Efficiency of Pumice-Sand Granular Filter in Removing Effluent Wastes in Shirere Wastewater Treatment Plant in Kakamega County, Kenya

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Abstract

Release of effluent directly from Aerobic maturation ponds into natural water bodies without more filtration has presented to be un optimal. Consequently, people down streams are exposed to greater risk of contracting waterborne diseases such as cholera, dysentery and typhoid. Skin problems, eye infections, and diarrhoea have all been linked to a lack of clean water and sanitation among community members. Introduction of filtering technologies such as sand, biochar, coconuts, pumice and crushed stone aggregates have been inadequate to treat the municipal waste water quality. Even then, no effort has been made to apply such technologies in the removal of wastes discharged into River isiukhu from Shirere waste water oxidation ponds. As consequence, its waters have been shown to be increasingly getting covered by algae which indicate the presence of cyno-bacteria that is very toxic to human and animal health. Thus, the objective of this study was to determine the efficiency of the pumice-sand granular filter in removing wastes in Shirere wastewater treatment plant in Kakamega. The wastes were Nitrates, Phosphates, BOD, COD and TSS. This objective was assessed under varying filter depths, effluent flow rate into the filter and seasons. Effluent, drinking water from protected springs along river Isiukhu, were collected using pre sterilized water sampling containers for microbial quality analysis at MMUST and KACWASCO laboratories. Sampling strategy was purposeful while sample size was 8 for water, 28 for waste water. Research design was experimental and data analysis used, regression and correlation methods. The average reduction of COD in the mid-season of June to August was 42.2 ±4.6%, being the highest.

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Concomitantly, BOD removal by the filter in the season of June to August was19.6±7% and 15.6 ±3.5% for September to November. The average rate of TSS removal in June to August was 19.3±4.5% followed by 16.6±3.8% of September to November and 18,0±7% of March to May. The average rate of Nitrate removal in June to August was 41.8±7.6% followed by 30.0±2% for March to May and 25.0±3.6% for September to November. Phosphates had an average rate of removal in June to August as 31.9±6.7% followed by 20.6±4.8% for September to November and 20.0 ±3% for March to May. This shows a trend of high efficiency in dry season of June to august and march to May followed by September to November. Conclusively, the use of composite filters in wastewater treatment reduced the organic matter intake, resulting in oxygen levels that were within natural values. Similarly, noted was good removal of COD a factor that led to levels that are within the NEMA standards. Findings of this study will influence waste water management policies and improve new technologies in waste water treatment for sustainable development. From the results, its therefore recommended that the composite filter technology should be applied to non-compliant sewerage treatment plants to boost the effeciency.

Keywords: Composite granular filter; filter depth; Hydraulic retention; Retention time; wastewater treatment.

1.0 Introduction

Water quality is essential for social economic development, environmental sustainability and human health. Nevertheless, as the globe's number of people grows, adequate and clean water sources for all become increasingly scarce. Release of effluent directly from Aerobic maturation ponds into natural water bodies has presented to be un optimal. Consequently, people downstream are exposed to greater risk of contracting waterborne diseases such as cholera, dysentery and typhoid. Skin problems, eye infections, and diarrhoea have all been linked to a lack of clean water and sanitation among community members. Effective wastewater treatment would aid in the protection of ecosystems while providing fertilizers and other recyclable resources [1,2,3].

Globally, around 1.8 billion people consume contaminated water, placing them at risk of waterborne diseases, [4]. Most cities lack the infrastructure and resources needed to address waste water management in an efficient and long-term manner, [5]. The removal of red dye by zinc peroxide could be useful for the industries involved in water purification, [6]. However, application of this method has some limitations such as use at fixed temperature, ultra-violet (UV) light and the need for sophisticated experimental set up. This tends to increase when there is poor handling and control of human waste. This problem is very much spread in urban areas where the population are high due poor urban planning and increased population making waste disposal a challenge.

Water contamination has increased in almost all watersheds in Africa, Asia, and South America during the 1990s, [7]. The highest increases in pollution exposure are projected in low- and middle-income nations, owing to high population density, particularly in Africa, [8]. Most urban areas in Kenya have a big challenge in both waste water and solid waste disposal. Nairobi County is mostly drained towards the Indian Ocean by Nairobi River which is a tributary of Athi river which supports millions of people along its 390 km channel. It is

polluted by high levels of cyanobacterial, [9]. During the rainy season the water normally turns red in colour, due to surface run off. During the dry season, the water turns totally green because of algae which results when high level of cyanobacteria grows in short period of time.

According to, [10], some cyanobacteria species produce toxins that harm both animals and humans. During the dry season along the Athi River, sludge hides in river beds beneath the white sand and is later washed down stream during rainy season. Athi River today is a green layer due to pollution. During heavy downpour the water transports most of the solid waste on surface runoff to sewerage manholes and eventually they end into the Shirere Waste Water Treatment Plant. According to [10], 93 percent of main residential estates in Shirere, including Amalemba, Town Scheme, Town Centre, Mudiri, Otiende, and Milimani, are supplied by a water-borne sewerage system. However, septic tanks are used in some regions, such as: Milimani, Kefinco, Lurambi, Sichirai, and Lutonyi. Pit latrines are used in other regions, mostly in low-income or informal communities, such as Karimu Estates, Masingo, Makaburini, Marram, Majengo, and Kakamega rural areas. These shanty areas collect water from unguarded springs polluted by pit latrines, such as the Masingo Spring, which is only 5 meters upstream from a pit latrine.

Kakamega Towns's water treatment system was built in two stages: phase one in the early 1970s to serve primarily the town area, and phase two to serve Amalemba Estate as well as Kakamega Boys High School. Three Treatment Works in Kakamega town area are; Shirere Waste Water Treatment Plant, Kambi Somali Treatment Works and MMUST Treatment Works. The research study site was Shirere Wastewater Treatment Plant (WWTP) which was identified with poor removal of wastes from effluent discharged into river Isiukhu. According [10], the river Isiukhu, a tributary of the Nzoia River, drains the Kakamega area into Lake Victoria.

According to research by, [10], cluster two which includes Kakamega, Busia and Nambale towns; skin disorders, eye infections, and intestinal diseases are all linked to a lack of clean water and sanitation among community members. In the same research, there is a lack of effluent quality monitoring procedures at wastewater treatment in Shirere Plant, causing environmental and health risks. The disposal of sludge along the site's embankment is not only unfriendly to environment but also big health risk. Increased green colour as a result of algae, scum into the effluent which indicates presence of cyanobacteria that produce toxins which affect humans and animals when exposed to by drinking or bathing.

Pollutants from poorly treated effluents discharged into Kenyan rivers are on the rise in an alarming rate as evidenced from rivers surrounding major towns and cities, e.g, Rivers in Nairobi city, Kisumu city and Kakamega town hence pose a great risk to health of the individuals that depend on the waters of these rivers for their daily use and survival [11,12]. Residents in Kakamega town are at a risk of contracting diseases due to lack of well-established sewerage system, [13]. According to data from affected areas' health centres, the majority of patients are being treated for Amoeba infections, bilharzia, typhoid, malaria, dysentery and cholera. Recently, three people died of cholera after drinking water at Masingo and more than one hundred hospitalized. Kenya Water and Sanitation Civil Societies Network (KEWSNET) on water and sanitation investigated pollution in major towns, Kakamega included and found out that its due to dysfunctional waste water treatment plants operated by licensed water services providers, [14].
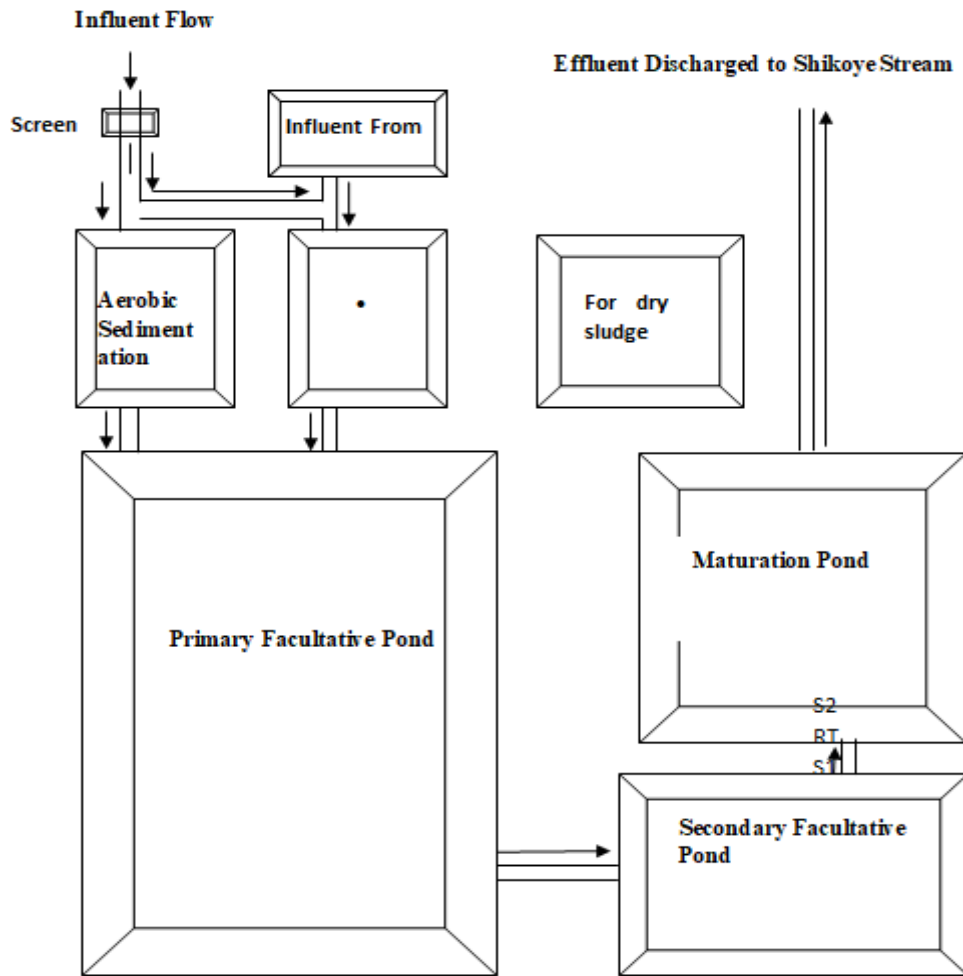
In this study, the researcher sought to incorporate a granular composite filter at maturation pond to address the wastewater quality problem at Shirere Waste Water Treatment Plant before being discharged into River Isiukhu. River Isiukhu is a major source of water distribution for both domestic and irrigation and serves two major towns, that is Kakamega and mumias towns in Kakamega county. Introduction of filtering technologies such as sand, biochar, coconuts husks, pumice and crushed stone aggregates have been inadequate to treat the municipal waste water. Similarly, no effort has been made to apply such technologies in the removal of wastes discharged into River isiukhu from Shirere waste water treatment plant.

The objective of the study was to determine the efficiency of the incorporated pumice-sand granular filter at the maturation pond in removing wastes in effluent from Shirere wastewater treatment plant. The importance of this study is hinged on its findings that will guide on enhancements of effluent treatment before discharge in water bodies. The results will benefit the surrounding community members at Shirere WWTP, KACUWASCO, WARMA and other stake holders. The results can be used for comparisons to management of other Waste Water Treatment Plant. The gaps in knowledge that the study will address will be on the filter depth and grain size ratio against quality of effluent expected as per the standards. The study will contribute to proper decision making on how to improve effluent filtration and minimize the risk involved. This will be achieved by continuous utilization of new technology and also enforcement of standards.
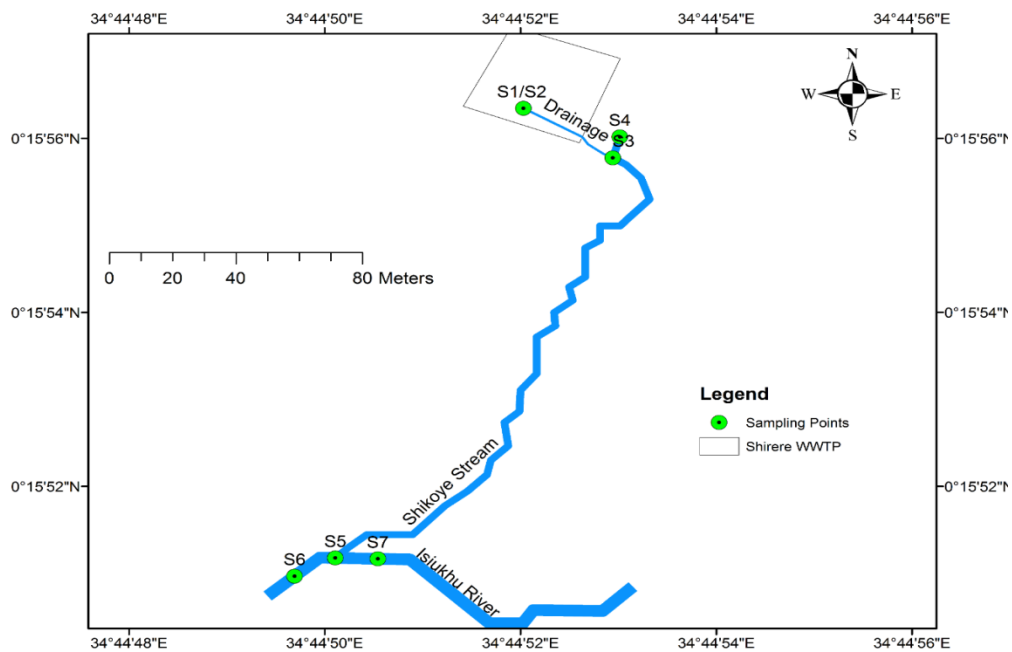
2.0 Materials and Methods

2.1 Study Area

This study was conducted in the Kakamega Municipality which comprises Mahiakalo, Sichirayi, Kakamega Township, and Shirere locations. According to [15], Kakamega town has a population of 120,000 people whose local inhabitants are mostly Luhya whose economic activity is farming and fishing. Sampling was done at Shirere WWTP, Shikoye stream and river Isiukhu as shown Figures 1 and 2. Shikoye stream receives wastewater discharged from Shirere WWTP. The catchment area for Shirere WWTP, Shikoye stream and river Isiukhu is defined by longitude $34^045^{'}36.40^{''}E$, $34^045^{'}8.65^{''}$ E and latitude $0^016^{'}4.61^{''}$ N, $0^015^{'}11.01^{''}$ N. The location of the treatment plant is longitude $34^044^{'}55.85^{'}E$, $34^044^{'}53.93E$ and latitudes $0^015^{'}58.76^{''}$ N, $0^015^{'}55.79^{''}$ N as shown in figure 2 and schematic diagram in figure 1. The stream joins river Isiukhu at river Isiukhu at $0^015^{'}19.74^{''}N, 34^044^{'}43.27^{''}E$. River Isiukhu is a major tributary of River Nzoia. Its waters are used by the community for domestic use, agricultural irrigation and abstraction by water companies and institutions. The wastewater from the plant is discharged into River Isiukhu via Shikoye stream.

Influent Flow

Effluent Discharged to Shikoye Stream

Screen

Influent From

Aerobic Sediment ation

.

For dry sludge

Maturation Pond

S2

RT.

S.

Primary Facultative Pond

Secondary Facultative Pond

Figure 1: Schematic Diagram of Shirere Wastewater Treatment Plant.

Figure 2: Sampling sites.

- SWWTP – Shirere Waste Water Treatment Project
- Municipality – Kakamega Municipality

Figure 2: Sampling locations: *S*1-Maturation Pond outlet prior to filter installation; *S*2-Maturation Pond outlet after filter installation. S3 - effluent confluence with Shikoye stream effluent, S4 - Shikoye water spring drinking water point, S5 - confluence of Shikoye stream and Isiukhu river, S6 - Lower Isiukhu river point after confluence, S7 - higher Isiukhu river point after confluence.

2.2 Study population

The points for analysis used in this study was wastewater S1and S2.

2.3 Research design

The research design used was experimental and scientific analysis involved sample collection, preparation and laboratory analysis to determine among others concentration of COD, BOD, phosphates, total suspended solids (TSS) and nitrates. Data was collected using purposeful sampling techniques.

Table 1: Research design for the study.

Specific objectives	Approach	Measurable Indicator	Research Design	Results
To determine the efficiency of Pumice-Sand Granular Filter in Removing Effluent Wastes in Shirere Wastewater Treatment Plant.	Measure, Filter, depth and effluent flow rate.	Effluent flowrate and Depth.	Experimental	Tables and Graphs

2.4 Sampling Strategy

Effluent discharge rate was measured before filtration by Arcostic Dopler Velocitmeter (ADV) method. The sampling strategy for the efficiency determination is shown in Table 2.

Table 2: Sampling strategies for the filter efficiency determination.

Study unit	Sampling methods	Sample size
Wastewater	purposeful	8, 4 from each point of 2 sampling sites

2.5 Data collection

Control sample conditions included triplicates collected at sites S1-S2 using labelled 500-mL sampling bottles and kept in ice boxes. Briefly, samples were collected at the outlet of the maturation pond before filtration (S1). The above was repeated with experimental sample conditions collected after the introduction of sand-pumice

composite filter within outlet manhole of the maturation pond, that created a three section of S1, reactor and S2. New Samples were therefore collected at S1 and S2. All samples were transported to MMUST laboratory for further analysis. This was done during the dry season, wet season and short rain season.

Particle Size Determination

To obtain optimal particles sizes for filter material, laboratory experiments involving determination of maximum wavelength (Lambda mark), and development of standard calibration curve were carried out. The optimum absorption wavelength Lambda mark for phosphate ions was determined in the range between 500nm to 950nm, [16].

2.2.1.2 Standard Calibration curve

Obtained Lambda wavelength was fixed on UV-VIS spectrophotometer for measurements of absorbance of stock solution having concentrations of $5ppM, 10ppM, 15ppM, 20ppM, 25ppM,$ and $30ppM$ and recorded. The absorbance was measured using a common calibration curve. Absorbance was determined before and after filtering the stock solution through three cylinders with composite materials, each with a 50% mixture of 1.18 mm pumice and 1.18 mm sand, 1.18 mm sand and 0.9 mm pumice, and 1.18 mm sand and 0.6 mm pumice filtering material. The ideal composite filter was chosen using absorbance variation. The combination of 50% sand (1.18 mm) and 50% pumice (0.6 mm) at 0.248 absorbance variance was determined to have the best absorbance variance.

2.5.6 Adsorption time determination for the composite filter

Using the optimal developed filter, batch experiments were carried using samples collected at S1. These were incubated between a period of 0.5, 1.0, 2, 4, 8, 16 and 64 hours at room temperature in the laboratory. Variation of absorbance with time was measured at Lambda mark wavelength.

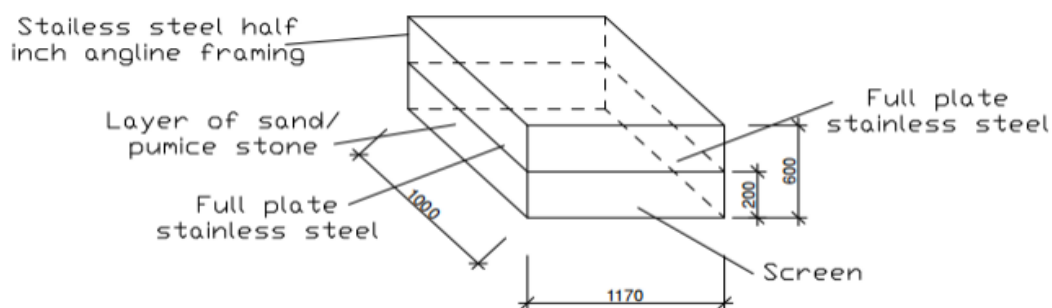*2.5.1 Reactor Design, fabrication and Filter material installation*

Figure 3: Design of Reactor/wastewater filtration instrument.

The waste water filtration instrument was designed to fit the outlet S1 of the maturation pond as described in Figure 2 above. Its dimensions were as follows: length of 1170mm; width1000mm; and height 600mm (**see Figure 3**). This reactor was made of stainless steel with an inlet screen and adjustable outlet notch for control. This was put in S1 to create $S1_2$, CFU and S2 sections.

Granular Sizes of Silica is frequently used as a filtration medium because of its capacity to hold onto particles [17]. Granulated Pumice stone's porous nature, improves filtration when combined with silica, [18]. Glass columns are often used in lab settings for filtration investigations and other controlled experiments, [19]. This vertical cylindrical glass column has a diameter of 30 mm and a length of 400 mm. Standard Phosphate Solution at 25 ppm were employed for testing and calibration in water quality studies, according to the [20]. UV-VIS spectrophotometers are essential for measuring absorbance in chemical analyses, which includes detecting phosphate content, according to [21].

The reactor was filled with composite granular filter made of homogenous mixture of sand and pumice stone at levels 200mm, 400mm and 600mm. The composite filtration unit (CFU) or reactor was installed at the exit manhole of maturation pond for filtration process where effluent entered through front screen plate by gravity, through the filter onto outlet notch as shown in figure 4 below. In related study [22], schematic diagram showed a vertical orientation of effluent flow in the reactors.
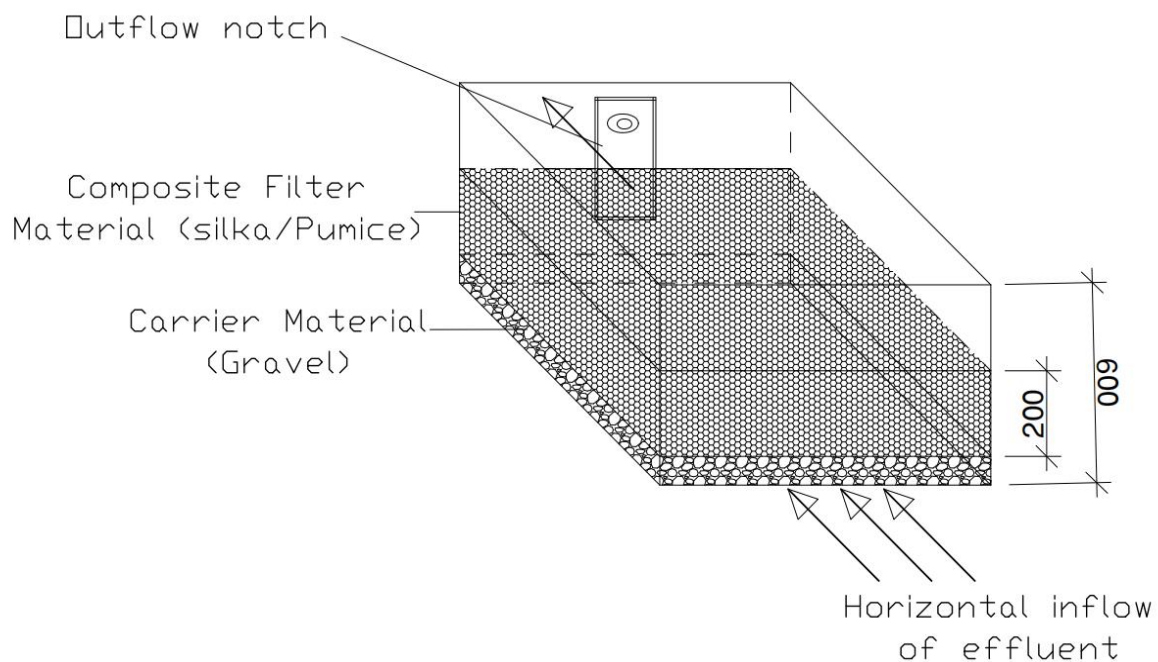
Figure 4: Schematic diagram of Composite granular filter in the reactor with horizontal inflow and outflow of effluent.

2.5.2 Composite filter material data

The composite filter material was made of silica (sand) and pumice stone granules of different rations. Clean

sharp river sand was obtained from local merchants in Kakamega town while pumice stones were obtained from Naivasha town. The latter were ground into particles at the soil mechanics laboratory in MMUST by a mallet and sieved using granular sieves of different pore sizes. The granular sieves used consisted of 0.6 mm, 0.9 mm, 1.18 mm, 2.75 mm and 3.25 mm.

2.5.3 Composite filter Parameter optimization

The size of particle affects porosity of the filter. Porosity is the ratio of volume of space in between the mineral particles and total volume of the media [23]. Granular filter media bed depth (L) to grain size (D) ratio is optimum between the range of 1000-1200 [24]. For plants using conventional clarification Pre-treatment, a common dual filter uses 600mm depth of sand having 0.9mm particles size and anthracite depth of 300m having 0.5mm particle size leading to L/D ratio of 1267. At Shirere WWTP the depth of maturation pond outlet was 800mm. Depth varied from 200mm, 400mm, and 600mm. The respective granular sizes calculated from the L/D ratios are represented in the Table 3.

Table 3: Depth, Particles Size Ratio Optimal Values.

		Ratio (L/D)					
		1000	1050	1100	1150	1200	1250
1	L		200	400	600	800	1000
	D		0.19	0.364	0.522	0.667	0.8
2	L	1000		200	400	600	800
	D	1		0.182	0.348	0.5	0.64
3	L	800	1000		200	400	600
	D	0.8	0.952		0.174	0.333	0.48
4	L	600	800	1000		200	400
	D	0.6	0.64	0.909		0.1667	0.32
5	L	400	600	800	1000		200
	D	0.4	0.571	0.727	0.87		0.16
6	L	200	400	600	800	1000	
	D	0.2	0.380	0.5454	0.7	0.833	

Table 4: Sieve Sizes Chart.

No	Sieve number	Opening size (mm)
1	4	4.750
2	6	3.350
3	8	2.360
4	12	1.680
5	16	1.180
6	20	0.900
7	30	0.600
8	40	0.425
9	50	0.300
10	60	0.250
11	80	0.180
12	100	0.150
13	140	0.106
14	200	0.075
15	270	0.053

From the Table 3, granular size ranges from 0.16mm to 1mm and depth from 200mm to 1000mm. However, the available standard sieves are given in table 4. The researcher chose to use 0.6mm, 0.9mm and 1.18mm as shown in below. Particle size preparation was undertaken by mechanical sieving which is more efficient, [25]. In the British standard, sieving test procedure, BS 410 standard sieves were used. The sieve numbers are from 4 to 270, which are provided in the table 4 below.

Sand and pumice stones were availed at MMUST Civil Engineering lab. The sand was clean sharp river sand and pumice stone was 50mm rock that was reduced by a Marlet on clean surface to sievable sizes. The sieves were cleaned by a brush. The granular materials were dried for 3-4 minutes in order to expel any moisture build up. The sieves were arranged in order as shown in Table 4.

2.5.4 Optimum pumice-sand ratio

Using sand of granular size of 1.18 mm and sand of 0.6 mm the ratios of sand: pumice mixture was varied from 100%, 75%, 50%, 25%, and 0% of sand while maintain the total weight of the two at 100%. The mixture was mixed uniformly and put in a vertical cylindrical glass of 400 mm length and 30 mm in diameter. It was filled with the mixture up to 300 mm and 25 ppm standard phosphate solution eluted down the column. A stock solution of 0.01mole of potassium dihydrogen phosphate was prepared by dissolving 1.36g of the salt into 500millilitres of distilled water and whose absorbance was measured in UV-vis spectrophotometer by varying the wavelength from 500nm to 950nm. Three trials of absorbance were carried for every wavelength in the range given and mean absorbance recorded.

2.5.5 Optimum granular size

The above experiment was repeated under same conditions while maintaining sand: pumice ratio at 50% and sand granular size of 1.18 mm. Pumice granular sizes were varied from 0.6 mm, 0.9 mm, 1.18, 2.75 and 3.25 mm respectively.

2.5.7 Field experiments Using Composite Filter in Reactor at maturation pond

Fabricated water-tight reactor was installed into maturation pond outlet to fit its length and depth. This created sample collection zones along the width labelled $S1_2$ and S2 as previously described. Composite materials were filled into it at heights of 200 mm, 400 mm and 600 mm. Wastewaters were allowed to pass through it overnight for 24 hours and samples collected for analysis at points $S1_2$-S7. This was carried out to each at every 200mm, 400mm and 600mm depth of the composite filter into the maturation pond. Triplicate samples were collected at sites $S1_2$- S2 during the seasons of March to May, June to August and September to November, [26]. The samples were collected in labelled 500 mL bottles sterilized by HNO_2 acid and stored under controlled container conditions before being transported to the laboratories. Three bottles per site were collected to enable sufficient analysis in the MMUST chemical laboratories. Preparation of field samples were filtered through 0.4-µm pore membrane filters and kept at 4^0C until analysis. An aliquot of 50ml of these used were digested with 20ml of HCl acid at 80^0C until the solution became transparent, [27].

2.5.7 Measurement of changes in levels of pollution, Reagents and Tools

The following analytical grade reagents were obtained in Masinde Muliro University of Technology Chemistry Laboratories: magnesium sulphate; calcium chloride; sodium phosphate; ferric chloride; ammonium heptamolybdate tetrahydrate; sodium hydroxide; distilled water; acetic acid; potassium hydrogen phthalate; and potassium iodine.

2.5.8 Preparation of standard solutions

Standard solution of one normal sodium hydroxide (NaOH)was prepared by adding 40 g of NaOH to 900 mL of deionized water. The mixture was stirred and brought to one litre mark with distilled water. Similarly, one normal Sulphuric acid (H_2SO_4) was prepared by adding 28 mL to 900 mL of deionized water. 1.575 g of Sodium sulphate (Na_2SO_3) and a few crystals of Cobalt chloride ($CoCl_3$) were dissolved in 1 Litre of deionized water and used immediately as required. Magnesium sulphate solution was prepared by dissolving 25gms of magnesium sulphate distilled water and diluting it to 2 Litre mark. Similarly, calcium chloride and ferric chloride hexahydrate solutions were prepared by dissolving 55 g and 0.5 g respectively into 2 litters. Potassium iodide and acetic acid solutions were prepared by adding 20 g and 100 mL respectively into 100 mL of distilled water and used as required.

High range digestion solution was made by adding 5g of potassium dichromate into 250 mls of distilled water, 85 ml of concentrated sulphuric acid added, and 16.5 g mercury sulphate ($HgSO_4$)   The solution was allowed to cool at room temperature and diluted further to 1000mls. Low range digestion solution was similarly prepared using 0.5 g potassium dichromate. Sulphuric acid reagent was prepared by adding silver sulphate (Ag_2SO4) to concentrated H_2SO_4 at the rate of 2.5 grams of Ag_2SO_4 per kg of H_2SO_4, distilled and mixed. Potassium hydrogen phthalate (KHP) was prepared by crushing 213 g of the salt and dissolving it in 1000 ml distilled water.

2.5.8 Measurement of Chemical Oxygen Demand (COD)

The oxidant in the COD test was potassium dichromate. Digestion was carried out on samples containing a specific number of oxidants, sulphuric acid, and heated at 150°C. The digestion process took two hours and the COD results were recorded. The reagents used were Sulphuric acid, high range digestion solution and low range digestion solution.

2.5.9 Measurement of Biological Oxygen Demand (BOD)

For every site, a sample of 500ml of waste water from controlled conditions, clean calibrated thermometer was installed for measurement of temperature. The temperature chamber was controlled constantly in the DO instrument for 30 minutes before calibration. The water was aerated and diluted before adding nutrient solutions. The solution was diluted up to one litre and one millilitre each of ferric chloride, calcium chloride, magnesium sulphate and potassium phosphate added to it. The container of the solution was shaken for one minute to saturate it with oxygen at maintained temperature of 20^0c.

The initial and final DO tests of water was determined and recorded as follows: - air diffusion stone was inserted into the warming container and aerated the sample for 15 minutes. Three, 50millilitres of subsample was thoroughly mixed by inverting them 20 times. Each subsample was poured into clean BOD bottle, topped by agitated dilution water. Other three blanks of dilute water were prepared for quality control. The initial DO concentration (D1) of each sample and dilute blank was measured in calibrated DO instrument, and final DO concentration (D2) of each sample in air incubator at the end of 5 days was measured in calibrated DO instrument and D2 recorded as BOD. The tools used in the measurement were, 300 ml BOD bottles, BOD metre, 100 ml beakers, 200ml for flask, Pipette bulb, stirring bass and 25ml measuring pipettes.

2.6 Measurement of Nitrates

500 millilitres waste water portions that were collected were used in this experiment. In this case, 3.5 millilitres of filtrate were transferred into 100 millimetres volumetric flask, diluted with distilled water to the marked line, and shaken until homogeneously mixed (dilution factor 28.5 litres), [28]. This was filtered through 0.45µm membrane filters to remove turbidity and sealed with paraffin paper. 10 millilitres of solution were transferred into 100 millilitres volumetric flask, added 0.1 grams of zinc powder, added 1 millilitre of hydrochloric Acid, allowed to stand for 10 minutes, 2.5 millilitres of Sulphuric acid added, shaken and left to react for 5 minutes. More 2.5 millilitres of Ethylenediamine Dihydrochloride solution were added and shaken with distilled water to the marked line. The amount of nitrates in the solution was determined by measuring the absorbance at 220 nm and 275nm wavelength after allowing to reach the operating time. Each treatment was repeated 6 times. Levels of nitrate in the sample was calculated by multiplication with conversion factor, volume and dilution factor and divided by weight and recorded accordingly.

2.7 Measurement of Phosphates

An analogous point was reached when all excess dichromate reacts. This indicates that the amount of ferrous ammonium sulphate used was equivalent to the excess dichromate. This endpoint was likewise be signalled by a colour indicator; however, the process was paired with a potentiometric indicator. (Like an electrode). Tools used in the measurement were UV-VI, spectrophotometer, 100ml beaker, 200ml flask, 25ml measuring pipettes and 10ml graduated cylinder. Reagents used in the measurement were distilled water, ammonium heptamolybdate tetrahydrate and potassium among titrate trihydrate.

2.8 Measurement of Total Suspended Solids

TSS analysis was performed by collecting the total solids potion on a filter. Typically, for the analysis, a what man934-AH glass micro-fibre or its equivalent with a nominal pore size of 1.5 mm was used, and a pre-determined volume, typically 0.1 litre, was passed through the filter. The filter was weighed both before and after the sample was filtered, and it was commonly dried at 103-1050 degrees Fahrenheit. The filtration method was ideal for samples containing 200mg/L of clay-size material. Tools used in the measurement of this use drying over, filtration apparatus, analytic balance, glass fibre filter and watch glass. The reagent used was pure water.

2.9 Validity and reliability of data collection instruments

2.9.1Validity of data collection instruments

Analytical Instruments

The validity of UV-VIS spectrophotometer was determined by letting the standard solutions of the parameter to be measured (e.g., phosphate) against the absorbance of the same solution. This was achieved by establishing analytical figures for determination of sample linearity. This proved the validity of beers Lambda's law which states that the amount of light absorbed by a compound dissolved in fully transmitting medium is precisely proportional to the concentration and light's journey length through the medium, [29].

2.9.2 Reliability of data collection Instruments

The reliability is the stability and consistency with which the instrument measures concept and helps to assess the goodness of a measure, [30]. It also indicates the extent to which it is without bias and hence ensures consistent measurement across time and across various items. The experiments of absorbance versus concentration were carried out at Lambda wavelength. The reliability of the phosphate data was used for calibration and ascertained by a plot concentration versus absorbance for standards, [29]. This was done to precede each of the samples analysed.

2.10 Data analysis

In this study, since the research design was experimental design, each objective was handled separately.

2.11. Develop the silica pumice composite filter

Here, the experiments were carried out to determine the lambda mark and standard phosphate calibration curve. In this study, Gaussian model was used to establish the relationship between the wavelength, λ and Absorbance, A as follows.

$$A = A_{max}e^{-\left[\left(\frac{\lambda-m}{s}\right)^2\right]}$$

(1)

where A_{max} is amplitude, m is the mean, and s is the standard deviation. These parameters were determined by non-linear curve fitting using Matlab software. From Figure 8, Lambda mark, λ_{max} corresponds to A_{max}.
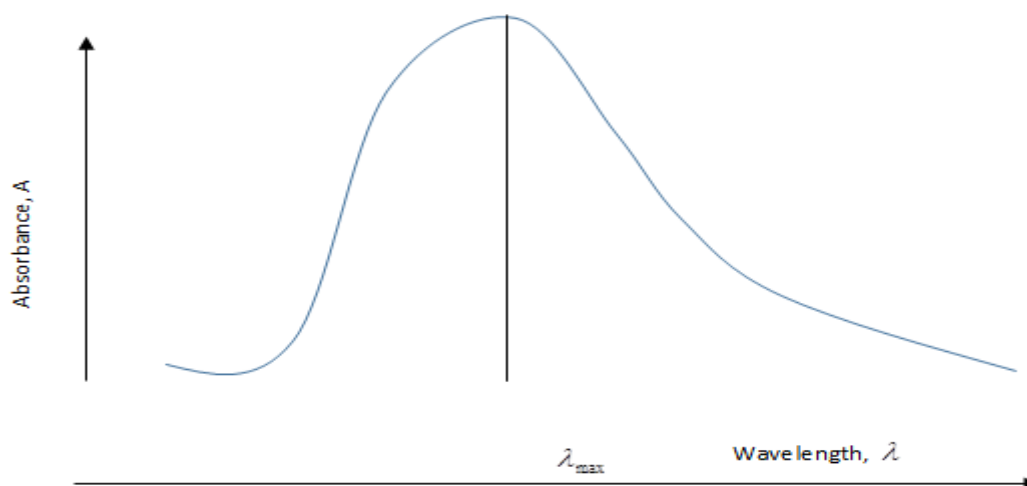
Figure 5: A plot of Wavelength versus Absorbance.

Determination of calibration curve requires Lambda mark λ_{max} which was optimized by use of differential calculus. This was calculated by maximizing Eq. (2.1), and solving the resulting equation for λ to obtain:

$$\lambda_{max} = m$$

(2)

Having obtained Lambda mark of $\lambda_{max} = m$, UV-VIS spectrophotometer was fixed at it. The stock solution of 5ppm, 10ppm, 15ppm, 20ppm, 25ppm, and 30ppm were used to read the corresponding absorbance. The measurements were carried in three trails, and the mean absorbance were tabulated. The plot of concentration versus absorbance resulted into a linear relationship. The linear relationship between concentration and absorbance is known as calibration curve as shown in chapter three, figure 8.

2.12 Limitation of the Study

The effluent was not wholly filtered through the reactor due to inadequate sealing into the maturation pond outlet manhole. This was addressed by incorporating more silica pumice material on its external sides.

3.0 Results and Discussion

This section presents findings of the study and their discussion. It also includes analyses of factors affecting the performance of the composite filter in laboratory and field tests; real life application of composite filter in removal of pollutants from effluents; and seasonal variability of pollutant removal from effluents. Data analysis was done by use of descriptive statistics of the parameters, standard deviations, means, frequencies, regression, and correlational analyses, after which inferences were drawn from the analyses.

3.1 Factors affecting Performance of the composite filter

The performance of composite filter was evaluated by use of both laboratory filtration experiments and field filtration experiments.

3.2 Laboratory investigations

Laboratory filtration experiments involved particle size determination, composite filter composition optimization, and adsorption determinations.

3.2.1 Particle size determination

Table 5 shows the particles sizes obtained after passing ground pumice stone through various molecular sieves. Briefly, the 0.60 mm sieve retained all particles sizes that were ≥ 0.60 mm while allowing particles that were < 0.60 mm sizes to pass. Similarly, particles of sizes< 0.9 mm, < 1.18 mm, < 2.75 mm and < 3.25 mm were obtained and used in preparation of the composite filter.

Table 5: Particle Size Sieving Order.

No.	Granular Sieve Size (mm)	Retained sizes (mm)	Size obtained (mm)
1	0.60	≥0.60	< 0.60
2	0.90	≥0.90	<0.90
3	1.18	≥1.18	<1.18
4	2.75	≥2.75	<2.75
5	3.25	≥3.25	<3.25
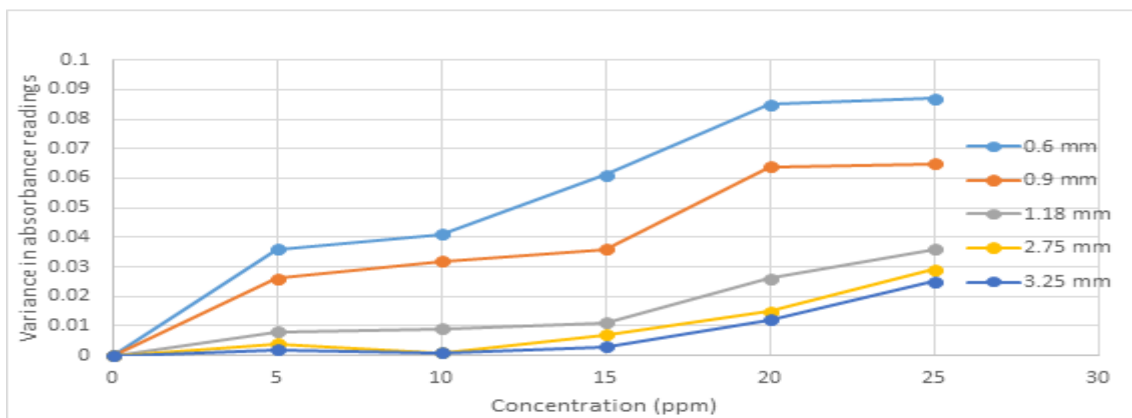
Figure 6: Variation of absorbance with particle sizes (Composite ratios used was 50% 1.18 mm sand and 50% pumice granular sizes).

Figure 6 shows 0.6mm as the optimum pumice particle size for the effective filtration of phosphates in waste water. In this case, the residual amount of phosphorus determined by measuring absorbance at 752nm, [31] and the exact concentration obtained from the calibration curve shown in Figure 10. More phosphates were adsorbed in the order 0.6mm > 0.9mm > 1.18mm > 2.75mm > 3.25mm as shown in figure 6 below. This finding was consistent with earlier works reported by, [24] showing that filtration efficiency often increased as the particle size decreased. The author, [24] revealed a range of 0.5mm of sand to 0.9mm which was within the

range of this study.

3.2.2 Composite Filter Composition Optimization

Maximum wavelength, lambda mark was to be determined for development of calibration curve. Using recorded results, the parameters of Gaussian function, $A = A_{max} exp[\frac{\lambda - m}{s}]^2$ were determined by non-linear curve fitting in MATLAB and their optimal values were found as follows:$A_{max} = 0.65, m = 752.02nm$, and $s = 146.24nm$.
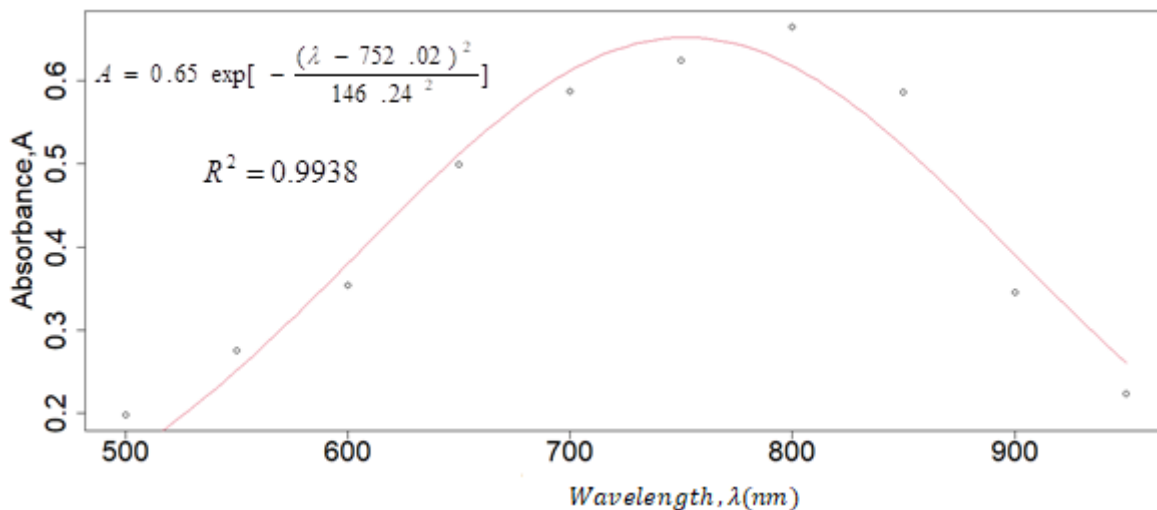

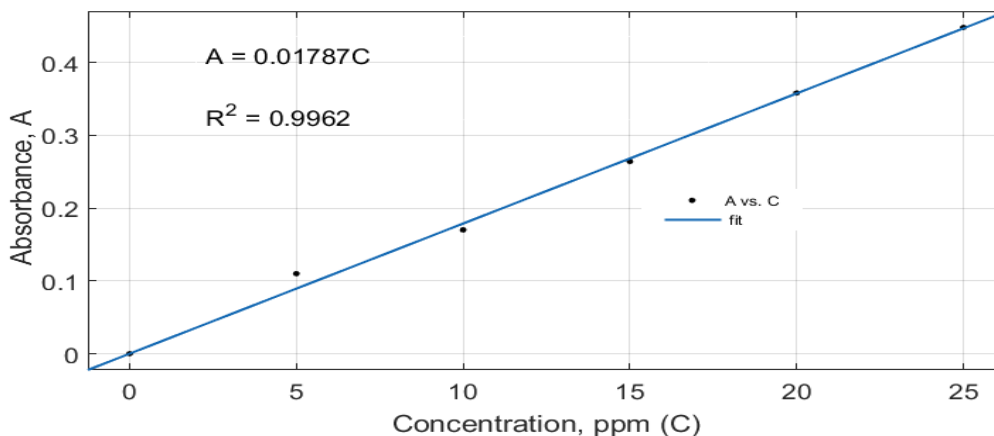**Figure 7:** Plot of wavelength versus absorbance for the determination of optimum wavelength.

Figure 8: Calibration curve showing a plot of concentration in ppm against absorbance of 0.01M potassium dihydrogen phosphate in distilled water.

From this graph, at maximum absorbance, using differential calculus, the lambda mark was found to be $m = 752.02nm$. In the study of [16], using the same ratios and materials, found lambda mark as $713nm$ and survey of [32], at $\lambda = 715 \ nm$ which compares well with the current results. Absorbance values were recorded at Lambda mark wavelength using Ultra violet spectrophotometer for development of standard calibration curve

as shown in figure 8.

Using the calibration curve, variance in absorbance of mix of sand 1.18mm and pumice 0.6mm, sand 1.18mm and pumice 0.9mm and sand 1.18mm and pumice 1.18mm were recorded. In this case the granular sizes were varied against residual absorbance using phosphate concentration set at 25 ppm. The results shown in figure 9 below were depicted in the graph, the maximum retention capacity of the pumice sand mixture was obtained at granular particle size of 0.60mm pumice and 1.18 mm sand respectively.
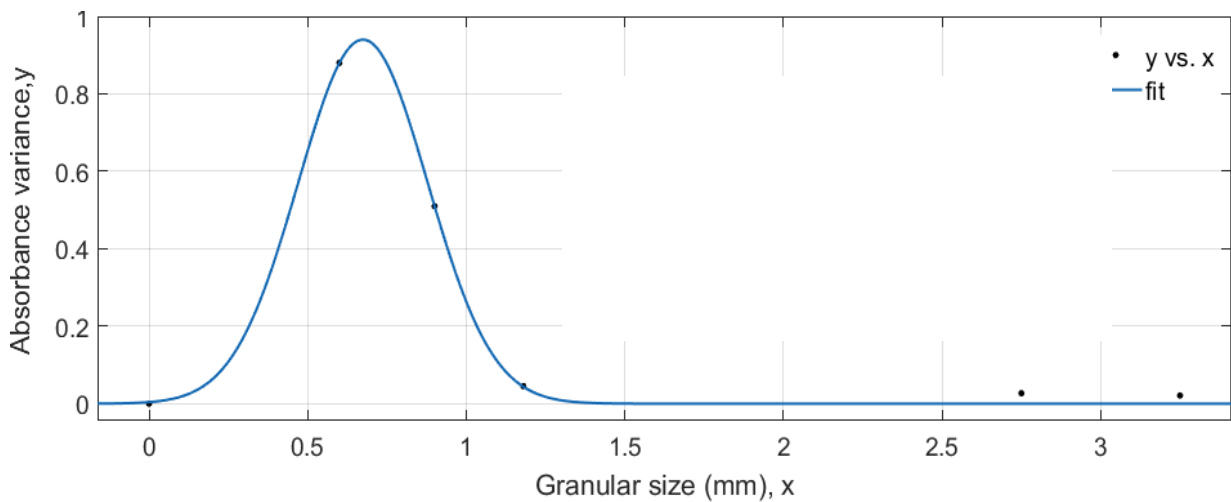
Figure 9: Granular Size versus absorbance obtained from Gaussian and r- programming function with best fit.
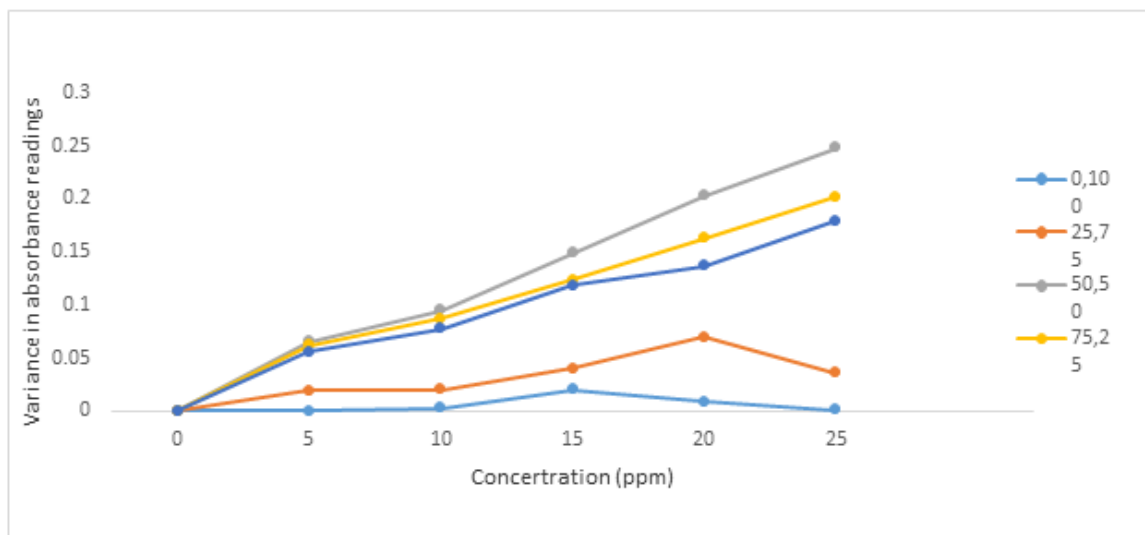

Figure 10: Variance in absorbance readings against concentration.

Complementary ratio of 0.6 mm pumice stone ratio was lower than the 50% composite ratio, (Figure 10). This was consistent with earlier study in which 0.2 mm -1 mm were established as effective sludge particle sizes for removal of nutrients in waste effluents, [33]. Arguably, pumice particles < 0.6 mm may have formed pores of sizes less < 0.45 um thus promoting clogging of the composite filter as revealed by, [34]. Similarly, particles >

0.6 may have formed pore sizes > 45 um thereby allowing more of the effluents to pass through. Figure 10, shows the variance in absorbance with concentration of the composite filter. The ratio of pumice 100% and sand 0% gave a variance of 0.02 while that of 75% pumice and sand 25% gave 0.20 for the same phosphorous concentration. These findings are in agreement with the work of, [24] who found out that optimum performance of granules at equivalent ratio percentage. Therefore, optimum composite filter performance was selected at the ratio of 50% both sand and pumice composite filter and used in field reactor experiments.

3.2.3 Adsorption time

Wastewater collected from Site 1a, was used in batch experiment at MMUST chemistry laboratories for measurement of adsorption time. Figure 11 below shows the variation in phosphorous absorbance against incubation time in batch experimental conditions.
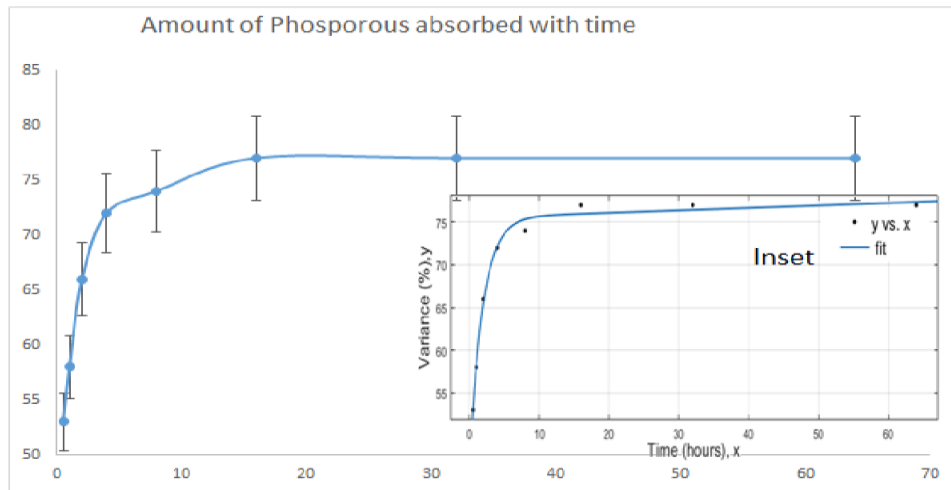
Figure 11: Plot of time versus absorbance variance (%).

The phosphate removal efficiencies were 53%, 58%, 66%, 72%, 74% and 77% for contact time of a half an hour, 1, 2, 4, 8, 16, 32 and 64 hours respectively. The rate of phosphates removed under these conditions increased sharply up to 8 hours and gradually reached equilibrium after 16 hours reaction time. Thus, the equilibrium 77% adsorption of phosphates by the composite filter reached was attained after 16 hours beyond which minimum was observed. Inset is an adsorption model for the same composite filter developed for the same experimental conditions. This still showed 77% asymptotically success for phosphate removal.

The chemical composition of the pumice is shown in Table 6 as posited by, [35].

Table 6: Chemical composition of pumice stone.

Chemical	Composition (%):
SiO_2	70.35
Al_2O_3	14.60

Fe_2O_3	1.05
Na_2	3.60
K_2O	4.40
MgO	0.10
CaO	0.80
TiO_2	0.15
Uniformity coefficient [D_{60}/D_{10})	1.35
Effective grain size D_{10} [mm]	0.59
Porosity (%)	69.24
Density (0.5-1.0 mm grain size) [g/cm^3)	0.69

Studies have shown that sorption kinetics by pumice are largely dependent on the physical and chemical characteristics of the sorbent materials, [36]. As shown in Table 6, pumice contains Al^{3+}, Na^+, Ca^{2+} and Mg^{2+} cations and the O^{2-} anion that played a key role in controlling the rate of removal of pollutants. The removal of waste by adsorption on the composite was found to be rapid at the initial period of contact time. This was caused by strong attractive forces between the chemical waste molecules and the cations/anions on the sorbent surface that caused fast diffusion onto the porous surface of the filter. However, this was followed by fast saturation of the pores by solutes in the wastewater matrix to attain rapid equilibrium thereby causing the levelling of the graph (Figure 11). It thus yielded an exponential model in which there was linearity at small distances near the origin. It then rose more steeply and flattened out gradually after 10 hours**.** The obtained results showed that the adsorption forces followed a decaying experimental equation of

$$y = 75.53e^{0.0003745x} - 29.45e^{-0.5332x}$$

with a correlation coefficient of 0.994. as given in figure 11.

3.3. Field Filtration Experiments

The real-life measurements were carried out on samples from S1 and S2 sites to establish the efficiency of the filter before and after filtration. This included seasonal Variability of COD, BOD, TSS, Nitrates and Phosphates and change in depth of the composite filter ranging from 200mm, 400mm, and 600mm.

3.3.1 Seasonal Variability of COD and BOD

It is common knowledge that COD is higher during the rainy seasons and the BOD in the dry seasons, [37]. However, the findings of this study show that the performance of the composite filter was affected by the hydraulic transient conditions in each season. This may be attributed to variations in average rainfall data (obtained from Kakamega metrological station). Comparatively, the months of March to May and September to November had high rainfall. In this case 186.33 ± 35.57 mm of rainfall was obtained between June-August. This changed to 276.9 ± 83.33 mm for September to November and then to 254 ± 61.05 mm for March to May respectively. Briefly, the season of June to August was a period of low rainfall, a factor that contributed to reduced effluent inflow rates. The reduced inflow rates increased retention time for wastes movement through the filter, leading to reduced hydraulic transient, a condition that favoured increased adsorption.

This resulted in increased effluent inflow rates thereby causing high hydraulic transient and reduced retention time. As a consequence, there was less resident time in the filter and therefore low efficiency. As shown in table 7a, as depth was increased from 200mm, 400mm and 600mm, COD reduction improved from 40.7% to 41% to

45.34%, respectively for the June to August season. The same trend was evident in the other two seasons due to increased retention period and reduced hydraulic transient. In retrospect, the performance of the filter in the month of September to November was in between the long rain season and relatively dry season. In a similar experiment done by, [22] using only pumice filter media, it was observed that reduced COD efficiency was at 27%.

Thus, the composite filter used in research performed better than the pumice media filter by, [22] and 19±25% for March to May of BOD. The reduced rainfall in the June to August season was responsible for low effluent flow rates. This in turn increased retention time as a result of reduced hydraulic transient. Thus, the levels of BOD and COD reflected reduced pollution as shown by removal of COD and BOD of more than 40% as shown in table 7b. This was a major achievement in terms of pollution control in our rivers. The performance of the filter for the month of September to November was between the other two seasons.

Tables 7a, 7b, 7c, 7d and 7e, shows the effect of Seasonal Variability of pollutants removal on varying depths of the composite filter in the year 2021.

Table 7a: COD (mg O_2/l) in percentages.

Depth(mm)	200	400	600	Trend	Explanation
March – May	36.4	35.15	42.0	Positive	Pollutants removal increased by 4% from 200 mm to 400mm and 7% from 400mm to 600 mm
June – August	40.7	41.0	45.34	Positive	Pollutants removal increased by 0.3% from 200mm to 400mm and 4% from 400mm to 600mm.
September – November	31.6	37.5	41.6	Positive	Pollutants removal increased by 5.9 % from 200mm to 400mm and 4.1% from 400mm to 600mm.

Table 7b: BOD (mg O_2/l) in percentages.

Depth(mm)	200	400	600	Trend	Explanation
March – May	14.0	5.8	11.4	Negative	Negative reduction of 8.2% between 200mm and 400mm and increment of 4.6% between 400mm to 600mm.Reduced pollutants removal of waste was due to reduced affinity between BOD and filter material.
June – August (more Removal)	10.2	10.16	13.57	Negative	Reduced pollutant removal by 0.04% between 200mm and 400mm and increased by 3.41% between 400mm to 600mm. Reduced removal of pollutants due to reduced affinity between BOD and filter materials.
September – November	12.3	15.46	17.4	Positive	Pollutants removal increased by 3.16 % from 200mm to 400mm and 1.9% from 400mm to 600mm.

Depth(mm)	200	400	600	Trend	Explanation
March – May	10.04	9.55	11.76	Positive	Pollutants removal reduced by 0.85% from 200mm to 400mm and increased by 2.21% from 400mm to 600mm.
June – August	19.72	10.4	11.1	Negative	Pollutants removal decreased by 9.32% from 200mm to 400mm and increased by 0.7% from 400mm to 600mm.
September – December	13.16	15.6	16.4	Positive	Pollutants removal increased by 2.44% from 200mm to 400mm and 1% from 400mm to 600mm.

Table 7c: TSS (Mg/l) in percentages.

3.3.2 Seasonal variability of TSS

TSS followed the same trend as Nitrates and Phosphates. This is in agreement with work of [22] in which 68% removal of TSS was achieved using pumice single filter. Comparatively, the composite filter used in this work had maximum a removal rate of 19.72% TSS in the field under real life situation. The low rate of removal in the field was due to continued inflow of raw effluent at different concentrations into the samples being collected. This emanated from seepage of the effluent on the sides of the filter into the effluent discharged. Thus, under the prevailing circumstances the 19.72% is a fair indicator the composite filter would have performed better in the absence of the leakages.

3.3.3 Seasonal variability of Nitrates and Phosphates

The reduced rainfall led to reduced effluent inflow rates into the filter. This resulted in reduced hydraulic pore pressure and consequently increased adsorption onto composite filter particles. Therefore, more of nitrates were retained by the filter during this season, a factor that increased efficiency of filter as indicated by $31.93\pm1\%$ in the same vein the season of March to May followed by $19.0\pm5\%$ and was trailed by the season of September to November of $20.4\pm7.9\%$ as shown in table 7d. This low removal rates are attributed to lower adsorptions of nitrates on to particles of composite filter as a result of increased effluent inflow rates during higher precipitation at these times. Comparatively more Nitrates were removed than the phosphates in all the three seasons. In table 7e, the phosphates were reduced in the last season at a maximum of 28% followed by middle season with the maximum of 21% and the first season maximum being 13%. Therefore, there is an inverse relationship between phosphates and nitrates reduction as observed. This implies that, high efficiency of nitrates reduction acts inversely to phosphate reduction. Notable is the fact that waste removal percentage often increase with increasing of the mass of adsorbent, the contact time and the initial solute concentration as revealed by, [36]. This explains the increase in amount of COD, TSS, nitrates and phosphorus removed by the filter as the depth increased. Arguably, increase in depth amounted to increased initial concentration of the wastes. As shown in Table 6, physical characteristics, the cationic and anionic nature arising from the presence of cations such as Ca^{2+}, Al^{3+}, Na^+, K^+ and the O^{2-} anion within the composite contributed immensely the removal of these chemicals through adhesion and ionic interactions, [22].

Table 7d: NO_3 (Mg_2/l) in percentage.

Depth(mm)	200	400	600	Trend	Explanation
March – May	4	9	13	Positive	Pollutants removal increased by 4% from 200mm to 400mm and 4% from 400mm to 600mm.
June – August	14	18	21	Positive	Pollutants removal increased by 4% from 200mm to 400mm and 3% from 400mm to 600mm.
September – December	17	25.6	28.8	Positive	Pollutants removal increased by 8.6% from 200mm to 400mm and 3.2% from 400mm to 600mm.

Table 7e: PO_4 (Mg_2/l) in percentage.

Depth(mm)	200	400	600	Trend	Explanation
March – May	16	17	26	Positive	Pollutants removal increased by 1% from 200mm to 400mm and 5% from 400mm to 600mm.
June – August	20.6	36.7	38.5	Positive	Pollutants removal increased by 16.1% from 200mm to 400mm and 2.1% from 400mm to 600mm.
September – November	16.6	20.6	24.5	Positive	Pollutants removal increased by 4% from 200mm to 400mm and 4.4% from 400mm to 600mm.

3.4 Performance of composite filter under varying depth

NO_3 , and PO_3 at varying effluent flow rate into the filter and its depth. These were carried out by taking 6, 500millitres of effluent samples to MMUST chemistry laboratories from sampling sites S1 to S2. In total were 18 trials for three seasons (March – May, June – August, and September – November) 2021. In all the seasons, the filter performance was based on measurements of five parameters namely COD, BOD, TSS, nitrates and phosphates, measured by evaluating the differences between samples at site one and two. The varying conditions were composite filter depth and effluent inflow rate. The depth of the filter varied from 200mm to 600mm at an interval of 200mm.

3.4.1 Effect of varying filter depth on phosphates

In the season of March to May, phosphates after filtration varied from 24.082g/ml to 21.9g/ml which is 4% at depth 200mm, varied from 29.12g/ml to 25.476g/ml which is 9% at 400mm and varied at 27.67g/ml to 22.097 mg/l which is 13% at 600ml. June to August season 2021, phosphates after filtration varied from 22.002ml/l to 19.99g/ml which is 14% at depth 200mm, varied from 25.16g/ml to 22.07g/ml which is 18% at 400mm and varied at 31.37mg/l to 29 mg/l which is 21% at 600ml. For September to November, phosphates after filtration varied from 31.35mg/l to 29mg/l which is 17% at depth 200mm, varied from 36.68mg/l to 32.5mg/l which is 25.6% at 400mm and varied at 22.15mg/l to 18.285 mg/l which is 28.8% at 600mm. From the results, the 600mm depth is showing high efficiency than 400mm and 200mm by difference of 13% in the mid-season. This implies that increased mass leads to increased filtration efficiency.

3.4.2 Effect of varying filter depth on Nitrates

In the season of March to May, Nitrates after filtration varied from 19.87mg/l to 16.08g/ml which is 16% at depth 200mm, varied from 32.776mg/l to 27.236mg/l which is 17.0% at 400mm and varied at 31.89mg/l to 26.783 mg/l which is 26% at 600ml. June to August season 2021, Nitrates after filtration varied from 17.87mg/l to 14.08mg/ml which is 20.60% at depth 200mm, varied from 22.76mg/l to 17.22mg/l which is 36.7% at 400mm and varied at 31.7mg/l to 22.983 mg/l which is 38.5% at 600ml. For September to November, Nitrates after filtration varied from 25.12mg/l to 22.56mg/l which is 16.6% at depth 200mm, varied from 46.135mg/l to 38.155mg/l which is 20.6% at 400mm and varied at 27.85g/l to 21.135 mg/l which is 24.5% at 600ml. Based on the results, the 600mm depth shows high efficiency of 38.5% in the middle season and 24.5% in the last season caused by volumetric increment.

3.4.3 Effect of varying filter depth on COD

In the season of march to May, COD after filtration varied from 300.9mg/l to 190.88g/ml which is 36.4% at depth 200mm, varied from 355.58mg/l to 231.13mg/l which is 35.15% at 400mm and varied at 296.71mg/l to 169.35 mg/l which is 42% at 600ml. June to August season 2021, COD after filtration varied from 270.18mg/l to 160.85mg/l which is 40.7% at depth 200mm, varied from 320.88mg/l to 251.13mg/l which is 41% at 400mm and varied at 256.75mg/l to 161.55 mg/l which is 45.34% at 600ml. For September to November, COD after filtration varied from 345mg/l to 236.95mg/l which is 31.6% at depth 200mm, varied from 265mg/l to 145.8mg/l which is 37.5% at 400mm and varied at 283.35mg/l to 181.95 mg/l which is 41.6% at 600ml. From

the findings, the 600mm depth reveals high efficiency of 45.34% due to higher retention time caused by increased volume. This is the best performance of the composite filter in the field and can still go higher if the challenges are addressed.

3.4.4 Effect of varying filter depth on BOD

In the season of march to May, BOD after filtration varied from 281.5mg/l to 272.6mg/l which is 14% at depth 200mm, varied from 300.16mg/l to 282.7mg/l which is 5.8% at 400mm and varied at 321.97mg/l to 285.25 mg/l which is 11.4% at 600ml. June to August season 2021, BOD after filtration varied from 281.32mg/l to 252.6mg/l which is 10.2% at depth 200mm, varied from 270.16mg/l to 24.7mg/l which is 10.16% at 400mm and varied at 331.3mg/l to 285.64 mg/l which is 13.56% at 600ml. For September to November, BOD after filtration varied from 307mg/l to 297.25mg/l which is 12.3% at depth 200mm, varied from 330.95mg/l to 290.2mg/l which is 15.46% at 400mm and varied at 317.2mg/l to 267.6 mg/l which is 16.4% at 600ml. From the results, the highest waste reduction was 16.4% at 600mm depth implying that the BOD reduction is inverse of COD reduction, when the COD reduction increases, the inverse to BOD in the composite filter.

3.4.5 Effect of varying filter depth on TSS

In the season of march to May, TSS after filtration varied from 325.15mg/l to 291.3g/ml which is 10.4% at depth 200mm, varied from 365.4mg/l to 330.5mg/l which is 9.55% at 400mm and varied at 341.2mg/l to 301.5 mg/l which is 11.76% at 600ml. June to August season 2021, TSS after filtration varied from 325.5mg/l to 261.3mg/l which is 19.72% at depth 200mm, varied from 325.4mg/l to 295.5mg/l which is 10.4% at 400mm and varied at 381.26mg/l to 341.25 mg/l which is 11.1% at 600ml. For September to November, TSS after filtration varied from 335.55mg/l to 298.25mg/l which is 13.16% at depth 200mm, varied from 380.25mg/l to 330.2mg/l which is 15.6% at 400mm and varied at 369.15mg/l to 328.6 mg/l which is 16.4% at 600ml. Based on these results, the trend in reduction of TSS reduces as you increase the volume of the filter. This shows that, the part of filter material inhibits adequate reduction of the TSS when the volume is increased. Therefore the more volume the poor the filter performance.

4.0 Conclusions

The study concluded that silica pumice composite filter performance is evidenced by big variations in the concentrations of COD, BOD, TSS, Phosphates and Nitrates at Shirere WWTP before and after filtrations. This is attributed to effective filtering capacity of the composite filter that had been installed. From the results, it was noted that the filter is most effective on COD throughout the seasons by 36.4% to 35.15% to 42% to 40.7% to 41% to 45.34% and 31.6 % to 37.5% and 41.6% efficiency. This is followed by BOD at 14% to 5.8% to 11.4% to 10.2% to 10.16% to 13.57% to 12.3% to 15.46% and 17.4%. The waste reduction of the pollutants had a positive impact on the discharged effluent into river Isiukhu for they were within the NEMA standards. Changes in TSS concentrations changed from 10.4% to 9.55% to 11.76% to 19.72% to 10.4% to 11.1% to 13.16% to 15.6% and 16.4%. this concludes that as you increase the depth of the filter the efficiency of the filter increases up to 16.4% which is a fairly good result. Phosphates removal changed from 4% to 9% to 13% to 14%

to 18% to 21% to 17% 25.6% and 28.8%. This also indicates an increase in efficiency as you increase depth of the filter. The nitrates removal changed from, 16% to 17% to 26% to 20.6% to 36.7% to 38.5% to16.6% to 20.6% and 24.5%. The current study revealed change from 4.0% to 38.5%. In summary, Increased housing and infrastructure construction activities within the plant's catchment area may also be to blame for the high quantities of settleable solids. The construction site waste and loose soils found their way to the treatment facility. Increased farming activities, such as tilling soil near sewer lines, could also have contributed to higher TDS and settleable solids levels in the final effluent. The high COD and BOD levels indicated that there was more organic substance in the sewage from the treatment plant's service region. The temperature and pH levels in the study sites did not differ significantly. It was also reported that the nitrate concentration in this investigation was 0.737 mg/l, which was within acceptable limits. It's also worth noting that none of the parameters were examined at the plant. Removal of the major organic matters from the effluent had a substantial impact on the water quality and biogeochemistry of river Isiukhu. Another option is to use a different water body for effluent dilution, one that is larger and capable of self-purification.

5.0 Recommendation

Based on the results, it is therefore recommended that the composite filter technology should be applied to non-compliant sewerage treatment plants such as Shirere WWTP to improve their efficiency.

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