Design of a Model Filtration System and Performing CFD/ Floxpress Analysis on It

Ing. Daniel Kweku Govi[1] Paul Goddey G[2].
1. Department of Mechanical Engineering,
2. Research and Innovation Centre
Accra Polytechnic, Accra, Ghana. Box GP 561 Accra, Ghana

Abstract
With regard to earlier experiment conducted to determine the characteristics of diluted waste water, a confirmation was obtained experienced by the levels shown using the litmus paper. This then provided a basis for the design of the filtration system which was simulated to ascertain its suitability. This can be said by "drink a minimum of two litres or eight glasses of 8 liquid ounces daily" is a statement with which we are all familiar; it is the recommendation by the UK Food Standard Agency (FSA), corroborated by the US-EPA (UKFSA 2002, & USEPA, 1945). In the high-pressure pipeline, the water energy may dissipate after flowing through the channels and the flow rate can be controlled to meet the water need of the life. To ensure the emitter's hydraulic performance, before the fabrication of emitter, computational fluid dynamics (CFD) is used to predict emitter's flow rate and analyze its hydraulic performance under various water pressures. The quality of the emitter has an important effect on the reliability, life span of the drip irrigation system and irrigation quality. Usually, the structure of the emitter channel is very complex with a dimension. A CFD/FloXpress analysis was carried out to determine the suitability of the filtration system while analysis of filtered water also confirmed that, production of the filters could help in enhancing the purification of the diluted Chemu lagoon and similar water system(Ing. Govi and Gablah, 2015).
Keywords: Carbon, Concentration, Filtration, Irrigation

1.0 Introduction

However in Ghana, water is becoming more and more a scarce and valuable resource as population and consumption rise. Evaluation of these factors, as well as technology and action to support healthy water supplies, is necessary to gain control of the situation. Agricultural use of water accounts for nearly 70 % of the water used throughout the world, and the majority of this water is used for irrigation. A successful uniform application through drip irrigation system depends on the physical and hydraulic characteristics of the drip tubing (Al-Amoud, 1995). In surface drip irrigation systems, uniformity can be evaluated by direct measurement of emitter flow rates. The emission uniformity (EU) criterion is used largely to design micro irrigation laterals and large at CFD/FloXpress. The EU is affected by the variation of pressure head due to elevation changes and head losses along the lines, as well as by water temperature, manufacture's variation, grouping of emitters, clogging, variability in soil hydraulic characteristics, and emitter spacing (Wu, 1997).

1.1 Filtration System

Images from the FloXpress/ CFD simulation of the designed filter are discussed in terms of velocity, pressure and discharge. The CFD/FloXpress discusses only the design, the suitability of which will affect the functionality of the elements when they are placed in the vessel. The pollutant concentration levels have been proven to be effectively dissolved/ removed by the use of the media chosen which were mainly obtained from natural sources than synthetic so that it becomes sustainable.

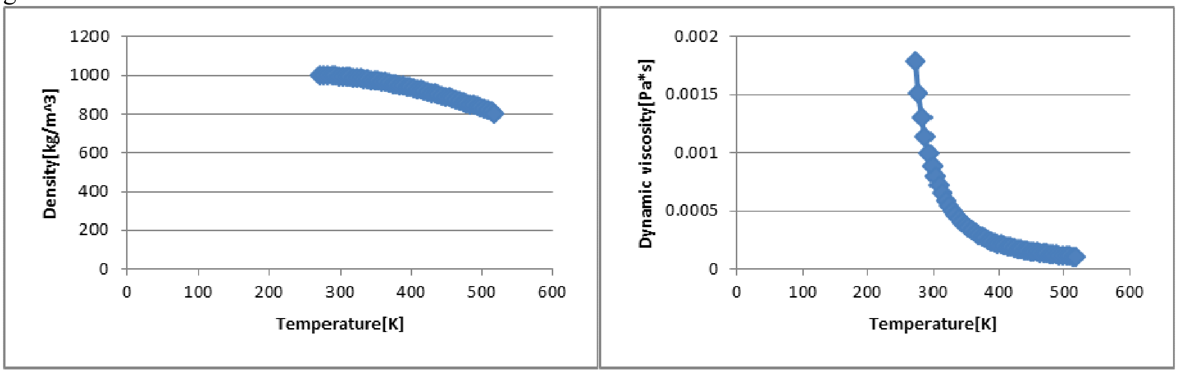
1.2 CFD Design

An air filter is generally a paper-like or fibrous material, folded accordion-style and arranged on a plastic or metal frame to fit your car's air filter holder. In an air filtration system, the air must pass through some sort of filter which traps impurities in the air. The design of the filter determines which impurities will be trapped. Most fuel injected vehicles use a pleated paper filter element in the form of a flat panel. This filter is usually placed inside a plastic box connected to the throttle body with an intake tube. Pleated paper filter elements are the nearly exclusive choice for automobile engine air cleaners, because they are efficient, easy to service, and cost-effective. A paper for air filters needs to be very porous and have a weight of 100 - 200 g/m^2. Normally long fibrous pulp is used to get these properties. The paper is normally impregnated to improve the resistance to moisture. Computational Fluid Dynamics (CFD) is considered to be the most cost effective solution for flow analysis of intake system along with filter media.

2.0 Literature

2.1 The Engineering Database

The engineering database is based on information from the Solid works simulation processor with unit system in SI (m-kg-s) of which the analysis type was internal and cavities excluded while the co-ordinate system was global in the x- axis.

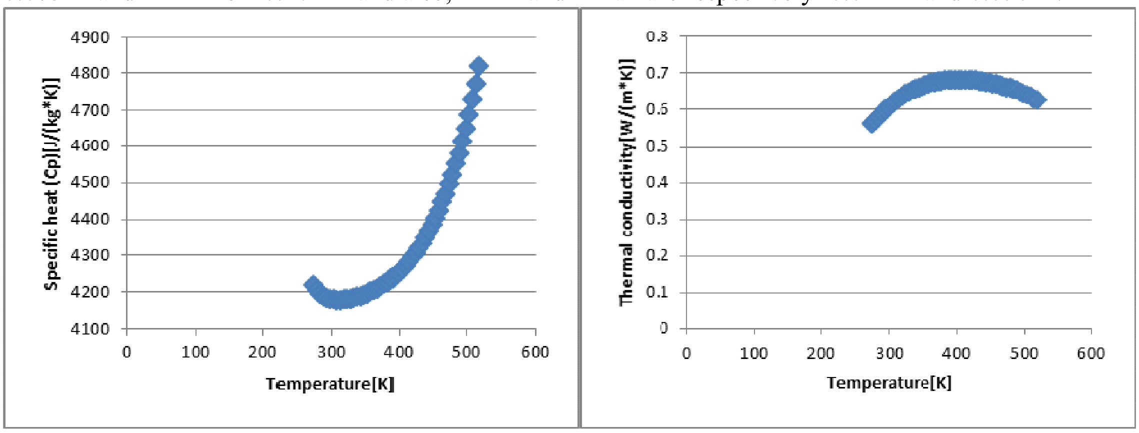


(a) Density vs. temp *(b dynamic viscosity vs. temp)*

Figure 1: effect of density and dynamic viscosity

In figure 1, the density would have dropped to 800 kg/m^3 from 1000 kg/m^3 if temperature had risen from 200 ^{o}C to 500 ^{o}C, but we know that the water is at atmospheric temperature of 20 ^{o}C it is not possible to reach that temperature, therefore density is constant.

Initial settings of mesh were turned on of resolution3 status with minimum gap size and minimum wall thickness in automatic mode. The computational domain in x-axis between 0.037 m and -0.059 m; Y- max is 0.073 m and Y-min is – 0.101 m and also, z-min and z-max are respectively -0.041 m and 0.056 m.



(a) Specific heat vs. temp *(b) thermal conductivity vs. temp*

Figure 2: effect of specific heat and thermal conductivity

There are no heat additions and subtractions from the system while the flow type is laminar with initial conditions of static pressure at 101325 Pa and temperature of 293.2 K therefore, even though the graph showed this, it is not possible to reach that limit as shown in figure 2.

Fluid type is water, at a mass flow rate of 0.688 kg/s having a turbulence parameter of 2 %, global goals of average static pressure, mass flow rate and average velocity were used. For the basic mesh dimensions, the number of cells in the X, Y and Z axis were 10, 20 and 10. The number of total cells was 51889, fluid cells were 17599, solid cells were 10359, partial cells were 23931 and irregular cells were none.

Table 1: Excel- generated goals

project work.SLDASM [project work]

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Av Static Pressure 1	[Pa]	130987.6648	131000.9547	130987.6648	131014.7676	100	Yes	27.10287031	218.560859
GG Max Static Pressure 1	[Pa]	149385.4772	149214.6289	148990.8969	149628.6044	100	Yes	637.7075324	674.6286527
GG Mass Flow Rate 1	[kg/s]	-1.9055E-07	-1.78365E-06	-5.63986E-06	8.16615E-07	100	Yes	6.45647E-06	0.016965674
GG Av Velocity 1	[m/s]	0.493488312	0.497440161	0.493488312	0.500266845	100	Yes	0.006778533	0.008749398
GG Max Velocity 1	[m/s]	9.453188254	9.440179416	9.426446662	9.453974478	100	Yes	0.026075559	0.050276386

Iterations: 105
Analysis interval: 38

The goals in the table 4 above were generated from 105 iterations at 38 intervals. It shows the maximum, minimum and average values for Global goals of the average and maximum static pressures, mass flow rate, the global goals for average and maximum velocities of the filtration system.

2.2 Analysis of the filtration

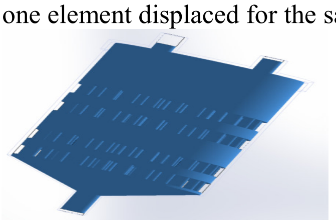
Membranes were used for the separation of substances by the application of an applied force to a semi-permeable material across it and the extraction of micro- organisms, particulates, bacteria, colour, odours, tastes, and particulates. Ultra-Filtration membrane pore sizes of about 0.002 microns to 0.1 microns [i.e. taking one micron equal to 0.0001 millimetres] at a pressure of between 30 PSI to 100 PSI [2.00 bars to 7.00 bars] therefore, micro-filtration (MF) 0.03 to 10 microns with feed-water pressure of 15 to 60 psi [100 to 400 kPa]), Nano filtration (NF) 0 to 0.001 microns with operating pressures of 90 to 150 psi [600 kPa to 1000 kPa] will remove all bacteria species without chemicals. From the pore sizes (0.005 microns) used, the conclusion is drawn that the bacterial/ viral pollutants have been removed as suggested by Sutherland, (2008).

Maximum velocities from hand calculations were 20.56 m/s while it was 9.392 m/s from flow simulation which again confirms the design being within the limits. Outlet was at atmospheric values indicating. The system should cause less differential pressure, provide enhanced dirt hold capacity, and deliver maximum filtration efficiency. Filtrate has managed to devise new filter concepts that offer advantages in terms of all three of these parameters.

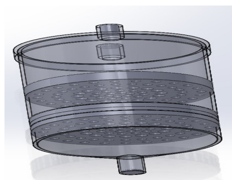
3.1 System Results

3.2 The Floxpress Results

In the FloXpress analysis, the geometry was checked to mean fluid touching all the surfaces of the vessel after which fluid volume is displayed and water chosen as the fluid flowing through the model. The figure 3 (a) shows how the checked geometry looked like while in figure (b), the assembled filter in transparent mode is shown with one element displaced for the sake of clarity.



(a) Testing the geometry

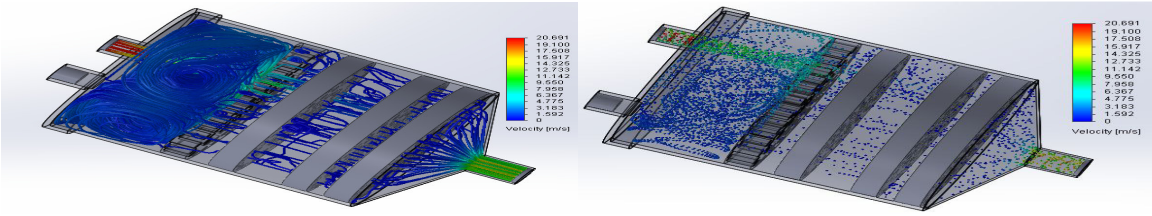


(b) filter before FloXpress analysis

Figure 3: checking the geometry

Pressure, volume flow rate and mass flow rate options were available but mass flow rate for the inlet of the container was chosen from the hand calculations as 0.68797 kg/s at ambient temperature of 293.2 K (20 ^{o}C). For the outlet of the vessel, pressure of one atmosphere (101325 Pa) was selected because it exits to the atmosphere.

The system now solves the model, and whether pipes or balls are selected, the desired image is displaced. The images obtained are often used to analyse quantitative flow giving an insight into the particle trajectory inside the model as in figure 4. However, to obtain detailed results with respect to flow rate, pressure drop, etc., then the model must be run using flow simulation.



(a) Using pipes to demonstrate the flow *(b) using balls to demonstrate the flow*

Figure 4:floXpress simulation

The figure (a) above shows lines of the flux as the fluid filters goes through the elements creating a bulk at the top resulting in whirling/vortex type mixing. This can be explained to mean the bulk resulting from the difficulty with which the polluted water filters through the first element (the membrane). At the exit, we can find the balls following the defined trajectory in the form of laminar flow with nowhere showing turbulence. This confirms the adequacy of the design to have met all the parameters of a good design.

4.0 The Filtered Water

The findings obtained while determining the suitability of the designed filtration system and its further analysis are presented in this section.

4.1Treated / Filtered Water Raw Data.

In order to ascertain that the treated water had thecontaminantsremoved well enough to make the water wholesome, litmus paper was dipped into it and from the colours that came out (figure 5 (a)) and comparing to the scale provided (in fig. (b), the tap-water (sw) as the standard to compare with, while the filtered water (fw) was the objective to be achieved and the polluted water (dw) is the basis for which the project was carried out.Table 5 shows the obtained value for tap water, filtered water and the polluted water to provide a basis for comparison of the results.

(a) Litmus paper dipped into fluids *(b) scale to compare with*

Figure 5: Test results

Dipping the litmus paper into the three liquids: the tap water, **sw** (as the standard), the filtered water, **fw** and the dirty/ polluted water, **dw** where the above colour changes took place and when compared with the scale, the obtained readings are shown in the Table 5 below:

Table 5: Test results

	Standard water (sw)	Treated water (fw)	Dirty water (dw)
Chlorine	0.8	0	7.1ppm
pH	6.8	6.4	8.84
Turbidity	1 NTU	0NTU	10 NTU
Colour	12TCU	10	25
Hardness	145 mg/L	140mg/L	186mg/L
Heavy metals	0.05mg/L	0.05mg/L	0.5mg/L
Nitrate	10.0mg/L	10.0mg/L	15.0mg/L

4.2 Analysis of the filtered water

Comparing the values, it will be realised that chlorine content in the tap-water was 0.8, but that of the treated water was zero (0) while for the dirty water, it is as much as 7.1. It is obvious (as shown in figure 6) that there was no contact with chlorine in the model filtration system hence its being zero reading is justified.

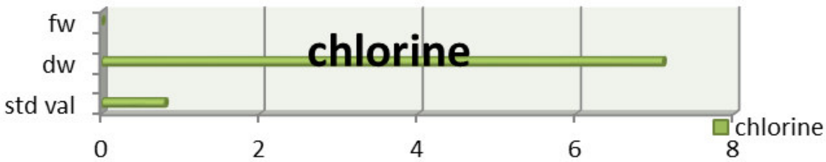


Figure 6: relationship between chlorine levels

Again, the difference between 6.8 and 6.4 for the pH is within the tolerable range for potable water (SCDHEC, 2009),whilst the 8.84 for the dirty water is beyond the acceptable level as shown in figure 7 hence, this must not be used for drinking.

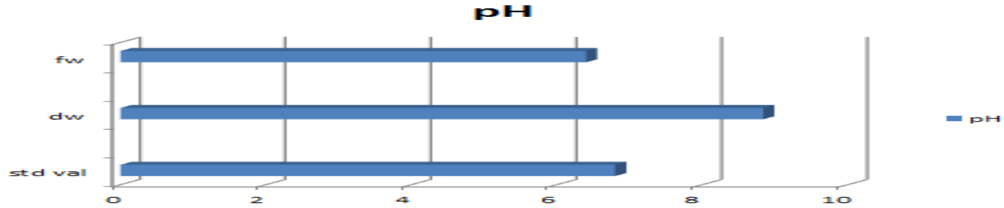
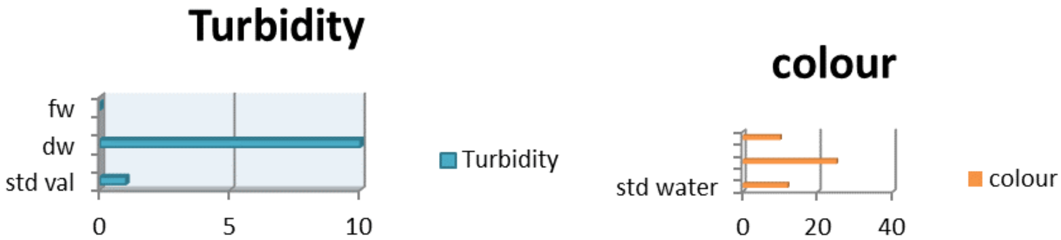


Figure 7: relative sizes of pH

Turbidity in the treated water was 0 NTU whilst that of the standard water was 1NTU, this could be attributed to scale, corrosion and infiltration due to leaky joints of the piping network as shown in (a) below. Values for colour were also 25 TCU for the dirty water, 10 TCU for the treated water and 12 TCU for the standard water attributable to scale forming as a result of storage containment as shown in figure 8(b).



(a) Turbidity levels (b) colour levels

Figure 8: relative concentration levels for turbidity and colour

4.3 Activated Carbon

Activated carbons (typical sizes; 0.5 to 50 microns) used to break- down chlorine, remove odour and taste, and then adsorb organic material existing in small amounts. Made up of charcoals that are highly porous with 300 to 2,000 sq. m/ g of surface area, it entraps inside the pore pollutant molecules from the fluid. Filtering by carbon is applied in air purifiers, water purification, gas processing of industrial volumes, and also in the removal of volatile organic compounds with its efficiency mainly determined by flow rate. They come either as powdered block filters or in the granular form as shown in figure 9.

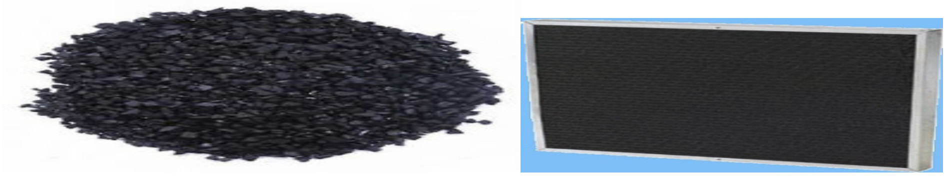


Figure 9: activated carbon
Source: Water Ionizers Station, 2013

4.3.1 Zeolite

Zeolites (pore size: 4x 10^{-10} m) are hydrated alumina-silicates of the alkaline- earth and alkaline metals (shown in figure 10) which come as synthetic and natural zeolites that find use as a result of the unique absorption, ion exchange, molecular sieve and catalytic properties. Known types are the chabazite, clinoptilolite, laumontite, phillipsite, analcime among others and are applied in odour control and animal nutrition supplements. It is applied in water filtration systems for the absorption of potassium permanganate and in cases where turbidity is reduced by 50 % to replace sand filtration beds, increased flow rates and reduced backwash requirement (Virta, 2004).

(a) Apophyllite (bchabazite

Figure 10: zeolite
Source: Virta, (2004)

4.3.2 Membrane

Membranes (pore size: 0.1 µm to 8 µm)are used for the prevention and passing through of very tiny particles with the aid of very fine pores as shown in figure 11.It has high porosity and purity, composed of cellulose nitrate or acetate although ceramic and polymer are employed for the conservation, reuse and cleaning of communal and industrial wastewater applications which is characterised by most uniform surfaces but the removal of particulate material is by pore size rather than the mass or weight of the particulate. pH figures from zero to fourteen (0 to 14) can be withstood while polymer membranes are capable of handling narrower ranges.Its use brings improved cost and process control while enabling efficiency in maximum viral filtration requiring no cleaning and validation.

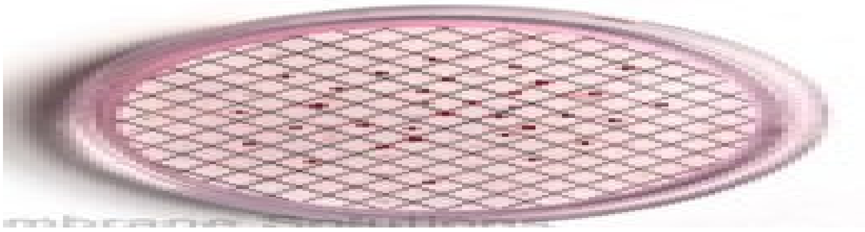


Figure 11: a membrane
Source:AMTA, 2013

4.4.1 Ion Exchange Resins

Ion exchange resins shown in figure 12 (supplied in 2 or 5 L bag) are made of synthetic resins that can be charged negatively as the case with alkalinity (for hydroxide ions) and in water, swap substances like metals that are positively charged for acidity (hydrogen ions). The elements have limited capacity to the amount of trace substances that can be absorbed and if stretched through continued use, may release them back into the filtered water. Filter elements must be replaced periodically to avoid this.

Figure 12: ion exchange resin
Source: Aqua Chem, 2013

It is employed as a softening agent by replacing sodium ions with the calcium and magnesium present through regeneration which must be done periodically for maximum efficiency. They also remove chlorine, bad odours, softening of hard water, and the removal of heavy metals.

5.0 Conclusion

The study provided a baseline for evaluating filtration systems used in achieving WHO stringent standards to safe drinking water quality. The study's major findings were as follows:

1. The dilution of the refinery wastewater did not significantly affect the concentration levels known to cause negative health effects.
2. The process of ion exchange resin, zeolite, and activated carbon reduced greatly the levels of hardness, turbidity, odour, taste, pH, chlorine, and colour of the treated water from the prototype.
3. The Solidworks modelling and CFD/floXpress simulations proved powerful tools for designing and

analysing the flow inside a solid body.

The call to responsible behaviour to the environment couldn't be stressed any further than when at a meeting with the Parliament of Ghana, the CEO of the Forestry Commission hinted "the eminent drying- up of water bodies which could result in Ghana importing water in 23 years' time" (myjoyonlinenews, 2013). Therefore policy makers should consider sustainable ways of providing safe-water for the citizenry.

References

Govi, K, D., Gablah, P, G., (2015) Determining the Characteristics of Diluted Wastewater in the Lagoon, Journal of Resources Development and Management, Vol.14, November -2015,. pp .71-77

MYJOYONLINENEWS (2013)*"Ghana may import water by 2036 if …"* (online) Available at: http://edition.myjoyonline.com/pages/news/201308/112141.php?storyid=112141 [Assessed on: 27 August 2013]

SCDHEC, (2009) *"Drinking Water: Common Water Quality Problems and their Treatment"*[pdf] Available at:https://www.scdhec.gov/environment/water/dwor/docs/WQproblems_Full.pdf[Assessed on: 4 September 2013]

UK FSA (2002) *"Guidance on food served to older people in residential care"*[pdf] Available at: http://www.food.gov.uk/multimedia/pdfs/olderresident.pdf [Assessed on: 19 July 2013]

USEPA (2009) *"National Primary Drinking Water Regulations"*[pdf]Available at: http://www.epa.gov/safewater/consumer/pdf/mcl.pdf[Assessed on: 3 September2013]

Wang, L.K., (2004) "*Handbook of Industrial and Hazardous Wastes Treatment*"2 ed. New York: Marcel Dekker, Inc