate which may be the explanation for the poor performance of adaptiveness in the governance of LVB. This is in line with Green et al. (2013) and Fenemor et al. (2011) which found that the system which integrates collaborative learning is responsive to changing pressures and becomes easy to mitigate uncertainties such as floods and droughts whose effects may result into conflicts. In a bid to adaptability in the LVB, the study recommends that governing institutions should endeavour to learn and better understand the outcomes from implemented strategies and actions and other events and promote flexible decision making that is adjustable in the face of uncertainties.

As regards to equity and ethical, the results imply that the stakeholders and the governing organizations do not adequately follow ethical principles of the societies they operate in and the LVB resources could be unethically utilized. More so, this result means that LVB governing organizations may not be providing their stakeholders with equal opportunities to improve their wellbeing and take part in decision making, and that they may not be consulting all stake holders in the riparian countries in order to agree on the best means of the basin's resource management respectively. In a similar view, this result implies that the LVB resources are not equitably shared among the various water interest groups as well as sharing the benefits and opportunities which can be a great source of disagreements between interest groups. The finding is consistent with the finding of Sadoff and Grey, (2005; 2002); Sadoff et al., (2002, 2008); Dombroksy (2009) which hold that lack of benefits- sharing mechanism within the watersheds is a challenges and contributes to water conflicts among the partner states. Furthermore, the result is in line with Iza and Stein (2009)'s finding which noted that, equitable sharing of benefits across the relevant stakeholders encourages the sense of ownership which is vital for stakeholders to safeguard and manage jointly the shared resources

Since collaboration entails an arrangement of involving a wide range of stakeholders often voluntarily in decision making, planning processes and implementation of projects and programmes, score of 36% indicates poor performance in respect to the level of collaboration among stakeholders in the basin. The results imply that the level of inclusive involvement of water users (stakeholders) and those affected by the water use in the management of LVB is very low and it requires immediate improvement for sustainable utilization and management of the LVB. To promote a better informed decision and implementation of activities and programs, it is important to decentralize decision making and involving all parties in order to achieve consensus which helps to mitigate disagreements on the implementation approaches. This result is in agreement with the Burnley et al. (2014); LVBC (2012) who noted that once the stakeholders' involvement in the management of the water resources in the Basin is insufficient, it can lead to water conflicts. They further opined that water conflicts can be worsened by the centralization of decision making and planning in the relevant ministries. Secondly, the Basin regulators and managers ought to capture and integrate new knowledge and experiences about Lake Victoria into the management of LVB through collaborative learning and partnership with the formal organisations such as government ministries and agencies and informal organisations like public and private sector, local communities and water users. In addition, the LVB managers should utilise the lowest government and non-government structures such as local councils, Beach Management Units and create Lake Victoria Resources Management Unit to generate and acquire information that should be continuously incorporated in the basin management systems through bottom-up and top-bottom planning and decision making approaches. The LVB according to GWP-EAC, (2015) confirms that LVB is faced with conflicts as the result of poor relationship with the local communities. The

poor connectedness of the Basin managers and the stakeholders may also explain the finding of poor stakeholders' collaboration.

Conclusion

With regard to the objective of the study which sought to assess the effectiveness of integrative and adaptive water governance systems on water conflicts management, the study concludes that their level of effectiveness in the governance of LVB towards conflict management is very low and lacking. It was further noted that AWG indicators are less effective compared to IWG indicators in the management of water conflicts. However, among all the six indicators of integration, rule of law, stakeholder engagement and participation, adaptability, equity and collaboration assessed in this study, it was equity, adaptability and stakeholder engagement that were found less effective to the management of water conflict in the LVB as compared to other indicators. This also leads to the conclusion that the water conflicts have persisted in the LVB due to the ineffectiveness and poor implementation of integrative and adaptive water governance systems.

COMPETING INTERESTS

The author declares that he has no competing interests.

AUTHORS' CONTRIBUTIONS

The author (NMM) carried out the various aspects of this work, from the design, data collection and analysis to the preparation of the manuscript.

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Amélioration du rendement de réseau par la réduction des pertes physiques

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RESUME

Les volumes d'eau potable distribués se répartissent en 2 catégories : Eaux Facturées et Eaux Non Facturées (ENF). Les Eaux dites Facturées correspondent aux consommations facturées à l'abonné. Les ENF représentent toutes les autres eaux distribuées mais ne faisant pas l'objet d'une facturation, à savoir : les pertes physiques (fuites etc…), certaines eaux d'utilité publique (défense incendie etc…) et les défauts de comptage ou de facturation. En 2015, la SODECI a réalisé une étude diagnostic du fonctionnement du réseau d'eau potable d'Abidjan afin de mieux évaluer l'origine des pertes. Cette étude a consisté à déterminer la répartition des Eaux ENF par typologie de pertes et a permis de déterminer la répartition suivante : part des pertes physiques (22,45%), part des pertes comptages (3,04%), part de la fraude (9%) ; Soit un total de 34,5% de volume d'ENF. La proportion des pertes physiques sur le réseau d'Abidjan représentait 61,5% de l'ensemble des pertes diagnostiquées. Ces résultats ont conduit la SODECI à entreprendre des actions vigoureuses en vue de réduire leur impact et améliorer le rendement de réseau. Ces actions ont consisté à la gestion des pressions, la sectorisation, la recherche active de fuite, au renouvellement des vieux compteurs, la modernisation du comptage et la lutte contre la fraude. Le présent rapport fait état des actions liées aux pertes physiques, notamment la gestion des pressions, la sectorisation et la recherche active de fuites.

Mots clés : Eau potable, eau non facturée, pertes physiques, performance réseau, rendement de réseau, gestion pressions, amélioration rendement, Recherche Active de Fuites (RAF).

Network production improvement thanks to the reduction of physical losses

ABSTRACT

Volumes of drinking water are grouped in two categories: billed water and unbilled water. Billed water are equivalent to billed consumptions of customers. Unbilled water represents all given water without any invoice: we are talking about physical losses, public utility water to fight against fire for example, or defect on counting or billing. In 2015, SODECI leads a diagnostic study of drinking water network functioning of Abidjan in order to evaluate the origin of losses. This study allowed to determine the repartition of unbilled water by types of losses. Thanks to this study, it appears the following repartition: part of physical losses (22.45%), part of defecting counting (3.04%), part of fraud (9%); for a total of 34.5% concerning unbilled water volume. Part of physical losses on network of Abidjan was 65.5% of total of involved losses. Following these results, SODECI decided some strong actions in order to reduce their effect and improve the production of the network. These actions consisted in managing pressure, sectorization, active searching of leakage, renewing old counters and

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fighting against fraud. This report mentions actions linked to physical losses, especially the management of pressure, sectorization and active search of escape.

Keywords: Drinking water, unbilled water, physical losses, network performance, network production, pressure management, production improvement, active searching of leakage (ASL).

INTRODUCTION

Dans un environnement, notamment dans les grandes agglomérations, où les défis à relever pour les secteurs de l'Eau Potable et de l'Assainissement sont de plus en plus nombreux, à savoir, la gestion durable de la ressource en eau par la réduction des pertes, le niveau d'exigence croissant des clients, l'extension géographique des activités et l'accroissement des activités industrielles et domestiques ; la performance des réseaux d'eau potable mesurée au travers du rendement technique de réseau ou ratio de facturation, est un facteur essentiel d'efficience.

La crise socio-politique qu'a connue la Côte d'Ivoire durant la dernière décennie a eu de nombreuses conséquences dans le secteur de l'hydraulique urbaine dont, les retards dans les investissements, les reports des travaux de renouvellement et d'extension. La conséquence de cette situation s'est traduite notamment par une baisse du taux d'accès au service avec son corolaire d'augmentation des fraudes et la dégradation du ratio de facturation (hausse des pertes) **(**Figure 1).

Dans ce contexte un objectif majeur pour SODECI est de tout mettre en œuvre pour revenir à un niveau de performance d'avant crise, à savoir, stabiliser puis faire progresser le ratio de facturation de l'agglomération d'Abidjan de 65% (niveau 2016) à 75% à l'horizon 2022.

Afin de relever ce défi de l'amélioration du ratio de facturation, SODECI a mis en place une nouvelle organisation en créant une structure dédiée nommée Sous-Direction Performance Réseau (SDPR) dont les missions sont les suivantes : la gestion des pressions, l'amélioration de la sectorisation sur le réseau d'Abidjan, et la recherche active de fuites.

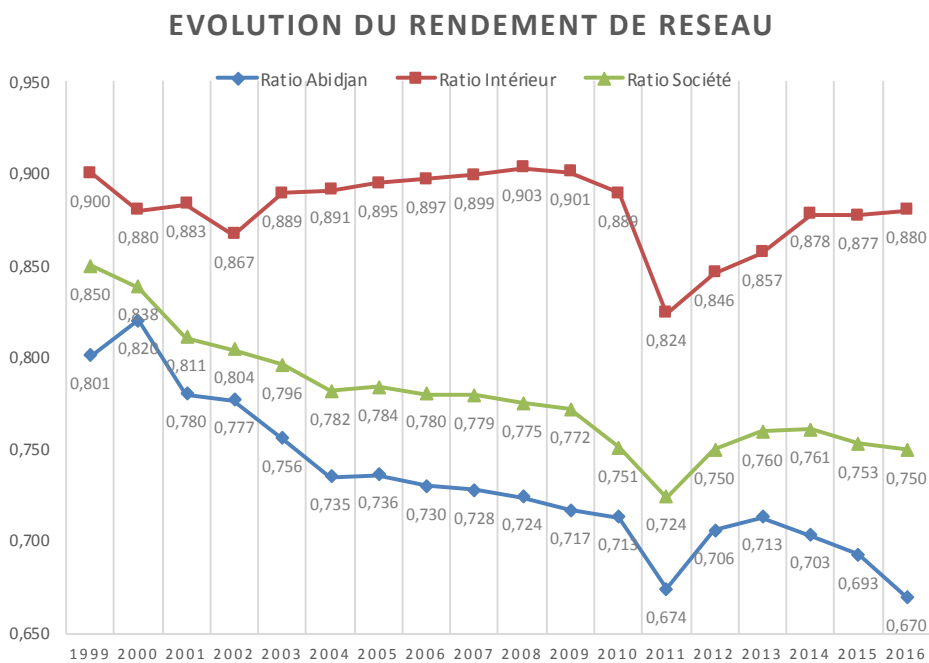


Figure 1 : Evolution du rendement de réseau.

MATERIEL ET METHODES

Matériel

Les capteurs de pression **:** l'enregistreur Non communicant et les enregistreurs communicants.

L'enregistreur Non communicant (Photo 1) a les caractéristiques suivantes : mesure et enregistre les données pressions et débits, ne permet pas de transmission de données à distance, peut lire jusqu'à 20 bars de pression ; tandis que les enregistreurs communicants (Photo 2) ont ces caractéristiques : mesure et enregistre les données pressions et débits, mesure et enregistre les niveaux d'eau dans les réservoirs, permet la transmission de données à distance par GSM, SMS et GPRS.

Comme équipements de gestion des pressions, 31 vannes de régulation ont été posées à ce jour sur l'ensemble du réseau d'Abidjan (Figure 2). Ces vannes permettent la stabilisation des pressions aval correspondent aux zones à gérer.

Méthodes

La gestion des pressions

La gestion des pressions est la capacité à adapter les pressions mises à disposition des abonnés pour leurs besoins.

Gérer les pressions consiste à assurer les valeurs minimales de service en tout point du réseau, y compris lorsque la demande est maximale. Cela peut se faire sur la totalité du réseau, sur un secteur ou une antenne.

Pour y parvenir, on utilise une vanne de régulation de pression, qui permet à partir d'une pression variable à l'amont, de maintenir une pression inférieure ou égale suivant le profil de consommation.

La sectorisation

La sectorisation a pour objectif de déterminer les volumes mis en distribution dans les différentes mailles afin d'en déterminer les ratios de facturation.

Elle permet également de réduire la taille des zones à investiguer en cas de dérive du rendement de réseau.

La recherche active de fuites

La couverture totale du réseau AEP d'Abidjan demeure une priorité pour la SODECI en matière de recherche fuite.

La Recherche Active de Fuites (RAF) adoptée par la SODECI consiste à parcourir l'ensemble du réseau à pieds et à écouter tous les points de contacts (Compteurs, vannes, ventouses…) (Figure 3).

Phase 1 : il faut parcourir l'ensemble du linéaire de réseau AEP d'Abidjan ; détecter un nombre de fuites avec un taux variant de 0,2 fuite/km à 0,5 fuite/km (Tableau 1).

Phase 2 : après avoir assaini le réseau après plusieurs cycles de recherche et détection de fuites, l'objectif de la phase 2 est de réduire et maintenir des débits de nuits à des niveaux de références pour ce type d'environnement urbain.

Organisation Recherche Active de Fuites (Figure 4)

Notre approche a été construite autour d'un prélocalisateur chargé de parcourir le réseau en écoutant tous les branchements et organes et d'un localisateur dont la mission est de précisément situer les fuites.

Afin d'optimiser leur activité, ces collaborateurs sont assistés par 2 agents de réseau, chargés de faciliter leur progression, et 2 nettoyeurs chargés du nettoyage des points d'écoutes.

Cette équipe constitue un groupe d'intervention dont l'avancement moyen est estimé à 3 kms/jour pour un taux de fuite de 0,5 fuite/km (Source : projet pilote DRAS)

Ce groupe d'intervention est appuyé sur les recherches spécifiques (utilisation d'un gaz traceur, step test…) par une équipe spéciale constituée d'un technicien RAF et d'un agent de réseau.

Dans chaque Direction Régionale, un ingénieur est en charge de piloter les activités des différents groupes d'interventions et l'ensemble des activités est encadré par le Sous-Directeur qui a la charge d'appliquer la stratégie définie par la Direction Générale.

Outil de gestion de la Recherche Active de Fuites (RAF Connect) **(**Figure 5)

« RAF Connect » est outil de suivi et d'ordonnancement disposant d'une plateforme de reporting et de partage d'infos établie sur Google Drive qui permet le suivi quotidien de l'activité RAF.

L'application permet de disposer en continue d'un accès immédiat aux informations utiles. Il est constitué de quatre (04) onglets principaux : **carte** : Dans cet onglet se situe la carte avec un calque pour chaque Direction Régionale. Les techniciens positionnent les fuites localisées sur cette carte en associant l'identifiant correspondant. Tout le personnel du service a un accès à l'onglet CARTE ; **partage** : Cet onglet regroupe tous les tableaux de suivi et de gestion de l'activité (tableau de bord, tableau de suivi SAV, etc…). ; **guide** : Cet onglet regroupe le guide stratégique et opérationnel du service. Dans ce guide est définie la stratégie du service, la mise en œuvre et le pilotage de l'activité, les canaux de communication, l'organisation du service et toutes les procédures utiles au bon fonctionnement du service ; **Suivi opérationnel,** c'est l'onglet principal du **«RAF Connect» :** il est composé de sous onglets associés à chacun des groupes d'intervention et des équipes spéciales, soit neuf (09) sous onglets. Un sous onglet comprend le tableau d'avancement, le tableau de vie de la fuite et le planning.

Photo 1: Enregistreur Non communicant

Enregistreur METROLOG P

- Mesure et enregistre les données pressions et débits,
- Ne permet pas de transmission de données à distance,
- Peut lire jusqu'à 20 bars de pression.

Photo 2: Enregistreur communicant

Enregistreurs CELLO 4C-8CH

- Mesure et enregistre les données pressions et débits,
- Mesure et enregistre les niveaux d'eau dans les réservoirs,
- Permet la **transmission de données à distance** par GSM.

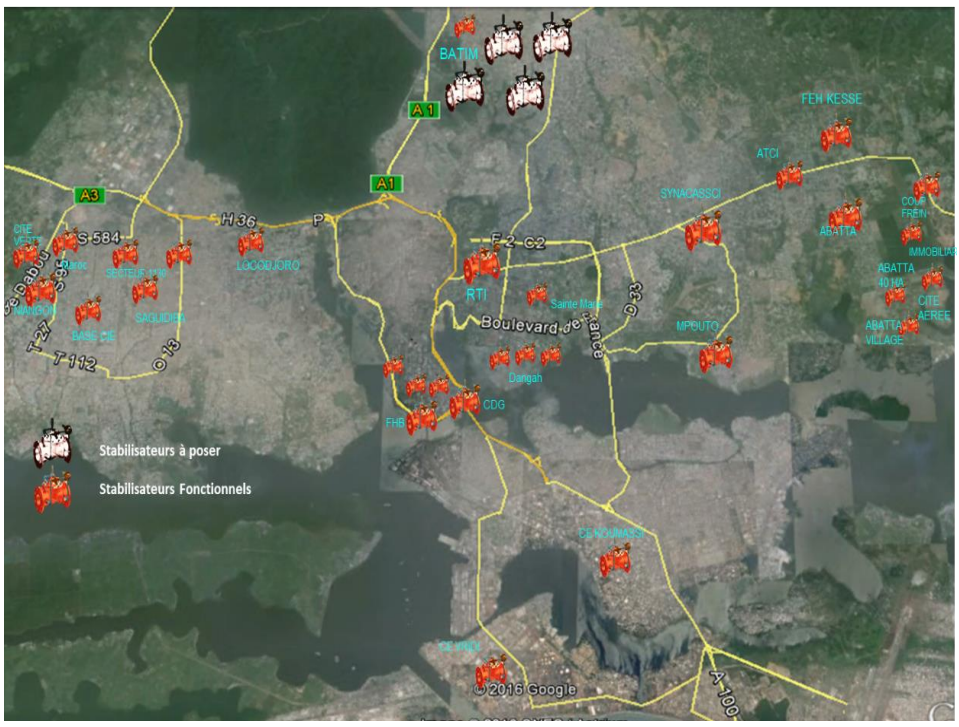


Figure 2 : Vannes installées sur le réseau d'Abidjan.

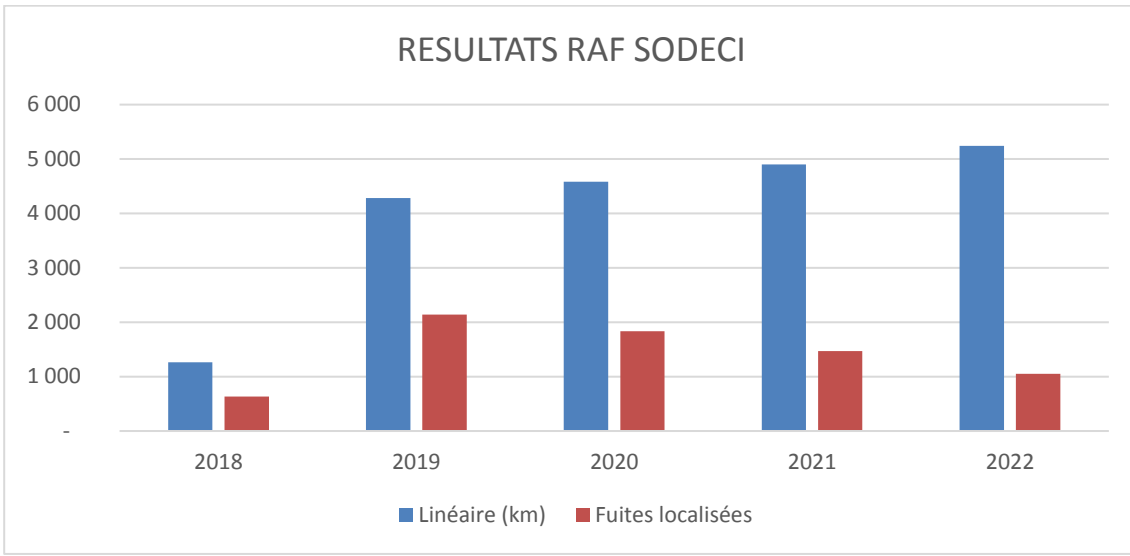


Figure 3 : Résultats RAF.

Tableau 1 : Cercle des eaux perdues.

Répartition des pertes	m3/an	% Volume mis en distribution		EUR
Pertes physiques	30 918 302	22,45 %		2 473 464
Pertes de comptage	4 186 238	3,04 %		1 800 082
Pertes clientèle	12 392 158	9,00 %		5 328 628
Eau non comptabilisée (ENC)	**47 496 698**	**34,50 %**		**9 602 175**
Consommation autorisée non-facturée	**404 000**	**0,29 %**		**32 320**
Eau non facturée (ENF)	**47 900 698**	**34,79 %**		**9 634 495**

Décomposition IWA des Pertes	m3/an	% Volume mis en distribution	% ENF	EUR
Volume annuel de pertes physiques (CARL)	30 918 302	22,45 %	64,55 %	2 473 464
Volume annuel de pertes apparentes (CAAL)	16 578 396	12,04 %	34,61 %	7 128 710
Pertes physiques annuelles minimales (UARL)	3 204 100	2,33 %	6,69 %	256 328
Potentiel MAX de réduction du CARL (ILI = 1)	27 714 201	20,13 %	57,86 %	2 217 136

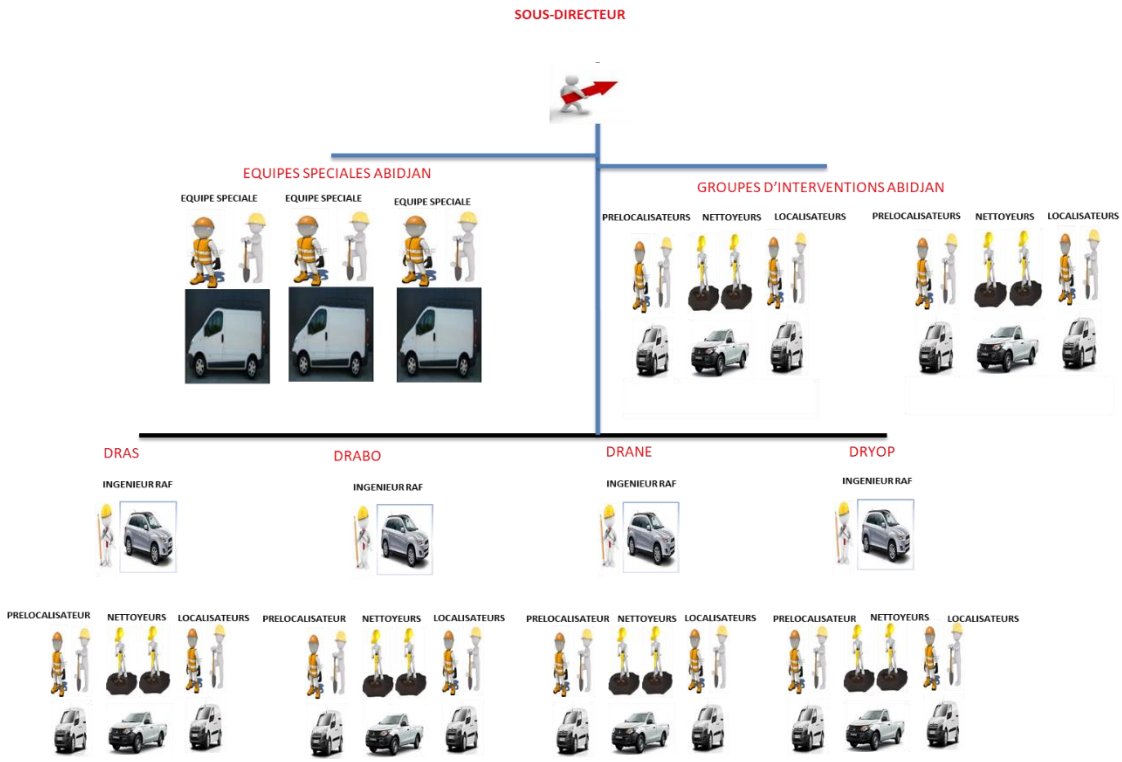


Figure 4 : Organisation Recherche Active de Fuites.

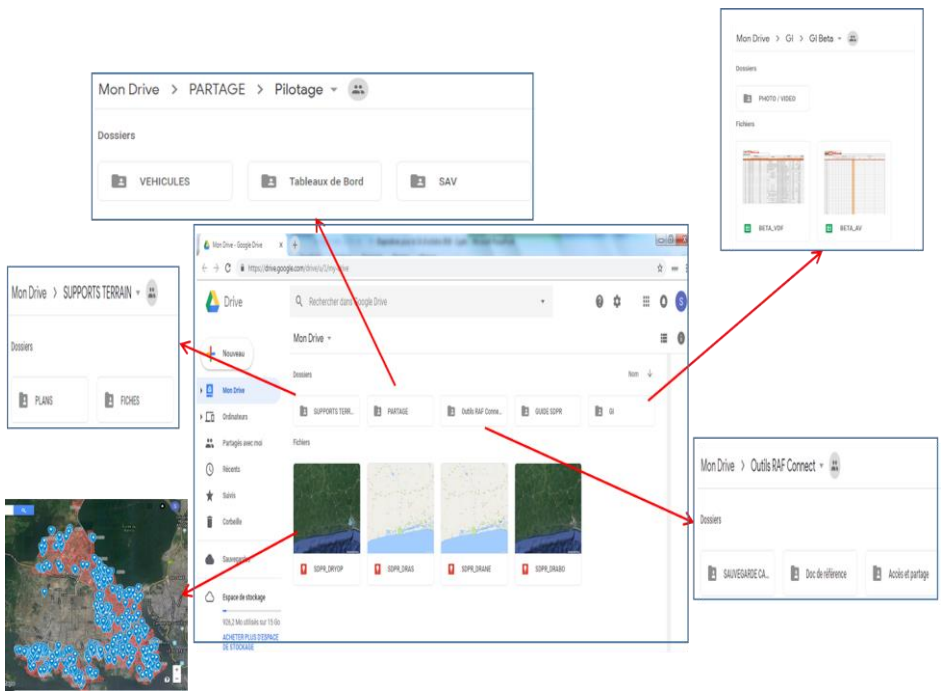


Figure 5 : Outils Recherche Active de Fuites.

RESULTATS

Volumes d'eau potable distribués

Les volumes d'eau potable distribués se répartissent en 2 catégories : Eaux Facturées et Eaux Non Facturées (ENF). Les Eaux dites Facturées correspondent aux consommations facturées à l'abonné (Figure 6). Les ENF représentent toutes les autres eaux distribuées mais ne faisant pas l'objet d'une facturation, à savoir : les pertes physiques (fuites etc…), certaines eaux d'utilité publique (défense incendie etc…) et les défauts de comptage ou de facturation. En 2015, la SODECI a réalisé une étude diagnostic du fonctionnement du réseau d'eau potable d'Abidjan afin de mieux évaluer l'origine des pertes (Tableau 2). Cette étude a consisté à déterminer la répartition des Eaux ENF par typologie de pertes et a permis de déterminer la répartition suivante : part des pertes physiques (22,45%), part des pertes comptages (3,04%), part de la fraude (9%) ; Soit un total de 34,5% de volume d'ENF (Figure 7).

La gestion des pressions

La gestion des pressions sur le réseau d'Abidjan a plusieurs impacts, notamment : la réduction des pressions dans les zones aval aux stabilisateurs suivant les profils identifiés après étude, l'amélioration de la qualité de service dans les zones amont aux Stabilisateurs généralement défavorisées du fait des dénivelés, la réduction du nombre de ruptures et de fuites sur le réseau, la réduction des pertes en eau, la réduction des volumes mis en distribution par l'adaptation à la demande.

La mise en œuvre sur le réseau d'Abidjan a permis l'économie de 62.000 m3/jour sur les volumes mis en distribution tout en améliorant la qualité de service et notamment la pression d'alimentation dans les zones précédemment mal alimentées (Figure 8).

La recherche active de fuites

La recherche active de fuites se déroule sur l'ensemble du réseau d'Abidjan avec des équipes dédiées dans chaque direction régionale (Figure 9).

Les équipes de recherche active de fuites ont parcouru du 1er Janvier au 30 juin 2019, **1 486 km** et ont détecté **952** fuites (Tableau 3).

L'avancement journalier est de **2,9 km/jour** avec un taux de fuites au km de **0,64**.

Ces fuites sont réparties comme suit : **42%** sur branchement, **15%** sur conduite, **23%** sur accessoires et **20%** après compteur (Figure 10).

La mise en œuvre de la recherche active de fuites sur l'ensemble du réseau d'Abidjan par la méthode de la systématique pédestre, a permis de déterminer l'ensemble des anomalies caractéristique des pertes apparentes.

A cet effet, les équipes parcourent l'ensemble du réseau et écoutent tous les points de contact dont les plus importants sont les compteurs des ménages.

Cette méthodologie permet de visiter tous les compteurs et les ménages afin de ressortir certaines anomalies liées au comptage et à la fraude.

Il y a à ce jour, une moyenne de 6 vieux compteurs au kilomètre sur Abidjan avec un taux plus élevé sur le réseau de la commune de Yopougon (14 vieux compteurs/km).

Comme l'indique le graphique ci-dessous en terme de fraude les constats sont très variable d'une zone à une autre (Figure 11).

On détecte en moyenne 3,5 cas de fraude/km de réseau sur la Direction Régionale de Yopougon, alors que la partie sud de la ville d'Abidjan affiche un niveau de fraude nettement moindre, de l'ordre de 0,2 cas de fraude/km (Tableau 4).

L'identification des anomalies autre que les fuites, permet d'établir une sorte de carte d'identité de chaque Direction Régionale et d'élargir les zones d'action en vue de l'amélioration du rendement de réseau.

Cas de la Direction régionale Abidjan sud (Figure 12)

La Direction Régionale Abidjan Sud (DRAS) a connu à partir de 2014, une chute de son rendement de réseau suite à la mise en service de l'Usine de production d'eau

potable de Bonoua 1 qui a une capacité installée de 80.000 m3/jour.

Cette chute a été de 8 points sur le rendement entre 2014 et 2015 et s'explique par une mise sous pression d'un réseau AEP qui a subi pendant de longues années un fonctionnement intermittent avec des zones à manque d'eau permanent.

Ainsi, le diagnostic fait par direction régionale Abidjan Sud, a permis de mettre en évidence la part importante représentée par les pertes physiques (32,3%) sur un total d'ENF de 38,6%, soient 84% de l'ensemble des pertes enregistrées (Tableau 5).

La gestion des pressions, la sectorisation et la recherche de fuites sur à la DRAS

La Direction Régionale Abidjan Sud compte à ce jour 5 stabilisateurs de pressions installés sur les principales entrées de la direction régionale (Figure 13).

L'ensemble des 800 kms du réseau AEP est maillé et est alimenté à partir de 4 usines de production d'eau potable.

Un réservoir d'eau sur tour situé sur la commune de Koumassi, sert de cheminée d'équilibre donnant ainsi les consignes aux stabilisateurs suivant son marnage afin de mieux gérer les pressions sur le réseau (Figure 14).

La gestion des pressions ayant été achevée sur l'ensemble de la Direction Régionale Abidjan Sud, des actions de Recherche Active de Fuites ont été initiées (Figure 15).

Les actions combinées de gestion des pressions et de Recherche active de fuites ont permis d'économiser 3.600.000 m3/an (Figure 16).

La Direction Régionale Abidjan Sud a connu une évolution de +17% de ses abonnés entre 2015 et 2017.

Néanmoins, sans augmentation des volumes distribués, la gestion des pressions a permis d'offrir la même qualité de service à tous les abonnés.

Les fuites et ruptures ont également été réduites de plus de 50% sur la même période (Figure 17).

La mise en œuvre de toutes ces actions a permis d'améliorer le rendement de réseau de +4% en le faisant passer de 60% à 64% (Figure 18).

NB : la Sectorisation a permis l'évaluation des volumes mis en distribution afin de mesurer les volumes et ainsi déterminer l'impact des différentes actions mentionnées ci-dessus.

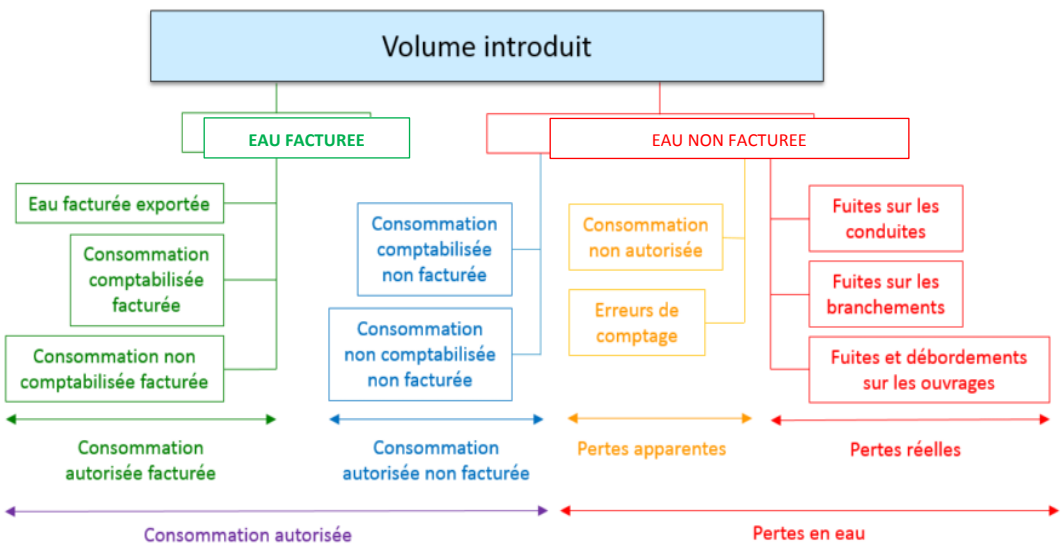


Figure 6 : Répartition des eaux non facturées.

Tableau 2 : Objectifs RAF.

	2018	2019	2020	2021	2022
Linéaire (km)	1 266	4 280	4 580	4 900	5 243
Fuites localisées	633	2 140	1 832	1 470	1 049

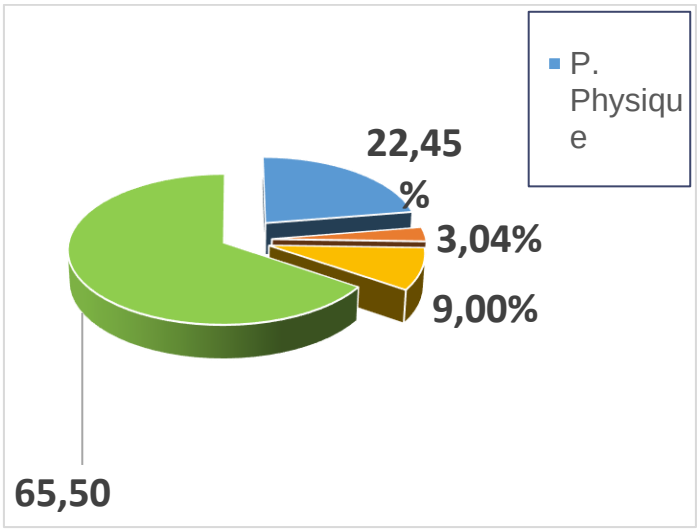


Figure 7 : Diagramme de répartition des ENF.

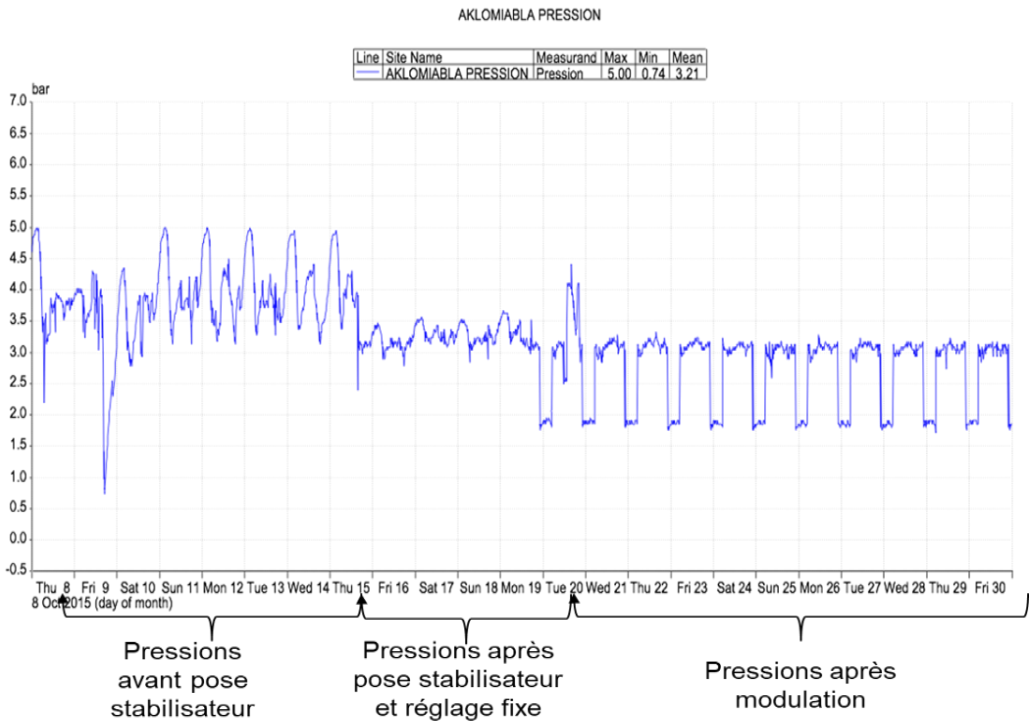


Figure 8 : Evolution des pressions en présence de stabilisateur.

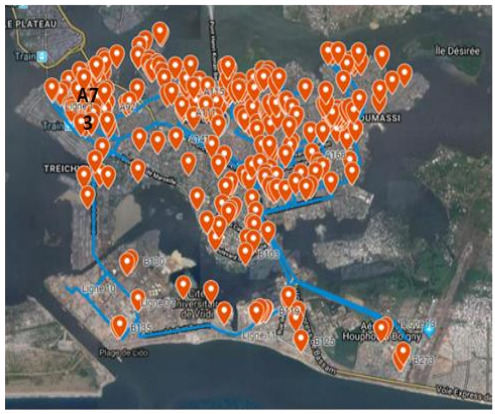


Fig1:Cartographie des fuites détectées au 1er passage à la DRAS

Fig2: Cartographie des fuites détectées au 2ème passage à la DRAS

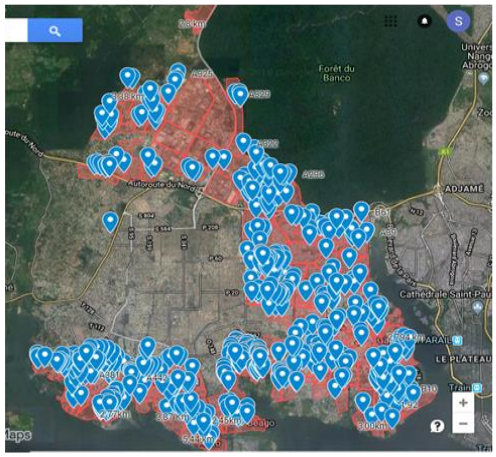


Fig3:Cartographie des fuites détectées au 1er passage à la DRYOP

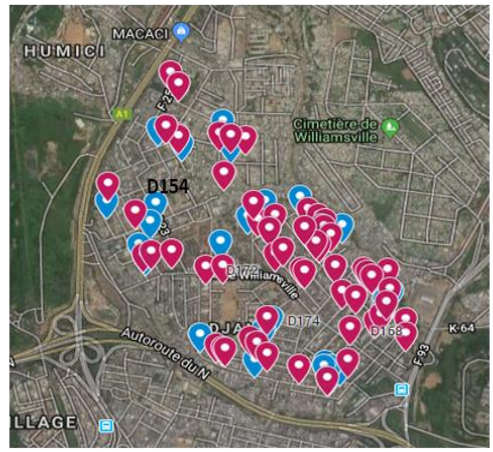


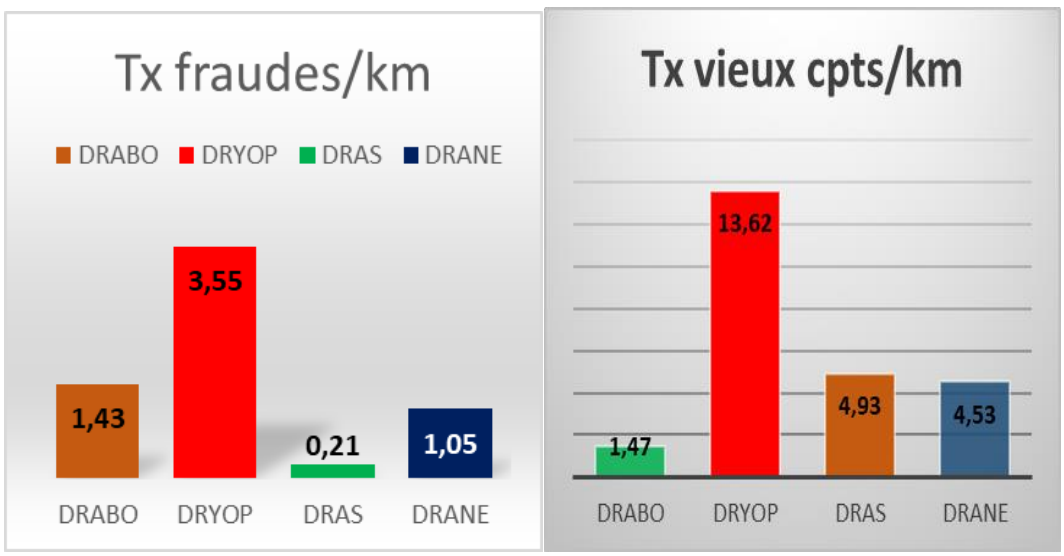
Fig4:Cartographie des fuites détectées au 1er et 2eme passage à Williamsville à DRABO

Figure 9 : Cartographies des fuites à la DRAS – DR YOP - DRABO.

Tableau 3 : parcours RAF 1er semestre 2019.

	Km Parcourus	Fuites localisées	Fuites/km	km/j
TOTAL SODECI	1486	952	0,64	2,9

Figure 10 : Diagramme de répartition des fuites localisées.



DRABO : Direction Régionale Abobo
DRYOP : Direction Régionale Yopougon
DRAS : Direction Régionale Abidjan Sud
DRANE : Direction Régionale Nord Est

Figure 11 : Taux de fraudes et vieux compteurs par km.

Tableau 4 : Résultats RAF par Direction régionale.

	DRABO	DRYOP	DRAS	DRANE	TOTAL
Km parcourus pour vieux compteurs	224	178,89	191,23	200	**794,12**
Nbre Vieux compteurs	329	2436	942	907	**4614**
Km parcourus pour fraude	448	167,5	325,23	391	**1331,73**
Fraude	640	595	69	409	**1713**
Tx vieux cpts/km	1,47	13,62	4,93	4,53	**5,89**
Tx fraudes/km	1,43	3,55	0,21	1,05	**1,67**

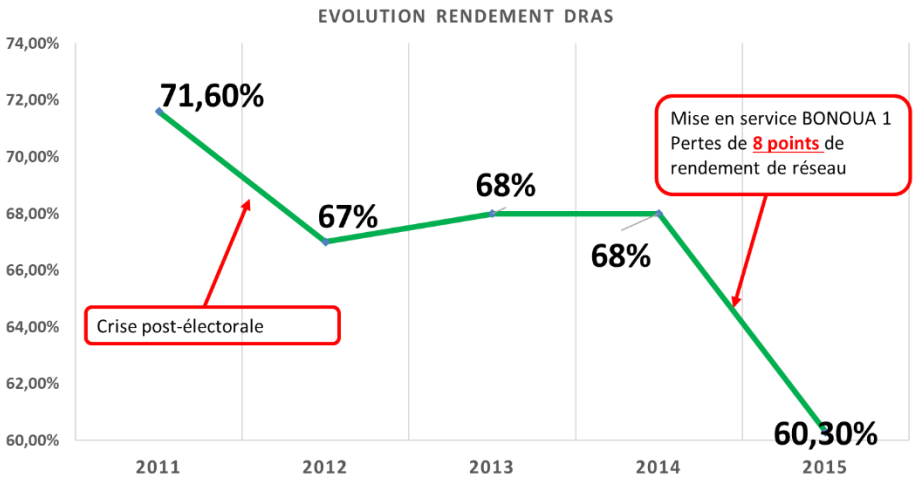


Figure 12 : Evolution rendement DRAS de 2011 à 2015.

Tableau 5 : Répartition des pertes en eau.

Répartition des pertes	m3/an	% Volume mis en distribution	EUR
Pertes physiques	11 068 849	32,33 %	996 196
Pertes de comptage	877 799	2,56 %	377 454
Pertes clientèle	1 257 059	3,67 %	540 535
Eau non comptabilisée (ENC)	**13 203 707**	**38,57 %**	**1 914 185**
Consommation autorisée non-facturée			
Eau non facturée (ENF)	**13 203 707**	**38,57 %**	**1 914 185**

Décomposition IWA des Pertes	m3/an	% Volume mis en distribution	% ENF	EUR
Volume annuel de pertes physiques (CARL)	11 068 849	32,33 %	83,83 %	996 196
Volume annuel de pertes apparentes (CAAL)	2 134 858	6,24 %	16,17 %	917 989
Pertes physiques annuelles minimales (UARL)	648 694	1,89 %	4,91 %	58 382
Potentiel MAX de réduction du CARL (ILI = 1)	**10 420 155**	**30,44 %**	**78,92 %**	**937 814**

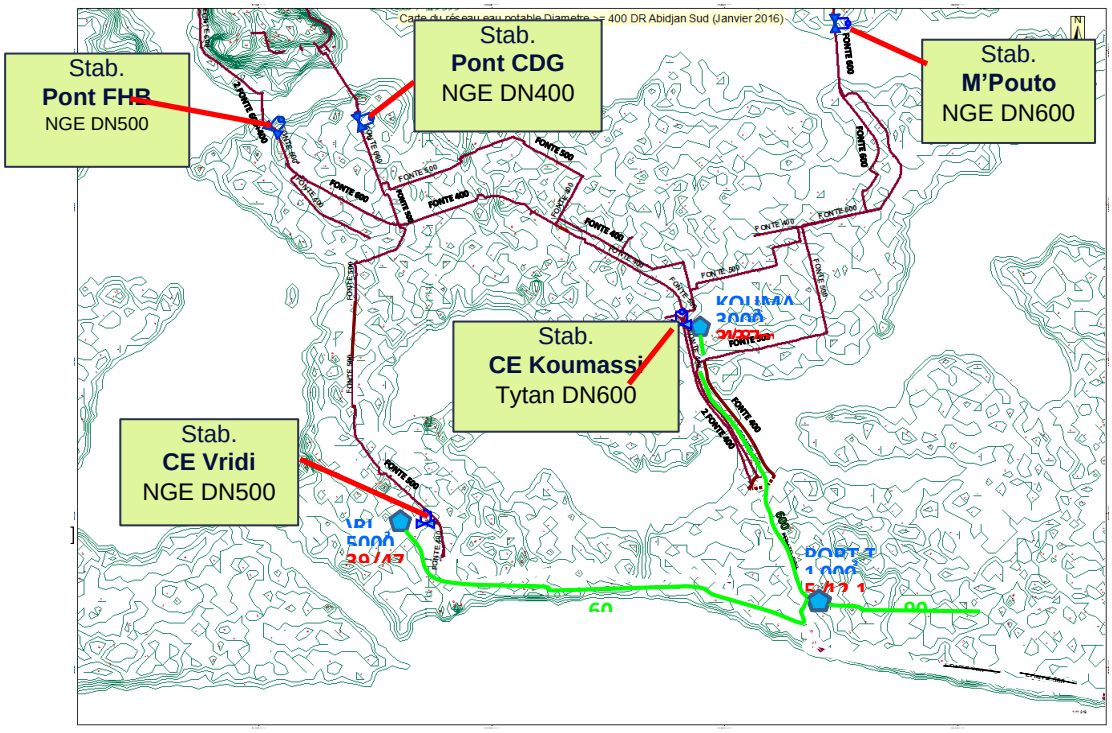


Figure 14 : Stabilisateur de pression DN 600 installé au pied du réservoir de Koumassi.

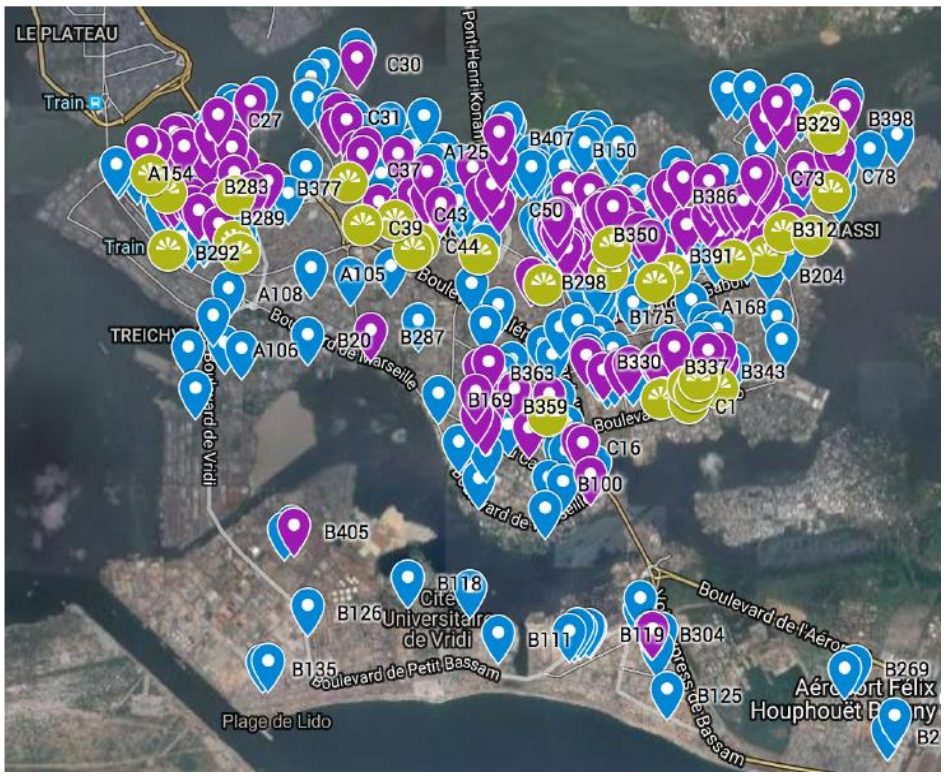


Figure 15 : Cartographie des taux de fuites par km (2017 et 2018).

- Taux de fuites par Km (1er passage en 2017) : 1 fuite tous les 700 m
- Taux de fuites par km (2ème passage en 2018) : 1 fuite tous les 2 000 m

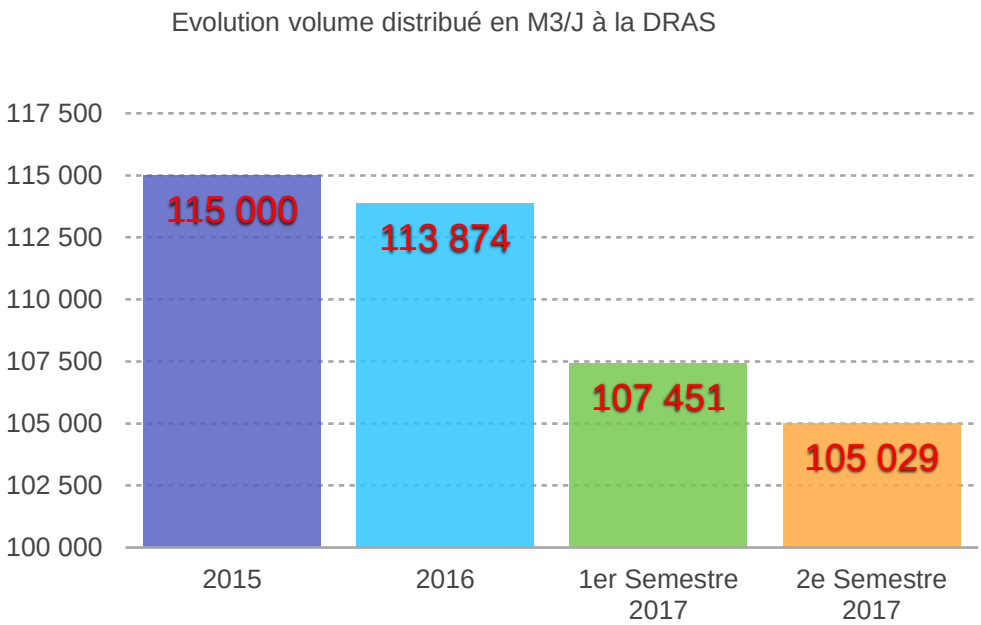


Figure 16 : Evolution du volume distribué en M^3/J à la DRAS.

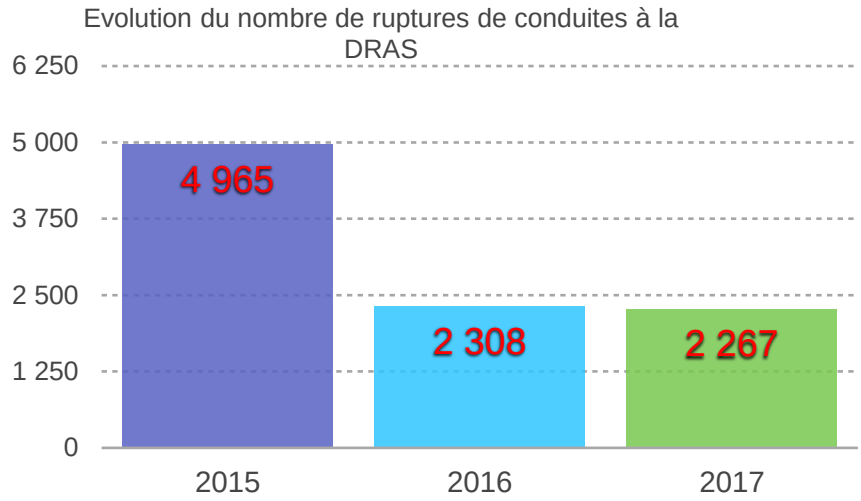


Figure 17 : Evolution des ruptures de conduites à la DRAS.

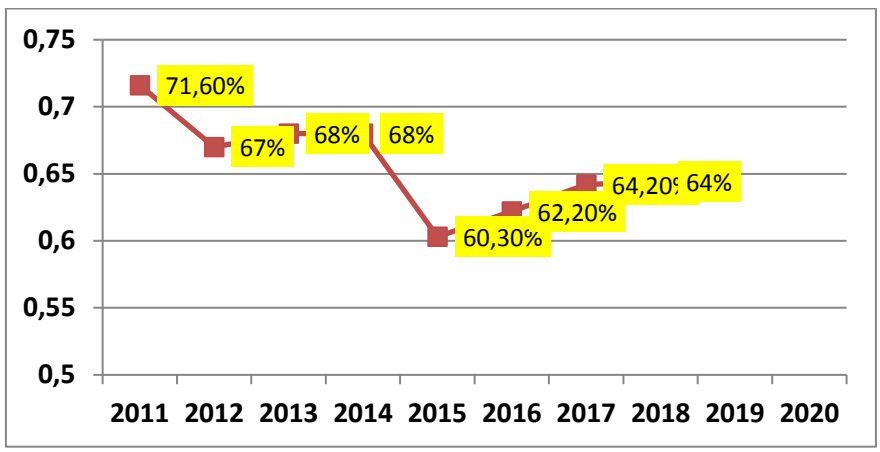


Figure 18 : Evolution du rendement du réseau.

DISCUSSION

La sectorisation

La sectorisation a pour objectif de déterminer les volumes mis en distribution dans les différentes mailles afin d'en déterminer les ratios de facturation.

Elle permet également de réduire la taille des zones à investiguer en cas de dérive du rendement de réseau.

77 mailles ont été identifiées sur le réseau AEP d'Abidjan et sont réparties sur 3 niveaux.

Le niveau 1 concerne 4 Directions Régionales ; le niveau 2 englobe12 secteurs (Agences) ; le niveau 3, ce sont 61 quartiers ou ensembles de quartiers (Figure 19).

La sectorisation niveau 1 et 2 tient compte des limites administratives des Directions Régionales et des secteurs.

762 équipements de mesure installés permettent les mesures des volumes des différentes mailles.

Le suivi des mailles est assuré par le télé-contrôle situé au Centre de Gestion Intégrée des Opérations (CGIO) de la SODECI.

Concernant la gestion des pressions**,** 3 actions prioritaires ont été identifiées.

Ce sont : l'acquisition et pose des capteurs de pression sur l'ensemble du réseau d'Abidjan, l'identification des zones d'opportunités et étude et l'acquisition et installation des équipements de gestion des pressions.

La SODECI dispose de 384 capteurs de Débit/pression et niveau d'eau, répartis sur l'ensemble du réseau d'Abidjan (4 Directions Régionales d'Abidjan) (Tableau 6).

Le Ratio km/capteurs est d'environ de 10 en moyenne sur le réseau d'Abidjan (Figure 20).

En plus du rôle que joue les capteurs dans l'acquisition des données pour l'identification des zones d'opportunité à possibilité de gestion des pressions, la SODECI utilise les capteurs à d'autres fins comme indiqué : surveillance des pressions, surveillance des débits, délimitation des zones de desserte, sectorisation AEP Abidjan, constitution d'une base de données d'évolution des pressions sur le réseau d'Abidjan, détection des zones de fuites, réalisation de la cartographie de la desserte sur Abidjan, calcul des volumes produits et mis en distribution.

La pose des 384 capteurs sur l'ensemble du réseau d'Abidjan a permis l'acquisition d'un ensemble de donnés en vue d'identifier les zones à opportunité de gestion des pressions.

17 zones à opportunité de Gestion des Pressions ont été identifiées sur l'ensemble de la ville d'Abidjan et réparties en 4 groupes, à savoir : G0 (Site Pilote) ; G1 (Court Terme) ; G2 (Moyen Terme) ; G3 (Long Terme) (Figure 21).

Les groupes sont définis suivant la criticité des zones, la disponibilité du matériel de pose, des contraintes d'exploitations et des impacts attendus.

La réalisation des travaux se déroule de manière chronologique suivant les ordres des groupes définis.

A ce jour, les travaux des groupes G0 et G1 sont complètement achevés avec des stabilisateurs posés et fonctionnels.

La recherche active de fuites

Afin de contrôler le respect des objectifs de la recherche fuites, 3 indicateurs stratégiques ont été définis : **le taux de fuite au kilomètre (fuites / km)** qui correspond au rapport entre le nombre de fuite total découvert dans une zone donnée et le linéaire parcouru dans cette zone ; **le taux d'avancement (km/j)** qui est la moyenne journalière de linéaire de réseau parcouru ; **le taux de réparation (%)** qui est le rapport entre le nombre de réparations et le nombre de fuites signalées.

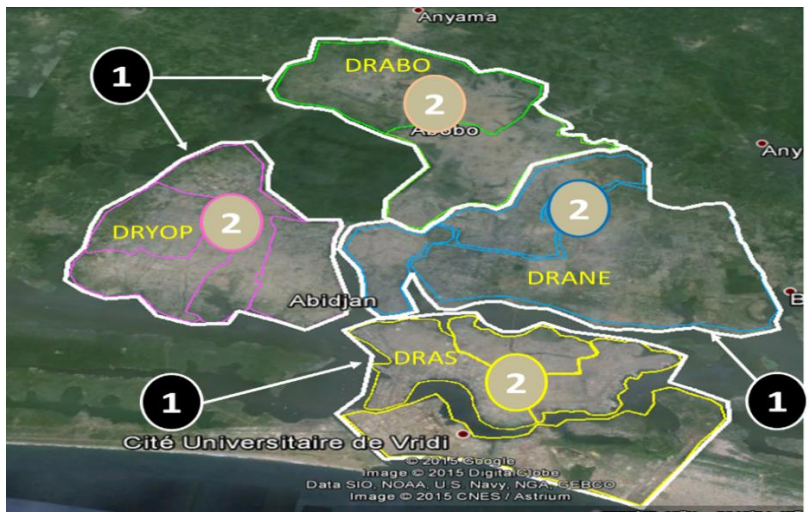


Figure 19 : Les niveaux de sectorisation.

Tableau 6 : Investissement global sur l'ensemble du réseau d'Abidjan.

	INVESTISSEMENT GLOBAL (FCFA)
GESTION DES PRESSIONS	4 000 000 000
SECTORISATION	10 000 000 000
RECHERCHE FUITE	2 350 000 000
TOTAL	16 350 000 000

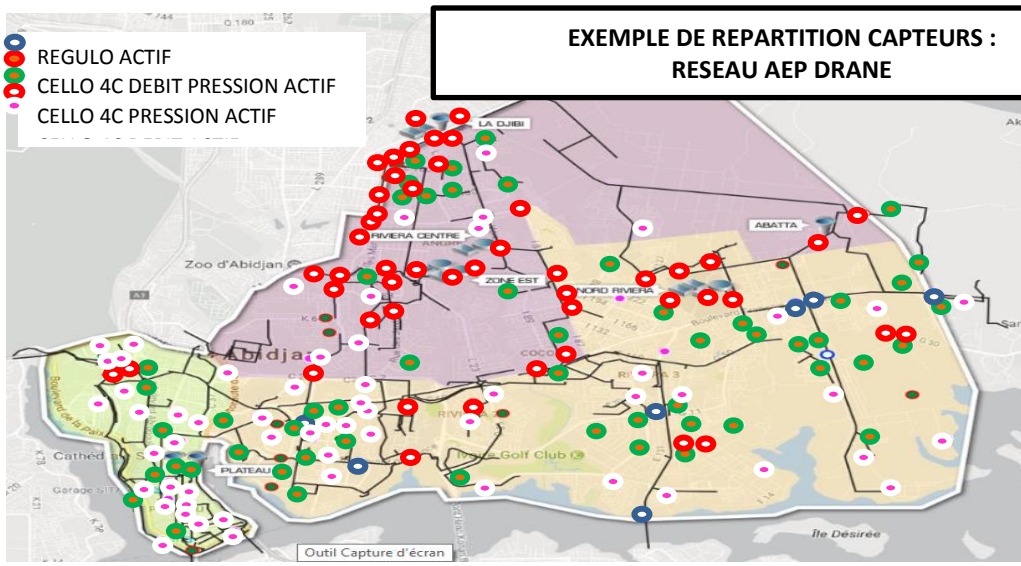


Figure 20 : Exemple de répartition de capteurs : cas de la DRANE.

Figure 21 : Identification des zones d'opportunités.

Conclusion

L'objectif final de cet ensemble d'actions est d'améliorer le rendement technique du réseau AEP d'Abidjan tout en améliorant la continuité de service. Bien que les résultats déjà obtenus soient très encourageants, beaucoup reste encore à faire pour amener le niveau de rendement hydraulique du réseau d'eau potable d'Abidjan à sa performance d'avant crise soit environ 80%. Il nous faut notamment : Finaliser la gestion des pressions sur l'ensemble du réseau de l'agglomération afin de réduire les pertes dues aux fuites et ruptures de canalisations et satisfaire parfaitement la demande en eau des clients ; Améliorer la sectorisation sur l'ensemble du réseau d'Abidjan avec un suivi en temps réel de l'évolution des pressions et débits de nuits par l'outil de Supervision du Centre de Gestion Intégrée des Opérations (Cela permettra la surveillance permanente de l'évolution du rendement de réseau et le déclenchement rapide des actions de corrections en cas de dérive) ; Parcourir chaque année l'ensemble du réseau d'Abidjan (4000 kms) afin d'atteindre un taux de fuites conforme aux standards internationaux, soit : **0.13 fuites/km/an** sur conduite (référence IWA) contre 1.46 actuellement sur le réseau d'Abidjan ; **5 fuites /1000brchts/an** (référence IWA) contre 22 actuellement sur le réseau d'Abidjan.

CONFLIT D'INTERÊTS

L'auteur déclare qu'il n'a pas de conflit d'intérêts.

CONTRIBUTIONS DES AUTEURS

L'auteur (JAN) a réalisé les différents aspects de ce travail, depuis la conception, la collecte et l'analyse des données jusqu'à la préparation du manuscrit.

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Diagnostic en vue de l'élaboration d'une stratégie municipale concertée pour l'accès à l'eau potable et l'assainissement : Cas de la commune de Kye-Ossi au Sud-Cameroun

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RESUME

L'approvisionnement en eau potable dans de nombreuses communes Camerounaises reste un défi permanent à relever ; c'est le cas pour la commune de Kye-Ossi qui ne possède pas de réseau publique de distribution d'eau, ni un service d'assainissement. La présente étude menée dans cette ville visait à y réaliser un diagnostic de l'alimentation en eau potable et de l'assainissement de base. Pour se faire, nous avons réalisé une analyse documentaire du cadre institutionnel, des interviews semi structurés, les « focus group » et des enquêtes ménages. Il ressort de ce travail que l'insuffisance des fonds et l'absence de l'énergie électrique sont les principaux problèmes des acteurs de l'offre et la demande. 71% des populations consomment sans traiter l'eau des forages, 47% des ménages utilisent les latrines à fond perdu aménagées. Bien que 69% des ménages soient satisfaits de l'assainissement de base, 74% ne sont pas satisfaits de l'approvisionnement en eau potable. 36% des forages équipés de pompes à motricité humaine sont non fonctionnels. Tous les puits modernes sont fonctionnels. Des sept latrines publiques recensées, quatre sont privées et trois appartiennent à la commune. La mauvaise gestion et la mauvaise qualité des équipements sont les principales causes des pannes sur les ouvrages.

Mots clés : Assainissement ; Diagnostic ; Eau potable ; Kyé-Ossi.

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Diagnosis for the development of a concerted municipal strategy for access to drinking water and sanitation: Case of the municipality of Kye-Ossi in South Cameroon

ABSTRACT

The supply of drinking water in many Cameroonian municipalities remains a permanent challenge; this is the case for the Kye-Ossi rural council which has neither a public water distribution network, nor a sanitation service. The present study carried out in this city aimed at realizing a diagnosis of drinking water supply and basic sanitation services. To do so, we carried out semi-structured interviews, "focus groups", household surveys and a documentary analysis of the institutional framework. We found from this work that insufficient funds and the absence of electric power are the main problems of the actors of supply and demand of water and sanitation services. 71% of the population use borehole water without any previous treatment, 47% of households use improved pit latrines for sanitation. Although 69% of households were satisfied with basic sanitation, 74% were not satisfied with the drinking water supply. 36% of boreholes equipped with hand pumps were non-functional. All modern wells were functional. Among the 7 public latrines identified, 4 were private and 3 belong to the municipality. Poor management and poor quality of equipment were the main causes of breakdowns on water and sanitation structures.

Keywords : Sanitation; diagnosis; potable water; Kyé-Ossi

INTRODUCTION

L'accès à l'eau potable en quantité satisfaisante demeure incontestablement un élément de survie majeur qui conditionne le développement économique et social des collectivités humaines. (Ta Bi Boti et al., 2019). L'eau est donc une ressource indispensable à la survie des êtres humains ; son indisponibilité et ou sa mauvaise qualité peuvent être à l'origine de nombreuses maladies hydriques (Lagnika et al., 2014). Cependant, les ressources en eau de la planète sont limitées ceci est accentué par la variabilité climatique et la croissance démographique. Selon GWP (2010) les ressources en eau dont dispose le Cameroun sont largement sous-exploitées, les besoins ne représentant que 4,14% du volume des eaux de surface. Or, L'OMS et l'UNICEF (2015) révèlent qu'en Afrique subsaharienne, 32% de la population n'a pas accès à l'eau potable et 70% ne bénéficie pas d'un système d'assainissement adéquat. Darmane et Potter (2009) affirment que le problème d'accès à l'eau potable nécessite une gestion collective par tous les acteurs (municipalités, privés, ...) qui doivent assumer leurs responsabilités. En effet, l'urbanisation anarchique et les mauvaises pratiques d'hygiène sont des facteurs qui augmentent les risques sanitaires au niveau des points d'eau (Ntep et al. 2014). La participation des populations à ce processus est fondamentale tel que le précise Dasylva et al. (2004).

La commune de Kye-ossi est l'une des dernières nées au Cameroun. Avec une population estimée à 75000 habitants, elle n'est pas couverte par le réseau public de distribution d'eau ni d'un service d'assainissement. L'approvisionnement en eau potable se fait donc à travers les forages, puits équipés et sources. Le processus de décentralisation actuel au Cameroun transfère le développement local aux Collectivités Territoriales Décentralisées (CTD). L'alimentation en eau potable et l'assainissement font partie des compétences transférées par l'Etat aux CTD. L'eau et l'assainissement étant des biens et services indispensables pour la vie et le développement durable, les rendre accessibles aux populations est un devoir pour les élus locaux. Or dans les zones du territoire national en plein

développement comme Kye-Ossi, la population sans cesse croissante, l'intensification et la diversification des activités (liées à sa proximité avec le Gabon et à la Guinée équatoriale) ont un impact direct sur la demande en eau ainsi que les services d'assainissement. Bien qu'il y ait eu quelques projets de construction de latrines individuelles et collectives issus des efforts des habitants et certains bailleurs de fonds, la mauvaise qualité du service d'assainissement est largement déplorée par la population et la vidange des latrines n'est jamais assurée (PIPAD, 2016). Une stratégie municipale concertée d'accès à l'eau et à l'assainissement de base qui se veut durable nécessite la connaissance de la situation actuelle sur le terrain, en matière d'infrastructure ainsi que les éventuels acteurs du secteur afin de quantifier les actions pouvant être menées et résoudre les problèmes rencontrés par les populations.

L'objectif principal de la présente étude était donc de réaliser un diagnostic de l'alimentation en eau potable et de l'assainissement de base dans la commune de Kye-ossi. Spécifiquement, il s'est agi de passer en revue le cadre institutionnel de la gestion des services de base d'assainissement et d'approvisionnement en eau potable ; d'analyser les acteurs de l'offre et de la demande de l'eau et des services d'assainissement de base ; identifier et cartographier les ouvrages hydrauliques et d'assainissement de base. Ces travaux ont été entrepris dans la perspective de l'atteinte de l'objectif de développement durable (ODD) numéro 6, cibles 1 et 2 qui voudraient que l'on mette de l'eau potable et les services d'assainissement de base à la disposition de tous d'ici à 2030 (ONU, 2015).

MATERIEL ET METHODES

L'analyse du cadre institutionnel a été effectuée à travers les interviews semi structures administrées auprès des sectoriels de la commune. Afin d'effectuer le diagnostic des acteurs de l'offre et de la demande, la recherche documentaire a permis de recenser les différents acteurs présents dans la commune puis un calendrier de rencontre a été dressé. La rencontre et la concertation avec les acteurs ont été effectuées en fonction de leur catégorie. En zone rurale, les concertations se sont faites à travers les discussions de groupes organisées dans les lieux de rencontre du village. Pour les institutions sociales (Ecoles, Hôpitaux, Eglises, Mosquées etc.), les interviews semi structurées ont été utilisées. En zone urbaine, les données ont été collectées à travers un questionnaire administré à 200 ménages choisis au hasard dans la ville. Une fois les données collectées, elles ont été traitées et présentées sous forme de tableaux et diagrammes.

Afin d'analyser les acteurs de l'offre et de la demande de l'eau et des services d'assainissement de base, nous avons évalué les besoins en eau et assainissement. Ces besoins portaient sur le nombre de points d'eau à créer, ceux à réhabiliter et les exigences en assainissement. Le nombre de points d'eau à créer a été déterminé par la méthode des équivalents points d'eau (EPE). Cette méthode consiste à évaluer la population à desservir en 2030, et globalement à appliquer un ratio théorique de personnes desservies par EPE. Le model de projection démographique était le suivant :

$\boldsymbol{p_n = p_0(1+\alpha)^n}$;

Où : $\boldsymbol{p_n}$ = Nombre d'habitants à l'année n ;
$\boldsymbol{p_0}$ = Nombre d'habitants à l'année 0 ;
$\boldsymbol{\alpha}$ = Taux d'accroissement et $\boldsymbol{n}$ = nombre d'années

Le ratio théorique dans le cadre de cette étude a été pris égal à 200 pour la partie rurale et 300 pour la partie semi urbaine. Le plan communal de développement de la commune de Kye-Ossi a donné la population de cette zone à l'année 2014 ; la population à desservir a été estimée en considérant un taux de croissance de 2,3% (MINEE, 2009). Nous avons par la suite estimé le nombre d'EPE nécessaires à l'horizon 2030, après avoir

retranché le nombre d'EPE existant déjà en 2017.

$$Points\ d'eau\ \text{à}\ créer = \frac{pop\ utilisatrice}{Ratio\ théorique} - atio\ thd'eau\ existants$$

Pour ce qui est de l'évaluation des besoins en assainissement de base, à partir de la population projetée à l'année 2017 et sachant que chaque ménage rural compte en moyenne 5 personnes (INS, 2012) et en considérant un taux d'équipement des ménages ruraux en toilettes modernes de 14,2% et 66,4% en zone semi urbaine (INS, 2007), le nombre actuel de latrines modernes a été estimé. Pour le nombre de latrines modernes nécessaires en 2030, le nombre de ménage en 2030 a été estimé en appliquant un taux d'équipement à pourvoir des ménages de 100% (ONU, 2015) et en retranchant les latrines modernes existantes.

$$Nombre\ de\ latrines\ existants\ en\ 2017 = \frac{population\ en\ 2017}{5} * t$$

t = taux d' équipement des ménages en latrines modernes

$$Demande\ en\ latrines = \frac{pop\ en\ 2030}{5} - latrines\ existantes\ en\ 2017$$

Afin de cartographier les ouvrages hydrauliques, chaque ouvrage a été photographié puis, à l'aide d'un GPS de marque Garmin etrex 10, son altitude et ses coordonnées géographiques ont été enregistrées. Pour chaque ouvrage, il a été noté si l'ouvrage est fonctionnel ou pas. Cette démarche a été suivie dans chacun des villages de la commune. Une fois les données collectées, elles ont étés traitées à l'aide des logiciels MS-Excel 2016, MAP Source et QGIS. L'ensemble des ouvrages hydrauliques a été présenté sous forme de tableau et a également été cartographié et présenté sous forme d'Images. Les entretiens ont eu lieu avec les populations autour des points d'eau afin d'enregistrer les pannes ainsi que d'autres informations utiles pouvant expliquer l'origine des pannes.

RESULTATS

Cadre institutionnel de la gestion des services de base d'assainissement et d'AEP

Les acteurs institutionnels intervenant dans l'alimentation en eau potable et l'assainissement de base dans la commune sont : la Délégation Départementale du MINEE (Ministère de l'Eau et de l'Energie) ; la Délégation Départementale du MINEPDED (Ministère de l'Environnement, de la Protection de la Nature et du Développement Durable) ; la Délégation d'Arrondissement du MINADER (Ministère de l'Agriculture et du Développement Rural) ; la Délégation d'Arrondissement du MINSANTE (Ministère de la Santé Publique) et la Mairie de Kye-Ossi.

Analyse des acteurs de l'offre et de la demande de l'eau et des services d'assainissement de base

Pour ce qui est des acteurs de l'offre en services d'eau potable et d'assainissement de base, l'eau est vendue à 100 FCFA le bidon de 20 litres, la somme de 50-100 FCFA est requise pour utiliser les toilettes publiques. Les Tableaux 1 et 2 résument les difficultés rencontrées ainsi que les suggestions pour améliorer ces services.

Pour ce qui est des acteurs de la demande, cinq principales catégories d'acteurs ont été identifiés pour la demande en services d'eau potable et en services d'assainissement de base. Les Tableaux 3 et 4 présentent une synthèse du diagnostic des acteurs de la demande.

Pour ce qui est de l'AEP, les eaux de boisson consommées dans la commune de Kye-Ossi proviennent principalement des forages (40%), des puits (17%), des sources (6%). Une faible proportion de la population (3%) ne consomme que de l'eau embouteillée, presque personne (0%) ne consomme l'eau des rivières. Les autres sources (4%) renvoient aux eaux d'origine inconnue dont on a confié la

responsabilité de puiser aux pousseurs et dont le chef de ménage ne connaît pas la provenance (Figure 1). Seuls 29% des ménages traitent l'eau avant consommation.

Les latrines utilisées par les ménages de la commune de Kye-Ossi sont majoritairement à fond perdu aménagées (33%), à fond perdu sommairement aménagées (superstructure en matériaux provisoires et ne comportent pas de toit). Peu de personnes (12%) disposent des latrines modernes (Figure 2).

Seulement 26% et 69% des ménages de la commune de Kye-Ossi sont satisfaits respectivement du service d'AEP et du service d'assainissement. La demande en points d'eau et en latrines pour la population à l'horizon 2030 est évaluée respectivement à 72 et 3656 habitants pour les zones rurales et 76 et 2441 habitants pour les zones urbaines.

Ouvrages hydrauliques et d'assainissement de base

Dans la commune de Kye-ossi (Figure 3), on a recensé 33 forages équipés de pompes à motricité humaine (PMH) dont vingt et un (21) sont fonctionnels et douze (12) non fonctionnels. Les quatre (04) puits communautaires et trois (03) puits privés équipés de pompe a motricité humaine sont tous fonctionnels.

Des sept (07) toilettes publiques payantes de cette ville, (04) appartenant aux acteurs privés sont fonctionnelles tandis que seulement deux (02) des trois (03) appartenant à la mairie sont fonctionnelles.

Tableau 1: Analyse des acteurs de l'offre en services d'eau potable dans la commune de Kye-ossi.

Acteurs	Ouvrages	Difficultés rencontrées	Suggestions d'amélioration
Société BOCOM	▪ Forages	▪ Pannes sur les robinets. ▪ Insalubrité de l'espace de puisage.	▪ Sensibiliser les populations sur l'utilisation des robinets et garder l'espace de puisage toujours propre.
Télé centre	▪ Forages	▪ Panne fréquente de la pompe. ▪ Pas de matériel pour la maintenance.	▪ Disposer des pièces de rechange et d'une caisse à outil pour effectuer les maintenances.
Vendeurs d'eau dans la ville et les quartiers	▪ Puits aménagés	▪ Coût élevé du carburant pour faire fonctionner la pompe. ▪ Qualité de l'eau inconnue et frais d'analyses coûteux.	▪ Restaurer l'électricité dans la ville et apporter des subventions pour faire des analyses fréquentes de la qualité de l'eau.
Commune de Kye-ossi	▪ Forages et Puits aménagés	▪ Insuffisance des fonds pour satisfaire toute la demande.	▪ Bénéficier d'un appui financier.
Société de forage «YAYA PANAMI»	▪ Maintenance et réalisation	▪ Difficultés de diagnostic des forages car ils n'ont pas été réalisés selon les règles de l'art.	▪ Veiller à ce que les forages soient réalisés en suivant les prescriptions réglementaires.

Tableau 2 : Analyse des acteurs de l'offre des services d'assainissement de base dans la commune de Kye-Ossi.

Acteurs	Difficultés rencontrées	Suggestions d'amélioration
Propriétaires et gestionnaires des toilettes publiques payantes	▪ Manque d'eau pour le nettoyage des latrines ; ▪ Pas de services de vidange des latrines ; ▪ Inadéquation et insuffisance des équipements de travail ; Insuffisance des produits de désinfection les latrines ; ▪ Mauvaise formation des gestionnaires de latrines sur les bonnes pratiques d'hygiène ; ▪ Pas de suivi médical des gestionnaires des latrines .	▪ Rendre l'eau disponible. ▪ Renforcer les capacités des gestionnaires en matière d'hygiène. ▪ Appuyer ces gestionnaires financièrement pour l'achat du matériel approprié et faire un bilan de santé de manière périodique. ▪ Former les gestionnaires de latrines sur les bonnes pratiques d'hygiène. ▪ Faire venir un camion pour la vidange des latrines pleines.
Commune de Kye-Ossi	▪ Insuffisance des fonds pour satisfaire toute la demande en services d'assainissement	▪ Bénéficier d'un appui financier.

Tableau 3 : Analyse des acteurs de la demande en services d'eau potable dans la commune de Kye-Ossi.

Acteurs	Synthèse des difficultés rencontrées	Synthèse des suggestions d'amélioration
Marché et Écoles	▪ Quantités d'eau potable insuffisantes ; ▪ Longues distances parcourues pour avoir de l'eau (plus de 2 km) .	▪ Installation dans la commune d'une société d'eau potable (CDE). ▪ Construction des forages.
Villages	▪ Éloignement des points d'eau (plus de 2 km) ▪ Nécessiter d'utiliser des motocycles et portes tous pour le transport de l'eau ; ▪ Dépenses élevées pour s'approvisionner en eau potable ; ▪ Qualité de l'eau disponible douteuse ; ▪ Vandalisme autour des points d'eau ayant un COGES ▪ Moyens financiers limités entrainant la réalisation d'infrastructures précaires. ▪ Qualité de l'eau disponible douteuse ;	▪ Aménager les points d'eau ou les sources et protéger les aires de captage. ▪ Renforcer les capacités des vendeurs d'eau potable pour une gestion durable. ▪ Installer les bornes fontaines payantes. ▪ Mettre autour des points d'eau communautaires un comité de gestion sérieux.

Acteurs	Synthèse des difficultés rencontrées	Synthèse des suggestions d'amélioration
Centres de santé	▪ Indisponibilité de l'eau dans les salles d'accouchement.	
Écoles	▪ Accidents lors des traversées de routes pour aller à la recherche de l'eau à boire par les élèves ; ▪ Absentéisme scolaire ;	
Établissements religieux	▪ Origine douteuse des eaux apportées par les élèves. ▪ La plupart des Eglises et Mosquées n'ont pas de points d'eau à proximité.	

Tableau 4 : Analyse des acteurs de la demande en service d'assainissement dans la commune de Kye-Ossi.

Acteurs	Synthèse des difficultés rencontrées	Synthèse des suggestions d'amélioration
Marché	▪ Latrines traditionnelles prédominantes ; ▪ Mauvaise ou absence de désinfection des latrines.	▪ Bonne formation des gestionnaires et fourniture permanente des désinfectants, du matériel de désinfection et de l'eau. ▪ Construire des latrines modernes. ▪ Mieux aménager les latrines traditionnelles.
Écoles	▪ Seulement 12,5% des écoles primaires publiques disposent des latrines modernes ; ▪ Mauvaise ou absence de désinfection des latrines. ▪ Latrines traditionnelles prédominantes ; ▪ Mauvaise ou absence de désinfection des latrines ;	
Villages	▪ Mauvaise construction/réalisation des latrines existantes (elles sont inaccessibles après les pluies et présentent également un risque d'effondrement) et mauvais entretien (émanation des odeurs nauséabondes et prolifération des mouches et moustiques) ▪ Latrines traditionnelles prédominantes ; ▪ Mauvaise ou absence de désinfection des latrines ;	
Centres de santé	▪ Plusieurs Eglises et Mosquées n'ont pas des latrines modernes.	
Établissements religieux		

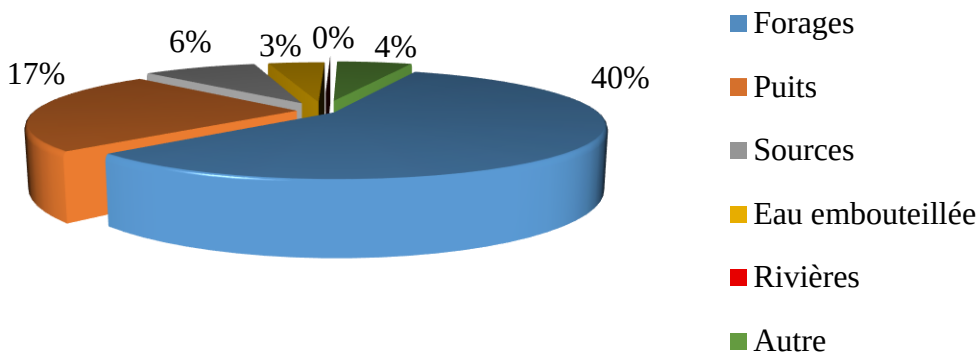

Figure 1 : Origine des eaux de boisson dans la commune de Kye-Ossi.

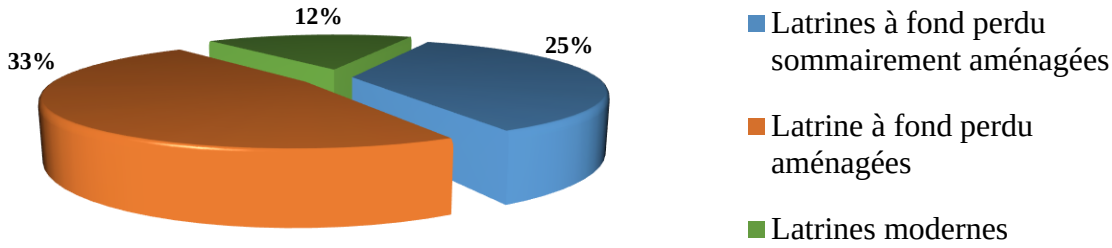

Figure 2: Type et proportion des latrines utilisées par les ménages.

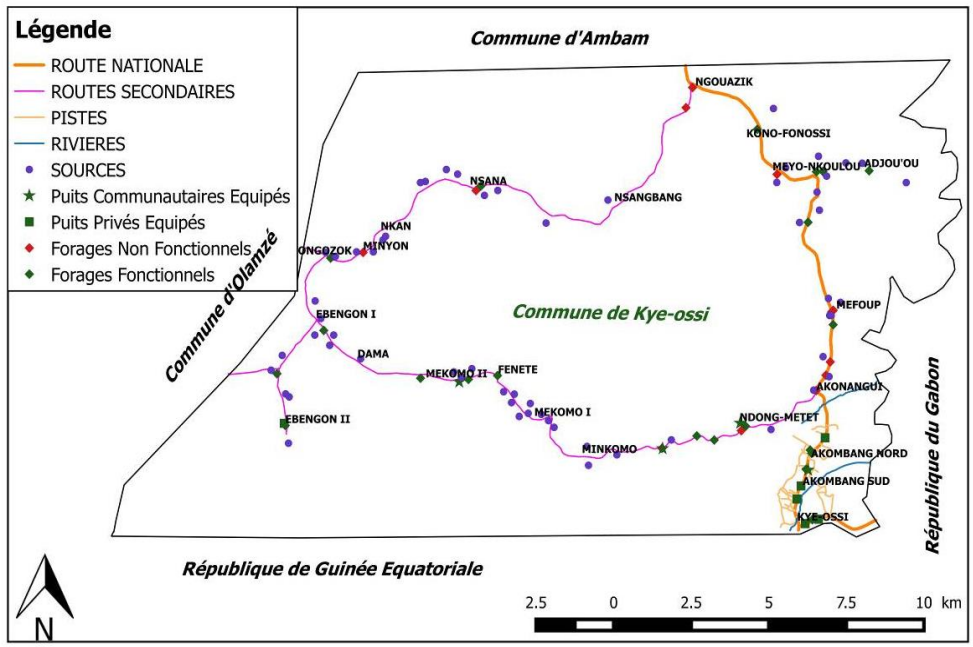

Figure 3: Cartographie et état de fonctionnement des ouvrages hydrauliques dans la commune de Kye-Ossi.

DISCUSSION

L'analyse du cadre institutionnel révèle que : les rôles des différents acteurs ne sont pas clairement définis et se recoupent très souvent. Il n'existe pas de plateforme de collaboration entre ces acteurs impliqués. Seule la Délégation Départementale du MINEE est en étroite collaboration avec la Mairie pour ce qui est des questions d'eau potable. Contrairement à ce que prévoit le cadre institutionnel national, il n'y a pas d'ONG (Organisation Non Gouvernementale) impliquée dans la fourniture en eau et en services d'assainissement de base, il n'y a également pas de réseau public d'alimentation en eau potable, encore moins de service de vidange des latrines. Ces faiblesses du cadre institutionnel ont été relevées par MINEE (2009) dans le cadre de l'état des lieux visant à établir un plan d'Action National des Gestion des Ressources en Eau.

En rapport avec l'offre et la demande des services d'eau potable et d'assainissement de base, nous observons que les acteurs de l'offre ne parviennent pas à satisfaire la demande sans cesse croissante des populations. En plus des moyens limités dont dispose la commune, s'ajoutent la mal gouvernance, l'incivisme des populations et parfois le non-respect des cahiers de charge de réalisation des ouvrages entrainant leur dysfonctionnement précoce. Des résultats similaires ont été obtenu par Temgoua et al. (2009) travaillant sur la qualité de l'eau et l'assainissement dans la ville de Dschang.

En effet, 36% des forages équipés de PMH sont non fonctionnels. Les forages sont très inégalement répartis dans les villages, certains villages possèdent jusqu'à 3 forages alors que d'autres n'en possèdent rien. Les puits communautaires sont surtout repartis en zone rurale alors que les puits privés sont plus accentués en zone urbaine. La prolifération des puits privés équipés en zone urbaine est une mesure d'adaptation face aux difficultés d'alimentation en eau potable en milieu urbain.

Le faible taux de satisfaction des ménages vis-à-vis des services d'eau potable (26%) traduit bien le fait que les populations attendent encore beaucoup de la part de la commune en terme de quantité d'eau à mettre à la disposition des populations. Ceux qui affirment être satisfaits se méfient cependant beaucoup de la qualité. En effet, le pourcentage très élevé des populations utilisant les latrines à fond perdu (83%) est potentiellement dangereux pour toutes les sources d'eau de surface et contraste avec le faible taux (29%) de populations qui traitent l'eau avant consommation, ces résultats contrastent avec ceux de Sokegbe et al. (2017) dans ses travaux à Lomé au Togo, qui affirme plutôt que La majorité des ménages traitent l'eau avant consommation et la chloration est le mode de traitement le plus utilisé. Cela laisse penser à la nécessité de mieux sensibiliser les populations de Kye-Ossi sur les risques auxquels ils seraient exposés. Le pourcentage relativement élevé du taux de satisfaction des ménages en rapport avec le service d'assainissement peut s'expliquer par le statut même des ménages qui sont pour la plupart des commerçants non établis de manière permanente et peux exigeants.

Afin d'atteindre ces objectifs à l'horizon 2030 des besoins en eau et en assainissement de la ville, une approche envisageable serait de réaliser les points d'eau de manière progressive à un rythme d'environ 12 points d'eau par an. Il est également important de mettre sur pied des comités de gestion des points d'eau viables afin d'assurer leur pérennité. S'il faille équiper tous les ménages en latrines en 2030, il faudra en construire environ 469 par an. Parallèlement à tout ceci il reste important de sensibiliser les populations sur les techniques de traitement des eaux avant consommation, notamment la méthode par chloration.

Conclusion

Au terme de ce travail dont le but était de réaliser un diagnostic de l'alimentation en eau potable et de l'assainissement de base dans la commune de Kye-Ossi, il apparaît que tous les acteurs institutionnels sensés intervenir dans le domaine de l'eau et l'assainissement dans la commune de Kye-Ossi ne sont pas présents et ceux qui le sont ne jouent pas pleinement leur rôle. Il n'existe pas une

plateforme de collaboration entre les acteurs actuellement sur le terrain et les mécanismes de renforcement de capacités des populations sont peu fréquents. Sept principaux acteurs de l'offre des services d'eau et d'assainissement de base interviennent dans la commune parmi lesquels 5 offrent les services d'eau potable et 2 offrent les services d'assainissement de base. Les principales contraintes auxquelles ils font face sont liées à l'insuffisance des fonds, de matériel et de compétences techniques. Cinq catégories d'acteurs de la demande en services d'eau potable et d'assainissement de base existent dans la commune, les problèmes majeurs auxquels ils font face sont liés à l'insuffisance en qualité et en quantité de l'eau de boisson et en infrastructures d'assainissement de base ; l'absence dans la commune du réseau public d'approvisionnement en eau potable ; l'absence du courant électrique pour équiper les forages privés en pompes électriques. En zone péri-urbaine, la majeure partie des ménages ne sont pas satisfaits du service d'approvisionnement en eau potable et une part non négligeable de ménages ne sont pas satisfaits des services d'assainissement de base ; tandis qu'en zone rurale, de manière générale, les populations ne sont pas du tout satisfaites des services d'eau et d'assainissement. Sur 33 forages équipées de pompes à motricité humaine existants dans la commune de Kye-Ossi, 21 sont fonctionnels et 12 sont non fonctionnels. L'assainissement individuel financé par les ménages prédomine largement et l'assainissement collectif reste très minoritaire. Le principal mode d'évacuation des excrétas est la latrine à fond perdu aménagée. Dans la perspective de l'atteinte de l'objectif numéro 6 des ODD à l'horizon 2030, il est nécessaire de construire de manière graduelle 72 points d'eau et 3656 latrines modernes en zone rurale ainsi que 76 points d'eau et 2441 latrines modernes en zone urbaine et de sensibiliser les populations sur les méthodes simples de potabilisation de l'eau.

CONFLIT D'INTÉRÊTS

Les auteurs déclarent qu'il n'y a pas de conflit d'intérêts.

CONTRIBUTIONS DES AUTEURS

Ce travail a été réalisé en collaboration entre tous les auteurs. Les auteurs MSS, JMS et BLD ont conçu le projet et encadré la collecte des données sur le terrain ; les auteurs BMDK et MFF ont encadré les analyses statistiques, géré les analyses de l'étude, et corrigé le protocole et le manuscrit produit par l'auteur MDT.

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