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POTENTIALS OF AGRIC WASTES ACTIVATED CARBONS FOR WATER SOFTENING

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ABSTRACT
Various studies have been conducted to address softening of hard water. Ion exchange, electro-based techniques, membrane filtration and adsorption are the most reported techniques in softening hard water. In the present work, performances of these techniques are reviewed and discussed. Likewise, adsorbents that have so far been used in water softening, their efficiencies and drawbacks have been reported. Best adsorbent has been proposed based on optimum pH and local availability. In addition to the review of existing work on hardness removal, we have performed some preliminary experiments to study the performance of adsorbents, namely coconut and cashewnut shell activated carbons. The results are presented in here and it was found that, both adsorbents perform better in water softening but cashewnut shell activated carbon performs the best. These adsorbents are cheaply and locally available, which makes their integration into the softening systems low cost and highly performing owing to their chemical contents and subsequent activations.

KEYWORDS: Hardness Removal, Coconut Shell Activated Carbon, Cashewnut Shell Activated Carbon, Softening, Efficiency.

INTRODUCTION
Groundwater is contaminated by number of chemical species such as nitrates, heavy metals, hardness ions, soluble iron, among others (Knivsland, 2012). Common chemical species known to cause hard water are Calcium and Magnesium ions (Davis, 2010); and associated problems in industrial and domestic uses of such water include scaling in boilers, washing machines and pipes (Seo, *et al*., 2010), difficult lathering with soap, undesirable spots on sinks and clothes as well as toughening of skin and hair (Johnson and Scherer, 2012). Additionally, WHO reports that excess intake of calcium is associated with kidney stones and that of magnesium leads to diarrhea and laxative effect due to change in bowel habit (2011).

Public acceptable level of hardness differs remarkably according to local conditions. In general, water supplies with total hardness higher than 200 mg/L can be tolerated by consumers but are considered as poor resources; while values higher than 500 mg/L are not acceptable for most of the domestic consumptions (WHO, 2011). Beside local acceptability of hardness, national and international standards have established the permissible level for the hardness in water. According to Tanzania Bureau of Standards and WHO standards, total hardness levels in water should not exceed 600 mg/L and 500 mg/L as $CaCO_3$ respectively (Napacho and Manyele, 2010; WHO, 2011). Various studies have been conducted to study the prevalence of hardness problem in Tanzania. Some of the reports show that in most areas of Tanzania, the level of ground water hardness is within Tanzania standards which is 600 mg/L as $CaCO_3$ (EWB Boston Professionals, 2012). However, Knivsland (2012) reported that in most groundwater sources of Dodoma region, the hardness is above the national standard. Calcite and gypsum rock that form largest geological part of Dodoma region is the main cause for high level of Calcium hardness. In another study, Napacho and Manyele (2010) reported the prevalence of hardness in water sources found in Temeke district, in Dar es salaam and reported that the hardness of most water sources comply with the TBS and WHO standards except for Tandika-Kilimahewa Kwa Mzee Yasini river (710 mgL^{-1}) and Kibonde Maji-Kwa Numbwa (710 mgL^{-1}) that seems to deviate from the standards.

The study of water softening techniques is relevant to the current era we are living. This is because access to safe and quality water is a right to every one (Vandenhole and Wielders, 2008). But rapid population growth and climate change stress the availability of safe and quality water to every individual (Vörösmarty, *et al*., 2000). Third world countries, such as Tanzania, are largely affected by water crisis (UNESCO-WWAP, 2009). Tanzania suffers from serious water scarcity (Ernest, 2005) and the little groundwater sources available are contaminated by chemical species including hardness ions (Knivsland, 2012; Napacho and Manyele, 2010). Therefore, the need to purify water which was not suitable for human consumption such as hard water is essential. Since available techniques for water softening are not feasible to most of Tanzanians due to poverty they face, then cheaply and locally available technique is highly required. The present study attempts to explore the potentials of adsorption by using low-cost and locally available biomasses viz, CSAC and CNSAC in water softening. The results from this study will add knowledge in the field of water treatment and purification techniques which will in turn increase availability of safe and quality water to meet water demands of the people.

Techniques ranging from conventional to innovative ones are being applied to provide appropriate solution to water hardness. This paper presents techniques and materials used in water hardness removal as well as their efficiency in doing the same and especially focuses on efforts that have been carried out in Tanzania. Hardness removal efficiency, local availability of the material, adsorption/desorption time and capacity as well as adsorption pH will serve as the criteria for quick assessment of what are the best, innovative and sustainable materials for water softening.

Techniques for Hardness Removal

In order to meet the standards of water quality, hardness has to be removed from water. As scientists struggle to find ways of softening hard water, some techniques are already discovered and they are in use. Although they show significant impact in removal of hardness ions, they are not free from setbacks. These methods include; ion exchange, electro-based techniques, membrane filtration and adsorption.

Hardness Removal by Ion Exchange

Ion exchange involves the exchange of calcium and magnesium ions in water for sodium ions as the hard water flows through a resin containing sodium ions. Consequently, the water leaving the resin has sodium ions in the place of calcium and magnesium ions (Manahan, 2000). In the application of this methods, various materials are being used. These are sulphonated waste plastics and zeolites among others.

Sulphonated waste plastics are obtained after treating waste polystyrene plastics with sulphuric acid to introduce functional groups and they are used to produce resin for hardness removal (Pentamwa, *et al*., 2011). The resin contain Sodium which during softening process Sodium exchange with Calcium and Magnesium (Pentamwa, *et al.,* 2011). The reported efficiency of sulphonated waste plastics is 43%. That is to say only half of the total hardness is removed and hence this is not effective hardness remover.

Zeolites are aluminosilicates of Sodium that have three dimensional crystal structures, insoluble in water which enables them to exchange their ions with suitable amounts of other ions substance (Panayotova, & Velikov, 2002). Zeolites was used as an ion exchanger to soften hard water and reported to do well. Gholikandi, *et al*., (2010) found that zeolite is more efficiency in removing permanent hardness (72%) than temporary hardness (64%). The later observation is because zeolite has less ability to remove carbonates which account for temporary hardness. Maximum total hardness removal efficiency attained by zeolite is 70% (Badalians, *et al*., 2010).

The process of hardness removal by ion exchange raises two serious problems in water. One, it introduces excess sodium ions in water that may cause health problems for people who are not supposed to take salt (Frankel, 2011). Two, the method is said to remove all Calcium ions and Magnesium ions from water (Skimpton, *et al*., 2008) which are very essential for health (WHO, 2011). Thus, materials that could balance these issues while having higher softening efficiency will stand these setbacks and thus provide potential for highly efficient techniques with subsequent low cost.

Direct information on applicability of ion exchange technique in softening hard water in Tanzania is not known. However, there are companies dealing with construction and building material supply in Tanzania that also supply ion exchange softeners. Nabaki Africa is one of such companies. The clients of Nabaki Africa range from domestic owners, who get basic needs such as building materials, to industrial level, which obtain machines, like ion exchange softener, and other building materials (Nabaki Africa quality building material, n.d.). Since softeners are being supplied to the industries rather than to the domestic, it is obviously that hard water treatment by ion exchange is done at industrial level. The reason for less applicability of this technique at domestic level is expenses that has to be incurred to buy and install the equipments (Nabaki Africa quality building material, n.d.).

Electro-Based Methods for Hardness Removal

Number of studies have been done to soften water by electro-chemical methods, whereby voltage is applied to the electrode and upon being charged, they become polarized and draw opposite charge ions from bulk solution towards their surface (Malakootian and Yousefi, 2009). The electro based techniques include electrodialyis, electrodeionization (EDI) (Younos and Tulou, 2005), electrocoagulation (EC) (Drouiche, 2007) and capacitive deionization (CDI) (Seo, *et al*., 2010). Electrodialysis is novel electro-based technique that is coupled with cation and anion exchange membranes (Nataraj, *et al*., 2006). It is well known method in water treatment plant. During water treatment process ions are exchanged under the influence of applied voltage. By so doing, contaminants such as hardness ions are removed. The efficiency of the electrodialysis method is said to depend on the applied potential. Maximum voltage for highest efficiency is 50V whereby 90% removal is attained (Nataraj, *et al*., 2006). The study conducted by Karabacakoğlu, et al., (2014) found that effectiveness of electrodialysis on hardness removal depend on type of membrane used. When Ionac MC3470 and MA3475 pairs of membranes are used, the removal efficiency for Calcium and Magnesium are 93% and 95% respectively at a pH of 6.8, feed concentration of 0.01 M and 2.6 mL/s flow rate. Removal efficiency of Neosepta CMX and Neosepta AMX pair at the same optimal conditions as previous case are 98.3% and 100% for Calcium and Magnesium respectively (Karabacakoğlu, *et al.,* 2014). The working pH (6.8) suggests that softened water by electrodialysis requires no pre and post treatment simply because the pH is almost neutral which is good for drinking water. Based on aforementioned studies, water softening by electrodialysis seem to be effective. However, high energy consumption and membranes requirements hinders its applicability especially in the community with low earning like Tanzanians.

EDI is a process which combines semi-impermeable membrane technology with ion-exchange media to provide a high efficiency desalination process under affection of applied current (Younos and Tulou, 2005). Optimum desalination is achieved when optimum current is applied. The application of EDI in hardness removal was studied by Fu, *et al*., (2009). They came out with the fact that an improved EDI technology is feasible for hard water softening. Lenntech (2012) added that EDI efficiency in hardness removal is about 99%. The limitation associated with this technique is that it can't soften water with hardness higher than 1 mg/L as $CaCO_3$ hence water must be pretreated (Lenntech, 2012). Pretreatment has cost implications in regard to this method.

Electrocoagulation (EC) is electro based technology used to remove dissolved contaminants such as metal ions from water (Drouiche, 2007). Principally, electrocoagulation works by introducing electric current to the aqueous medium whereby contaminants are stabilized by chemical reactions that make metal less soluble and easily removed by filtration (AWWT, 2014). Since electrocoagulation is capable of removing water contaminants, therefore it can be used to remove hardness from water.

Studies have been conducted to establish the efficiency of EC in removing hardness. It was found that at optimum condition using iron-rod electrode, maximum hardness removal efficiency attained was 97.4% (Malakootian, *et al*., 2010). Similar results were reported by Malakootian and Yousefi (2009). They did an investigation on performance of electrocoagulation process using aluminium electrode in hardness removal where it was discovered that electrocoagulation process using aluminium electrode removes water hardness by 95.6%.

Capacitive Deionization (CDI) is recently capturing researchers' attention. The reason behind is low cost it bears in installation, operation and maintenance as compared to other desalination techniques (Seo, *et al*., 2010). The CDI is nothing but a technique for salt ions removal with the help of polarized carbon electrode of high surface area and low resistivity (Welgemoed and Schutte, 2005). In the process, cations and anions are electrosorbed on the electrode polarized by direct current and ions-free water is collected separately (Welgemoed and Schutte, 2005). The CDI has reported to be an alternative method to reverse osmosis (RO) as the latter being energy intensive technique (Zhou, *et al*. 2011; Seo, *et al*., 2010).

For the purpose of softening water, electrode used is crucial factor to put into consideration because of ions adsorption selectivity. For instance Gabelich *et al*., (2002) found that carbon aerogel electrodes preferentially remove monovalent ions than divalent ions. Since in most cases divalent ions are the main causative of water hardness (Meena *et al*, 2011), then carbon aerogel electrodes are not suitable for hardness removal. On the other hand, activated carbon electrode is reported to be suitable for hardness removal by CDI technology due to its preferential electroadsorption of divalent ions (Seo, *et al*., 2010).

Electro based techniques are reported to be time effective as require less time compared to conventional methods (Agostinho, *et al*., 2012). Furthermore, the process of softening is associated with acceleration of calcium carbonate precipitation there by reducing scale formation in the reactor (Agostinho, *et al*., 2012). However, energy consumption associated with electrolysis process increase running cost of these techniques (Frankel, 2011). The disposal of the precipitated scale and increased electrical resistance due to deposit at the cathode is another associated problem (Hasson, 2010). Applicability of electro-based techniques in softening hard water particularly in Tanzania is still restricted to the industrial level. The rationale for this remains to be high costs associated with installation and operation of the equipments (American Water Works Association, 2014).

Hardness Removal by Membrane Filtration Technology

Membrane filtration technology is another method of water treatment. Specifically, for hardness removal from water, nanofiltration membrane are mostly applicable (Dow Water & Process Solutions, 2013). Nanofiltration membrane is one of pressure driven membrane technologies effective in salt removal from water (Eikebrokk, *et al*., 2006). Hardness removal requires operating pressure and pore diameter of 10 – 20 bar and 0.5 –1 nm respectively (Eikebrokk, *et al*., 2006). Hardness removal efficiency by nanofiltration ranges from 50% to 97% depending on the membrane selected (Younos nd Tulou, 2005). For instance, UTC 20 membrane is capable of maximum of 70% removal while NF90-400 removes more than 97% hardness (Dow Water & Process Solutions, 2013).

Study conducted by Van der Bruggen and Vandecasteele (2003) found nanofiltration to be efficient in hardness removal regardless of number of parameters being removed simultaneous. According to them, with nanofiltration it is possible to remove hardness together with other parameters such as nitrates and pesticides without affecting hardness removal efficiency. This sounds to be of great value as more than one water problem is solved simultaneous. Izadpanah and Javidnia (2012) studied the ability of a nanofiltration membrane to remove hardness and ions from diluted sea water. The membrane type used was NE4040-90. They compared their results with reported results obtained from the use of other membrane types and concluded that nanofiltration can retain 95% of total hardness (Izadpanah and Javidnia, 2012).

Despite high efficiency of nanofiltration in hardness removal, drawbacks have also being reported. In order to achieve high efficiency, water need to be diluted to a certain conductivity and TDS (Izadpanah and Javidnia, 2012) which is not applicable for large scale water softening plant. Again, it has been reported that the efficiency is increased with the increase in operating pressure (Frankel, 2011). Increasing pressure has impact on energy consumption to generate more pressure. With the latter observation, nanofiltration technology to soften water is not free from high operation costs. However, it is a promising technique as it removes hardness by above 90%.

Tanzania lacks published information about the use of membrane based methods for hardness removal. So, it is not clear if these techniques are in use or not. But according to the high costs associated with the membrane technologies, it can be anticipated that the affordability of the techniques to Tanzania communities, which most of them are poor, is restricted. Lack of skilled personnel in that filed might also account for its restriction.

Hardness Removal by Adsorption

Adsorption is becoming a promising approach for water treatment (Saeed and Hamzah, 2013). The reasons for its acceptance include its simplicity of design (Gayatri and Ahmaruzzaman, 2010), consumption of locally available waste material, sludge production and chemical consumption free (Saeed and Hamzah, 2013). For the purpose of removing hardness ions from water, various adsorbent materials are being used. Most of the adsorbents seem to fit adsorption isothermal theories that explain the suitability of the adsorbent in softening hard water.

Adsorbent materials that have so far been tested in hardness removal include pumice stone (Sepehr, *et al*, 2013), *Moringa oleifera* seed (Muyibi and Evison, 1994), polyacrylic acid (Gilbert, 2010) and peanut hull (Idris, *et al*., 2012) among others. These natural materials are preferred because of their easy modification thereby increasing the efficiency.

Pumice Stone Adsorbent

Pumice stone is a volcanic rock formed by solidification of frothy lava when highly pressurized and super-heated rock is vigorously erupted from a volcano (Sepehr, *et al*, 2013). Study conducted by Sepehr, *et al*. (2013) found natural pumice stone removing about 80% Ca ions and 50% Mg ions. Furthermore, alkali modified pumice stone were found to remove 95% Ca ions and 78% Mg ions at optimum adsorption conditions. Based on the aforementioned results, it is clear that pumice stone is good in removing Ca ions than Mg from hard water. It suitability is because of the SiO_2 and Al_2O_3 it contains that provide great chance of ion adsorption (Samarghandi, *et al*., 2013)

***Moringa* Oleifera Adsorbent**

Moringa oleifera have been reported to be selective in a sense that Ca ions is more favored than Mg ions (Muyibi and Evison, 1994). The reason for that is likely to be smaller hydrated radius of Ca ions compared to that of Mg ions which leads to Ca ions to be adsorbed faster than Mg ions (Weber, 1972). Fahmi, *et al*., (2011) observed that hardness decreased with the increase of *Moringa oreifera* dose. In addition to that, it was reported that lower dose of *Moringa oleifera* (25-30 mg/L) is needed to remove hardness by less than 50%. The same study conducted by Fahmi *et al*., (2011) observed that hardness removal efficiency largely affected by water turbidity in a sense that the efficiency decrease with the increase of turbidity. Therefore, pre-treatment is required so as to achieve highest adsorption possible. However, *Moringa orifera* has the tendency of decomposing when exposed to water for some times and give odor smell. The smell is likely to again reduce the quality of treated water

Polyacyrilic Acid (PAA) Adsorbent

Another adsorbent material of interest is Polyacyrilic acid (PAA). The latter is used in disposable diapers and feminine hygiene products as they have a tendency of absorbing water (Gilbert, 2010). Saeed and Hamzah (2013) found PAA to be applicable in hardness removal. In their study, the influence of adsorption parameters on hardness removal was studied and the findings prove that the maximum adsorption capacity of polyacrylic acid is attained at the pH of 6.3. The adsorbent were found to remove Ca ions by about 95% and Mg ions by about 94%. This high adsorption capacity might be due to the fact that in a water solution at neutral pH, PAA is an anionic polymer i.e. many of the side chains of PAA will lose their protons and acquire a negative charge (Orwoll and Chong, 1999). It was also observed that the percentage of ions removal increase with an increase in adsorbent dose. This is due to the fact that additional adsorbents provide more binding sites for ion adsorption. PAA has the property of swelling when dissolved in water at neutral pH (Rodríguez and Katime, 2003). However, the effect of this property to hardness removal is not reported.

Peanut Hull Adsorbent

Peanut hull is carbonaceous, fibrous solid waste which encounters disposal problem (Idris, *et al*., 2012). Its bio-sorbent property is contributed by possession of insoluble organic compounds and poly functional groups such as NH_2, –COO-, –C=O, OH- and PO_4^2 (Ilyas, *et al*., 2013). The latter property makes peanut hull to be effective in removal of heavy metals (Ugwekar and Lakhawat, 2012) and dye bleaching (Hassanein, *et al*., 2011). Similar test was conducted by El-Sayed (2010) to remove water hardness ions. Results from this study shows that the maximum adsorption capacity was observed at pH 4.0 for the two metal ions and adsorption was increased with increasing adsorbent concentration and contact time. Additionally, both equilibrium adsorption isothermal models verified the suitability of the peanut hull. Langmuir equation showed that the maximum sorption capacities of metal ions onto peanut hull were 17.48 mg g-1 for Ca(II) and 16.36 mg g-1 for Mg(II) (El-Sayed, 2010).

Beside advantages offered by adsorption in water treatment, disadvantages have also being encountered. They include deterioration of adsorbent capacity as number of cycles increase (Dongre, 2013). Moreover, since high efficiency is attained at low pH (El-Sayed, 2010), pretreatment is inevitable and this imply extra operational costs.

Although most of adsorbent materials such as peanut hulls, pumice stones and *Moringa oleifera* are found in Tanzania, there is no published information to reveal the application of these potential adsorbents in hardness removal.

Hardness Removal Approaches in Tanzania

A conversation made with local people leaving in one of the villages in Kisarawe district reports the water hardness in ground water sources found in that village. The treatment is done at the sources and treated water is supplied to the villagers for domestic consumption. This information was confirmed by Daily news article (17th January, 2014) titled Kisarawe 104m/-water filtration launched. A project is funded by a Japanese company, Poly-Glu Social Business Limited. The actual hardness removal process undertaken is flocculation by which Poly-Glu is used to flocculate hardness ions. Thereafter, the filtration is done to provide water with reduced hardness (Mwakyusa, 2014). When asked about the quality of the treated water by aforementioned process, the villagers commented that the hardness is slightly reduced as hardness can still be felt during consumption of softened water. The conclusion that can be drawn here is that, flocculation is not efficient in softening hard water.

At the domestic level, hardness removal is done by boiling. Boiling is the conventional way of removing water hardness whereby the calcium carbonate are precipitated and filtered out (Sincero and Sincero, 2003). However, the efficiency of boiling to soften water is low. Its failure is due to the fact that boiling method can only remove temporary hardness (Spellman, 2000). If the water has permanent hardness, the problem will remain unsolved with the boiling technique.

Ideal Hardness Adsorbent or Remover

Good material for hardness removal can be characterized by various criteria. The main criteria include adsorption/desorption capacity, adsorption/desorption time, hardness removal efficiency, maximum adsorption pH and availability of such materials. Among the many discussed hardness remover, polyacrylic acid has been found to meet many of the criteria as it removes 95% hardness at almost neutral pH (6.3). That means, it requires no pre and post treatment. Once the water is treated, it is ready for consumption. Pumice stone is another promising hardness remover. Its ability to remove Calcium nd Magnesium ions by 95% and 78% respectively (Sepehr, *et al*, 2013), and being locally available in areas with volcanic mountains justify its usability in hardness removal. For that case, in areas like Arusha, Tanzania, where volcanic mountains are found (Leakey*, et al*., 1972) pumice stone is the best hardness remover of choice. Alternative material that shows great efficiency in hard water softening is activated carbon. Seo, *et al*. (2010) used activated carbon impregnated in the cloth electrode thus the activated carbon composite electrode were used in the CDI process to soften water. It was found that activated carbon has high adsorption/ desorption capacity and can achieve adsorption and desorption at short period of time (Seo, *et al*. 2010). With this insight, activated carbon has the potentials of being good material in softening hard water.

CONCLUSION AND FUTURE PERSPECTIVES

Essentiality of water for life demands us to pay attention not only to its availability but also its quality. As it has been pointed out earlier, water hardness is among the water quality hindrances. Techniques, namely ion exchange, electro-based techniques, membrane filtration and adsorption have been put in place to remove hardness from water. Not only that but also, various materials including zeolite, sulphonated waste plastics, pumice stones, peanut hull, activated carbon and PAA have been used in different settings to soften water. The reported capability of these methods and materials have been discussed in this paper.

High capability of activated carbon as reported in previous sections in this paper motivated us to carry out some preliminary experiments with activated carbon derived from agric wastes. Agro-waste materials, viz. coconut and cashewnut shells have been chosen to make activated carbon. Coconut shell activated carbon (CSAC) used was commercial, bought from KWHB Company. For cashewnut shell, activation process started by carbonization of materials which was achieved by heating the materials in 400^{o}C furnace temperature under limited supply of oxygen for 1 hour. The resultant charcoal was soaked in 2M KOH overnight. The KOH saved as activating agent to introduce some functional groups and increase pores depth as previously reported. The charcoal was then washed, dried and grinded to get granular activated carbon made from cashewnut shells. Produced cashewnut shell activated carbon (CNSAC) together with commercial CSAC were used to soften synthetic hard water. It was revealed that, CSAC and CNSAC performed well in hardness removal.

Figures 1 and 2 show the trend of hardness removal efficiency of CSAC and CNSAC respectively at different adsorbent doses.

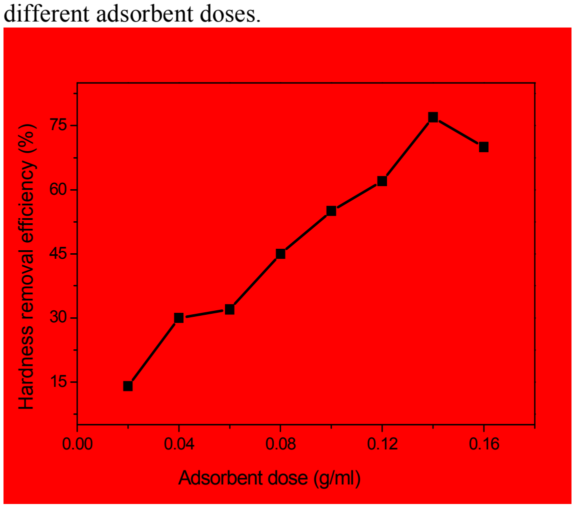

Fig. 1. Hardness removal efficiency as the function of adsorbent dose (CSAC). Temperature=30^{o}C, pH=8, adsorption time=7 hours, shaking speed=100 rpm

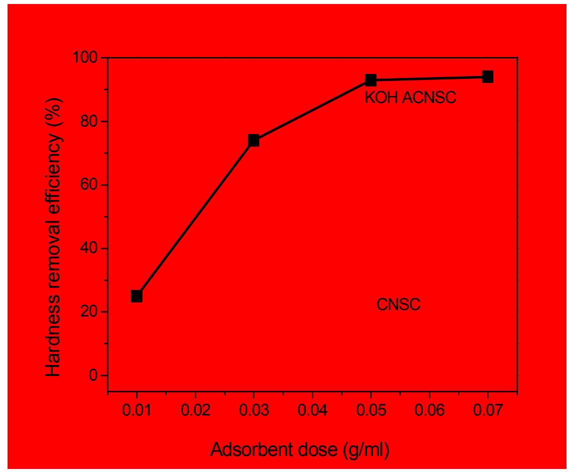

Fig. 2. Hardness removal efficiency as the function of adsorbent dose (CNSAC and non-activated cashewnut shell charcoal). Temperature=60^{o}C, pH=8, adsorption time=6 hours, shaking speed=150 rpm

From the graphs (figure 1 and 2), it is evidenced that as the adsorbent dose increases, efficiency also increases until the maximum adsorbent dose. Increase in hardness removal with an increase of adsorbent dose is due to the greater availability of exchangeable sites at higher concentration of adsorbent (Chakramarty and Srma, 2012). After maximum adsorbent dose, hardness removal efficiency trend start to descend as shown in the graphs. This suggests that, at maximum adsorbent dose maximum possible adsorption is attained and thereafter, there is no significant adsorption.

KOH Treated cashewnut shell activated carbon shows better removal efficiency than untreated one. The reason could be that KOH used to treat cashewnut shell charcoal increases the depth of the micropore hence increase surface area (Viswanathan, *et al*., 2009). Furthermore, KOH introduce functional group such as -OK which is important for adsorption (Viswanathan, *et al*., 2009). The rationale for untreated cashewnut shell activated carbon to remove hardness, though at a lower percentage, is possession of multiple bonds in the alphatic part and hydroxyl as well as carboxyl group on the aromatic party of its structure (de Sousa Riosa and Mazzettob, 2009).

CSAC and CNSAC tested to be efficient in removing hardness. Therefore, from these preliminary results, much details on the applicability of the materials and their activations are currently underway by the authors to shade more light on the potentials for water softening further research need to be done to investigate the performance of CSAC and CNSAC in softening water so as to improve the water access and supply to meet the millennium development goals. Such efforts are geared to establish optimum conditions such as adsorption/desorption time and capacity, adsorption pH and maximum possible efficiency they can attain.

Despite interesting efficiency displayed by adsorption technique using CSAC and CNSAC in water softening, there are some limitations encountered. They include uncertainty in sorption/desorption characteristic of the adsorbents, adsorbents regeneration requires a steam or vacuum source which is expensive in application, spent adsorbents raises the disposal problem and adsorbents tend to release solid particles which lead to increased total dissolved salts (TDS) in the treated water. For CNSAC, filtration takes long time, thereby negatively affecting analysis time which is required to be done immediately after batch experiment.

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