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Alum Treated Grey Water for Toilet Flushing, Mopping and Laundry Work

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Abstract

The paper presents the study carried out in a peri urban settlement of Nairobi Kenya and involved treatment of raw grey water generated from bathroom, kitchen and laundry for flushing toilet and laundry work. The study utilized both chemical and physical treatment. The chemical treatment involved alum addition in the raw grey water and pH adjustment using bicarbonate salts. The physical treatment involved filtration using Quartz sand and filtration of pH adjusted treated grey water using filter paper. The major ions studied were ions which could interfere with lathering of soaps or could cause stains on clothes and toilet fixtures or could be potentially health hazardous. These ions were Fe, Mn, Ca, Mg, Pb and Hg. The levels of these ions in raw grey water and in treated grey water were determined using atomic absorption spectroscopy. The results for the levels of these ions before treatment were compared to the set standards for potable water by Kenya Bureau of Standards [1]. The levels of these ions in the treated grey water after adjusting the pH were found to be within the Maximum Contaminant Limits (MCL) set by KEBS [1]. Thus the overall treatment of the raw grey water produced water of good quality which complied with the set standards for potable water by KEBS [1]. The results of this treatment could contribute immensely in the fulfillment of the millennium development goals.

Keywords: Chemical treatment; Physical treatment; Grey water re-use; Quality; Sand filtration; pH adjustment

Introduction

Water scarcity has become a global problem especially in the cities of developing countries. The escalating living costs of the cities have resulted in the development of peri urban settlements which are over populated. As a result of the high population density, existing infrastructures and other basic utilities such as centralized drainage system cannot remotely keep up the pace with the rapid growing population [2]. Githurai, peri urban settlement of Nairobi city is not an exception; it is densely populated, 26,357 people per square kilometer and associated with unsafe disposal of huge volumes of grey water. The estimated population and number of household per 2 square kilometer are 51,610 people and 17,966 respectively [2].

Due to its high population density, the amount of grey water generated per day is equally high. The centralized drainage system cannot sustain huge volumes of grey water generated per day. Therefore this has resulted to an increase in the surface run off of grey water posing healthy risk.

As a result of the high population density acute fresh water shortages are experienced. This demand has prompted the search for other new water sources. These sources include boreholes drilling and rainwater harvesting. However borehole drilling is very expensive for most residents of peri urban settlement. Rainwater on the other hand is seasonal and rainfall patterns have changed. Furthermore there is limited space left for storing huge capacities of water which can sustain the existing high population for many months. Therefore most sustainable approach for reducing the demand for fresh water is to treat wastewater and reuse it as an alternative source [3]. Grey water refers to the wastewater generated from washing utensils, from bathing and from doing laundry [4]. High volumes of grey water generated as a result of high population density can substantially reduce fresh water demands if treated and reused in toilet flushing and laundry work. This will equally reduces the surface ponds of grey water which possess as healthy hazardous. Due to inherently variable sources of this grey water, they contain different ions contaminants at different levels .Laundry and bathroom grey water may contain dye, body oil, soap and detergents constituents. The dye contaminants could be removed from grey water using low cost adsorbents [5]. At different levels of these ion contaminants they negatively impact on cleaning processes. For example Fe above 0.3ppm and Mn above 0.5ppm cause stain on clothes and porcelain toilet fixtures [6]. Whereas Ca and Mg above 120ppm in the water is considered to be hard water and adversely interferes with lathering of soaps [7].Above 0.01ppm of Pb in the water it is considered toxic [8], whereas Hg above 0.001ppm in the water can seriously cause nervous disorder [9] therefore a robust treatment system involving physical and chemical treatment is applied which ensures the water meets the required standards for flushing toilets and for laundry use [10].

Various waste water treatment processes are suggested in the literature but most have not been tested or implemented. Those which have been implemented involved filtration and disinfection [11]. Most treatment units reported in the literature (and advertised commercially) are based on physical processes, while the more current ones incooperates biological treatment as well [12]. Some of the biological treatment involves the use of biosand/ media filter which comprises of bacteria which purifies the water aerobically [13]. Also green algae spirogyra species could be used as biological treatment to check down the levels of lead to the recommended levels [14]. This paper reports a study carried out in a peri urban settlement of Nairobi

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Kenya and involved treatment of raw grey water generated from bathroom, kitchen and laundry.

Materials and Method

Sampling and sample treatment

The grey water samples were collected from Githurai, a peri urban settlement in Nairobi. The collection of grey water samples in quadruples from different sections of the household. The selection and collection was done at different hours and intervals. This was from kitchen, bathroom, laundry and tap. The bottles were labeled B, L, K, T and M respectively for bathroom, laundry, kitchen, tap and matrix of kitchen, laundry and bathroom grey water. The pH of all the samples were measured at the point of collection then the sampling bottles sealed tightly, prior to sample collection, 1 litre sampling bottles were soaked in warm water with detergent and caustic soda for few hours then scrubbed with scotch brush then soaked in acid and rinsed severally with distilled water before drying them overnight. A total of 300 samples were collected systematically for a period of five months, 60 samples per month. Only 280 samples were analyzed, 20 samples got spoilt. All the samples of grey water were sieved to remove solid particles which could interfere with subsequent analysis. Sieving was done using filter paper number 541 fixed on the glass funnel.

Alum treatment

An 800 ml beaker was filled up to 600ml with grey water and 20 grams of granular alum added then stirred to dissolve. Subsequently 5ml of 14M aqueous ammonia was added to provide hydroxide ions concentration needed to form aluminium hydroxide

Filtration of alum treated water

Filtration of alum treated water was done through a glass column of internal diameter 5.4 cm and height of 66 cm filled with medium sized quartz sand and a cotton wool plunged at the bottom to enhance sieving. To avoid segregation of the particle, compaction was done using a flat rubber ended rod and the sand packed to a height of 46 cm. The filtrate was collected and analyzed for metal ions.

Analysis for the metal ions

The raw and treated grey water was first digested using concentrated nitric acid. Metal ions in raw and alum treated grey water were then analyzed using Atomic Absorption Spectroscopy (Varian Spectra AA10, Australia).

Adjustment of the pH of the filtrate

The pH of the filtrate from the sand packed column were subjected to pH between 6.5 and 8.5 using bicarbonate salts, filtered using filter paper number 542. The filtrate was analyzed for levels of metal ion.

Results and Discussion

Metal ions in untreated grey water

The results of the analysis of the metal ions in untreated grey water is presented in Table 1. Due to many samples from different categories of untreated grey water with different levels of metal ion contaminants, mean levels of each ion contaminant from each category was determined. The mean levels for the same ion contaminant in different category were compared statistically using Analysis of Variances (ANOVA). This comparison helped in the determination of fundamental differences in the mean levels of metal ion contaminants through significant tests. The mean levels of metal ion contaminants bearing the same superscript were found to have no significant difference. The ones bearing different superscript had significant difference in the mean levels of metal ion contaminants. These are as discussed below.

From table 1, there is no significant difference in the levels of Fe ions in tap water and bathroom raw grey water. The level of Fe ion in tap water is below the (Maximum Contaminant Limit) MCL set by [1] however the level in the bathroom is above the MLC of 0.300mg/l set by KEBS [1]. This level in the bathroom can cause stains on clothes and toilet fixtures if used for cleaning and flushing without treatment. There is no significant difference in the levels of Fe in laundry and matrix grey water though all being above the MCL prescribed by KEBS [1] for the levels of Fe in potable water. There is a significant difference in the levels of Fe in kitchen grey water with the rest of the category and the levels in kitchen is above the MCL set by KEBS [1]. As observed in the table 1 all the categories of raw grey water contains levels of Fe above the MCL. Treatment is therefore necessary before used in flushing toilets and washing clothes. The high level could cause reddish to brown stains on clothes and toilet fixtures if the water is used without treatment. This is in agreement with findings of O'Connor [6].

There is no significant difference in the levels of Mn ion in raw bathroom grey water and tap water. There is also no significant difference in the levels of Mn in kitchen and matrix raw grey water but there is significant difference in laundry and all the other categories of raw grey water.

The mean levels for Mn ion in bathroom, kitchen and matrix were relatively low with values of 0.021±0.003 mg/l, 0.307±0.061 mg/l and 0.225±0.028 mg/l respectively. At this level there is no threat of stains on clothes and toilet fixtures associated with Mn ion. The prescribed MCL by KEBS [1] for Mn is 0.5000 ppm. However the mean levels were relatively high in laundry raw grey water with a value of 0.483±0.112 mg/l. This high level could cause black to brown stains on clothes and toilet fixtures if the water is used without treatment. This is in agreement with O'Connor [6].

For Pb, there is no significant difference in the levels in tap water, laundry grey water and matrix raw grey water. However there is significant difference in the levels of Pb in bathroom raw grey water and kitchen raw grey water. The level of Pb ions in bathroom, laundry, kitchen and matrix raw grey water was above 0.01 mg/l which is the MCL recommended for the levels of Pb ion in potable water by KEBS [1]. The values were 0.028±0.003 mg/l, 0.029±0.007mg/l, 0.018±0.005 mg/l and 0.024±0.006 mg/l in bathroom, laundry, kitchen and matrix raw grey water respectively. The high level could have originated from the plumbing systems which are alloys of Pb and Fe as observed in tap water which has a value of 0.014±0.006 mg/l while the rest originated from domestic washing. This is in agreement with the findings of Gulson et al. [15]. This level requires treatment before use.

There is also no significant difference in the levels of Mg ion in tap water and other categories of raw grey. From table 1 the levels of Mg ions in grey water ranged from 4.840±0.599 mg/l in laundry water to 5.740±0.690 mg/l in kitchen water whereas tap water had 4.431±0.505 mg/l.

The levels of Mg ions in all the categories of raw grey water were below 100 mg/l which is the MCL prescribed by KEBS [1] for potable water. The levels for Mg ion in the raw bathroom, laundry, kitchen and matrix raw grey water were 5.364±0.542 mg/l, 4.840±0.599 mg/l, 5.740±0.690 mg/l and 4.956±0.138 mg/l respectively. At these levels of Mg ions, the water is considered to be very soft in accordance to

EPA [7]. This cannot significantly interfere with lathering; however, treatment is necessary to reduce the levels of other ions that are above the set MCL.

For Ca ions, there is no significant difference in the levels in tap water, bathroom and matrix raw grey water. There is also no significant difference in the levels of Ca in laundry and kitchen raw grey water. However there is significant difference in the levels of Ca ions in tap water, bathroom, matrix and the other two categories of raw grey water.

The levels of Ca ions in tap water were relatively low with a mean value of 150.193±13.390 mg/l. At this level, it is considered moderately soft according to EPA [7]. The other categories of raw grey water contained high levels of Ca ion above the recommended MCL of 150 mg/l set by KEBS [1]. At the level it can adversely interfere with lathering of soaps which is in agreement with the findings of EPA [7] hence requires treatment for laundry purposes.

Also determined was Hg and there was no significant difference in the levels in tap water and all the categories of raw grey water.

The levels of Hg ions in tap water and kitchen grey water was within the prescribed MCL by KEBS [1] for potable water which is 0.001 mg/l, both having a mean value of 0.001±0.001 mg/l. However the mean levels of Hg in bathroom, laundry and matrix raw grey water were relatively above the recommended levels by KEBS [1] for potable water, with values of 0.006±0.001 mg/l, 0.005±0.001 mg/l and 0.003±0.001 mg/l respectively. At these levels treatment is necessary to lower Hg ions to the recommended levels otherwise it can cause serious nervous poisoning in case it gets in the body, this is in agreement with Counter et al. [9].

Metal ions in treated grey water

The results of the analysis of the metal ions in treated grey water is presented in Table 2. From table 2, the p-values statistically represents significant limits, whereas if the p-value is less than 0.05 implies there is significant difference in the levels being compared, if greater than 0.05 there is no significant difference in the levels under comparison.

From table 2, it is observed that the levels of Fe ions after pH adjustment of the filtrate obtained from sand filtration were all below 0.3 mg/l which is the MCL prescribed by KEBS [1] except for the levels of Fe in kitchen grey water. The level of Fe ions in kitchen was 1.315±0.156 mg/l which is above the MCL set by KEBS [1] and can cause severe stains on clothes and toilet fixtures if the water is used for laundry and toilet mopping. Therefore, kitchen category of grey water requires multistage treatment [16]. There was no significant difference in the levels of Fe ions in all categories of water except for the kitchen grey water.

It is observed from table 2 that the levels of Mn ions after pH adjustment of the filtrate were all below 0.5 mg/l which is the MCL by KEBS [1]. The values ranged from 0.001±0.001 mg/l in laundry to 0.004±0.001 mg/l in kitchen. At these levels of Mn ions in water no stains can occur when the water is used in toilet mopping and laundry. There was no significant difference in the levels of Mn ions in all the categories of water after the pH adjustment.

The levels of Pb ion also after pH adjustment of the filtrate were all below the Limits of Detection (LOD). This is agreement with work of Gulson et al. [15].

The levels of Mg in all categories of grey water after pH adjusted were below 100 mg/l which is the MCL recommended by KEBS [1] and considered to be very soft in accordance to EPA [7]. The values ranged from 2.485±0.758 mg/l in matrix to 7.631±0.599 mg/l in bathroom. There was no significant difference in the level of Mg ion in tap water, laundry and matrix grey water. There was also no significant difference in the levels of Mg ions in bathroom and kitchen grey water.

The levels of Ca ions were all below 150 mg/l which is the recommended MCL KEBS [1] for the levels of Ca ions in potable water. The levels of Ca ions in bathroom, laundry, kitchen and matrix grey water with values of 95.078±4.022 mg/l 106.977±5.991 mg/l 108.516±6.931 mg/l and 90.406±4.382 mg/l respectively are considered to be moderately soft. There was no significant difference in the levels of Ca ions in all the categories of pH adjusted water.

The levels of Hg ions were all 0.001±0.001 mg/l which is also the MCL prescribed by KEBS [1] for the levels of Hg in potable water. Therefore the pH adjusted water is considered to be very safe for laundry use and toilet mopping. At these low levels no nervous disorder can be associated with Hg ions in case of ingestion or penetration of Hg into the body through an open skin. This is in agreement with the work of Counter et al. [9].

Water Category	Fe (p=0.000) Mean±SE	Mn (p=0.000) Mean±SE	Pb(p=0.000) Mean±SE	Mg(p=0.051) Mean±SE	Ca (p=0.005) Mean±SE	Hg(p= 0.050) Mean±SE
Tap water	0.006±0.005[a]	0.018±0.009[a]	0.014±0.006[c]	4.431±0.505[a]	150.193±13.390[a]	0.001±0.001[a]
Bathroom	0.626±0.253[a]	0.021±0.003[a]	0.028±0.003[a]	5.364±0.542[a]	165.625±15.731[a]	0.006±0.001[a]
Laundry	3.813±0.144[b]	0.164±0.016[c]	0.029±0.007[c]	4.840±0.599[a]	190.049±20.833[b]	0.005±0.064[a]
Kitchen	16.522±2.524[c]	0.307±0.061[b]	0.018±0.005[b]	5.740±0.690[a]	200.938±23.749[b]	0.001±0.001[a]
Matrix	2.661±0.321[b]	0.225±0.028[b]	0.024±0.006[c]	4.956±0.138[a]	171.159±9.670[a]	0.003±0.002[a]

The same superscript indicates no significant difference.

Table 1: The levels of metal ions in (mg/l) in untreated grey water.

Water category	Fe (p=0.000) Mean±SE	Mn p=0.050) Mean±SE	Pb (p=0.050) Mean±SE	Mg (p=0.001) Mean±SE	Ca (p=0.576) Mean±SE	Hg (p=0.239) Mean±SE
Tapwater	0.000±0.000[a]	0.000±0.000	0.000±0.000	3.861±3.767[a]	128.846±8.640[a]	0.001±0.000
Bathroom	0.001±0.001[a]	0.003±0.000	0.000±0.000	7.631±0.599[b]	95.078±4.022[a]	0.001±0.000
Laundry	0.004±0.000[a]	0.001±0.001	0.000±0.000	3.577±0.920[a]	106.977±5.991[a]	0.001±0.000
Kitchen	1.315±0.156[b]	0.004±0.000	0.000±0.000	5.419±0.657[b]	108.516±6.931[a]	0.001±0.000
Matrix	0.003±0.222[a]	0.002±0.001	0.000±0.000	2.485±0.758[a]	90.406±4.382[a]	0.001±0.000

NB: Same superscripts mean no significant difference and different superscripts indicate significant difference

Table 2: Levels of metal ions (mg/l) in pH adjusted tap water and treated grey water.

Conclusion

The overall treatment of raw grey water using quartz sand filtration of alum treated grey water and pH adjustment for the purposes of toilet flushing, mopping and laundry work produced excellent results. The untreated grey water had high levels of metal ion contaminants and upon alum dosing the pH changed significantly to acidic. Upon quartz sand filtration of alum treated grey water the levels of some ion contaminants increased. This could be attributed to the change in the pH on alum dosing which dissolved some contaminants on quartz sand during filtration thus shooting high the levels of ion contaminants in the filtrate. However, upon adjustment of the pH of the filtrate between 6.5 to 8.5 huge amounts of precipitate were obtained and upon determination of these ion contaminants the levels had gone below the Maximum Contaminant Limits. This implied treated water met the qualities for potable water set by Kenya Bureau of Standards [1]. The levels of metal ion contaminants were all below the prescribed Maximum Contaminant Limits (MCL) set by KEBS [1] for potable water after the final pH adjustment of the filtrate except for levels of Fe ions in the kitchen grey water.

Considering the contribution by volume of all the categories of grey water from bathroom, laundry and kitchen, kitchen section contributes the least by percentage volume. Therefore it can be eliminated from the treatment as a way of cost cutting measure for it is heavily polluted, labour intensive and increases the cost of recycling. Therefore treated grey water can be an alternative source of water for flushing toilets, mopping and laundry work.

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