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Application of Solid Works Computer Software on Treatment of Water Samples

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ABSTRACT

The focal point of the study is based on analysing the mixing rate, pressure drop and other thermodynamic properties of water sample and disinfectants in water treatment process with the aid of Solid works simulation tool. It is imperative to critically examine this concept because of the incompatibility of mixing two or more fluids mostly liquid together. The technological idea behind this research is to create and maintain hygienic water distribution system to the society through engineering philosophies. The significance of the study cannot be over emphasized. All efforts to combat this dreading global fight are on the shoulders of researchers. However, the paper is aimed to compare different water samples with the help of a designed water treatment plant using Simple Osmotic Water Filtration Technology (SOWFIT) with an aided Solid works Simulation programme to analyse the mixture of disinfectant in the water sample selected. Meanwhile, laboratory test results were also obtained in the process and were compared to World Health Organisation's (WHO) standard based on their turbidity, hardness, conductivity, alkalinity, PH range, temperature, salinity, etc. Sample results from borehole were validated with WHO's values which makes it more considerate in selection with respect to other samples. The selected sample were further analysed in the Solidworks simulation tool to attest the mixing condition of the fluid, the necessary pressure drop and other thermodynamic properties. The results obtained confirm effectiveness of the software in respect of the objectives of the study.

Keywords *- Model, Osmotic Pressure, Pressure drop, Semi-preamble membrane, Simulation, Solidworks, Treatment plant.*

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I. INTRODUCTION

Water is one of the most essential facilities in life. Thus, due to its importance the pattern of human settlement throughout history has often been determined by its availability. In developing countries, several disease outbreaks are associated with the use of untreated surface water, contaminated well water, treatment plant deficiencies and infected distribution systems. The primary purpose of water treatment is to render the water fit for human consumption.

This requires the improvement of microbiological quality and the control of dangerous chemical substances and metals present in the consumable water [1, 2]. Therefore, meeting the goals for the production of clean, safe and maintaining aesthetic quality of water requires a multi-barrier approach that includes the protection of water source from contamination, appropriately treating raw water and ensuring safe distribution of treated water to consumer taps. Hence, the treatment requirement for potable water supply in rural areas will depend on water quality and the quantity required, and variation in quality of the source.

The task to fulfil the goals above is the objective of the research study, because statistical data unveils from study indicates that 11.4 out of 39.5 million of the population of Sudan do not have access to improved drinking water. This has resulted to the death of one (1) out of every four (4) children at the age bracket of five (5) from kidney failure and diarrhea diseases which has been very common in recent years [3]. A review literature shows that an estimated value of 1.1 billion of the world's pollution drinks unsafe water which has led to about 89% of diarrhoea disease circulation around the globe. Also approximately 3.1% of annual deaths and 3.7% of annual health burden world-wide are attributed to unsafe water consumption, poor sanitation and hygiene [4 ,5]. This danger mostly engulfs the rural dwellers.

It is reported in a research studies that, the non-existence or poorly developed water network has upshot to the transmission of waterborne and enteric diseases such as cholera, shigellosis and Campylobacteriosis, typhoid fever and dysentery [6 – 9]. It is surprising to note that cities and nations along the coastal line, for instance

Khartoum City – the capital of Sudan situated on the river Nile experience shortage of drinking water up to 400,000 cubic meters per day [4]; also in the South – South region of Nigeria, Bayelsa State in particular which is surrounded with water still lack portable drinkable water from the part of the government. These demands of water by the citizens of the said area voluntarily pay 15 – 20% compulsory tax to water vendors from their monthly income to buy water without treatment of any kind due to lack of well design water treatment plant.

Thus, the focus of a well design water treatment plant is to overcome all the challenges to maintain quality water. Therefore the technological strategies to monitor and continuous control of the pathogens and other related water borne diseases is a major target. In view of this, brilliant literatures which expose the simple, economic and rapid technique for high frequency and basic monitoring of water quality and the efficiency of treatment systems to enhance microbiological quality is considered [1]. Also, recent studies unveil the need for the use of disinfectants which is capable of removing or inactivating pathogenic organisms and preventing recontamination [10].

Thus, the need to procure small equipment attached to individual home use water supply, distribution and storage tank is a key focus in this study. Hence, a new sampled technological idea for water treatment plant with the aim of increasing water quality is analyzed on solidworks model/simulation software. The proficiency of this tool is displaced in the achieved results because of its capability to determine the mixture of fluids, their pressure drops, mass flow rate, density, and other thermodynamic properties of the fluid.

II. TREATMENT PROCESS

The reduction of microbial and chemical ingredients in water depends on treatment techniques applied. Meanwhile, different scholars have proof that the use of a conventional treatment plant that had not been optimized has contributed to several disease outbreaks and the physical and bacteriological contamination of water makes it unsafe for domestic use unless reliable treatment, including filtration and disinfection, is provided [11, 12]. Hence, study carried out also ensures the following practical techniques; coagulation, flocculation, sedimentation, filtration and disinfection. These processes were performed in the chemical laboratory of Niger Delta University, Wilberforce Island.

III. SAMPLING TECHNIQUE/METHOD

Four (4) different water samples were selected to be analysed in a prescribed water treatment plant. They are water sample from the pond, river, borehole and rain. Tests were run with and without the application of treatment technique based on World Health Organisation's (WHO) standard for temperature, conductivity, PH-value (acidic or alkalinity test), salinity, total dissolved solid, turbidity, total suspended solids, nitrate, atomic absorption spectrometry, Sulphate, Chloride, etc. for two weeks (14 – days) to obtain optimal results for analysis.

IV. DESIGNED WATER TREATMENT PLANT

The lack of potable water is an important challenge facing the under developed nations; based on that a simple water treatment mechanism is setup to reduce such complications which will be cost-reductive, reliable and eventually produce a satisfactory drinking water that is free of microbial diseases. The methodology employed for the equipment is Simple Osmotic Water Filtration Technology (SOWFIT). The implied technology is as a result of the osmotic pressure involved in the system which is a phenomenon or tendency of a pure solvent to move through a semi-permeable membrane to a solution containing a solute to which the membrane is impermeable. The process is capable of removing most sediments and particles as well as bacteria, viruses, cryptosporidium; because the machine is designed with a pneumatic disinfectant component where chlorination and other chemicals/reagents are sprayed periodically to the rotary fluid (water) before passing through the membrane walls and that take cares of all micro-organisms. Figure 1 below is a schematic diagram demonstration of the treatment plant designed in AutoCad windows.

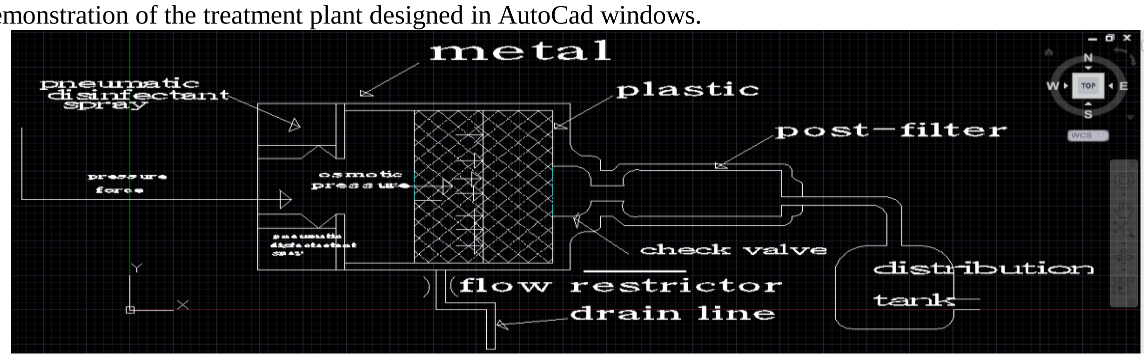

Figure 1. Simple Osmotic Water Filtration Technology [SOWFIT]

4.1 DESIGNED SPECIFICATION AND ANALYSIS

4.1.1 PRESSURE FORCE

A pressure force is required to push the fluid via the semi-preamble membrane, and it could best determined by the location of the machine from the receiving water tank connected to it. Mathematically, the pressure force is illustrated in (equations 1-3):

$$\text{Pressure, } P = \frac{Force}{Area} \quad \ldots\ldots 1$$

$$\text{Area, } A = \frac{\Pi d^2}{4} \quad \ldots\ldots 2$$

$$\text{Force, } F = Pressure \times Area \quad \ldots\ldots 3$$

Where, pressure is measured in pascals (Pa) or Newton per meter square (Nm^{-2})

4.1.2 OSMOTIC PRESSURE

In order to calculate the Osmotic Pressure of an aqueous solution, we need to know the molar concentration of the dissolved species.

4.1.3 FLOW RESTRICTOR

The flow restrictor is designed to maintain the flow rate required to obtain the highest quality of useable water (based on gallon capacity of the membrane). It also helps to maintain pressure on the inlet side of the membrane; without the use of this device, very small quantity of water would be produced due to divert in flow path down the drain line.

4.1.4 CHECK VALVE

The check valve is capable of preventing the backward flow of fluid (water) from the distribution tank because a backward flow could rupture the process.

Thus, the governing equations for Osmotic Pressure, Π (Pi), Flow Restrictor (Q), and Check Valve is presented in (equations 4 – 8):

$$\text{Osmotic Pressure (Pi), } \pi = MRT \quad \ldots\ldots 4$$

$$\text{Flow Restrictor, } Q = K(r) \times A(r) \times \Delta P^n \quad \ldots\ldots 5$$

$$\textit{For Laminar:- } K(r) = \frac{d(r)^2}{32\mu l} \quad \ldots\ldots 6$$

$$\textit{For Turbulent:- } K(r) = C(d) \times \left\{\frac{2}{\rho}\right\}^{0.5} \quad \ldots\ldots 7$$

$$\text{Check Valve; } K_1\left(\frac{c+2a}{dia}\right) + K_2\left(\frac{D}{\frac{\Pi dia^2}{4}}\right) = K_3 \quad \ldots\ldots 8$$

4.1.5 POST FILTER

The post filtration chamber is responsible of taking care of the final filtration processes before allowing the fluid to the distribution tank. At this point all the remaining tastes and odour is removed.

4.1.6 DRAIN LINE

Through this compartment of the system all impurities and contaminants found in the fluid are disposed. It runs from the outlet end of the Osmotic Water Filtration membrane housing to the drain. There is also an installation of the flow control valve along the line.

V. ANALYSIS WITH SOLIDWORKS

Solidworks determines the impact of fluid on product performance which is capable of analyzing the fluid mixture of different fluids mixed in a project. It is used in this study to analyze the mixture of the disinfectant (chlorine) and water at the entrance of the treatment plant to determine how well the fluids were mixed together before passing through the semi-permeable membrane unit, and also to evaluate their pressure drops, monitoring the fluid solution progress, mass flow rate for inlet and outlet fluid, density, viscosity, and other thermodynamic properties of the mixed fluid in question.

The simulation tool was used in modeling the cross pipe model shown in figure 2 below which represents a cut out view of the entrance of the treatment plant where the disinfectant is sprayed periodically into the pass-away of the water treatment plant before the housing of the semi-preamble membrane. At the openings of the pipe is three inlet of fluid; one is for water (H_2O) and the two opposite for Chlorine (Cl_2) with an outlet of their mixture ($t_{max\ -\ outlet}$). Meanwhile, a mesh file was equally created for the model at the result and geometry resolution wizard to ensure good mesh quality which is very important for getting a converged accurate solution of the mixed fluid. However, at the flow simulation analysis tree; the computational domain, fluid sub-domain, boundary conditions and engineering goal were all set to accommodate the end results of the objectives of the research as shown in figure 3 and 4 respectively. Thus, results for this analysis are discussed in subsequent section.

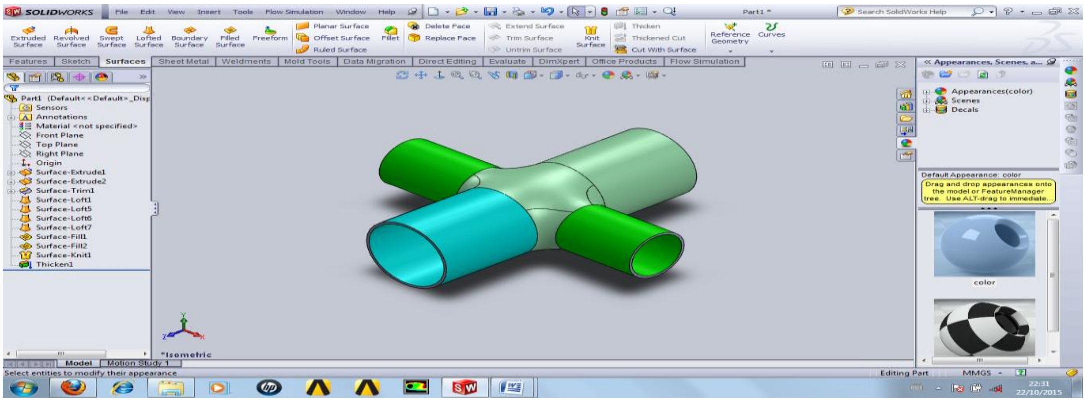

Figure 2. Cross pipe representation of disinfectant and water mixture

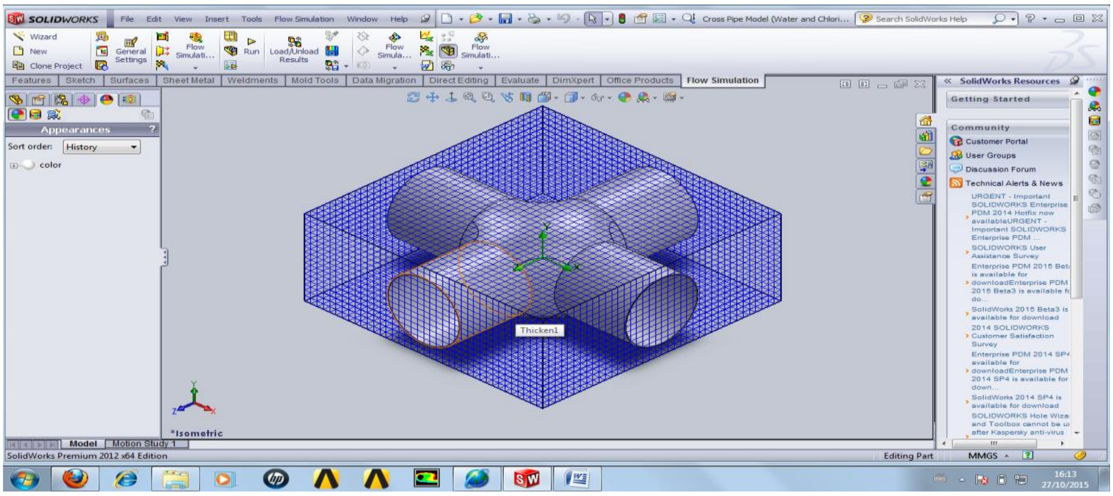

Figure 3 Cross pipe representation of disinfectant and water mixture

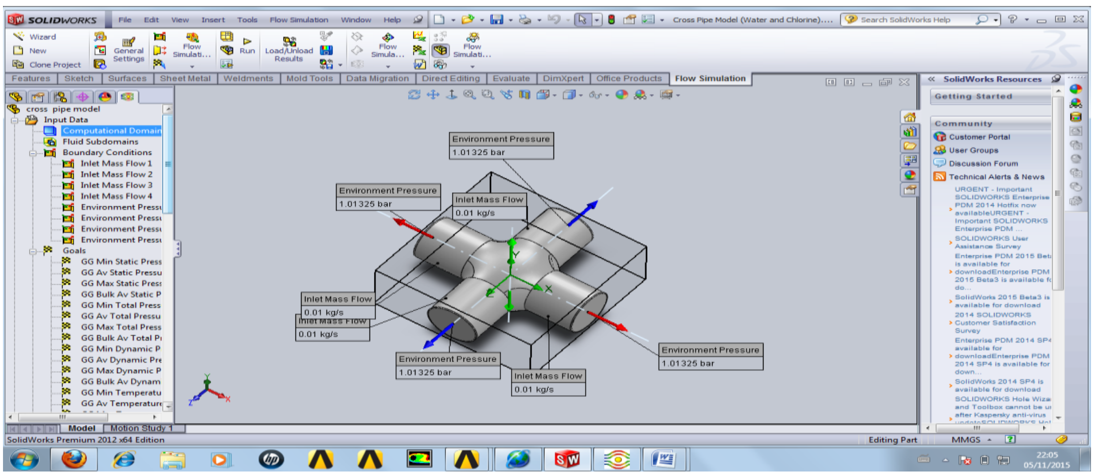

Figure 4 Display of callouts, Computational domain and Boundary Conditions

VI. Chemical Reaction of Chlorine and Water

The obtainable products when Chlorine dissolves in water are mixture of hydrochloric acid and chloric(I) acid (hypochlorous acid). This is a reversible reaction which is bound to produce a greenish solution. Meanwhile, a reviewed literature reveals that the exposure of hypochlorous acid to sunlight rays will gradually decompose in producing more hydrochloric acid, releasing oxygen gas [14]. The chemical equation for the reaction process is presented below in (equations 9 – 10):

$$Cl_2 + H_2O \leftrightarrow HCl + HOCl \quad \ldots(9)$$

$$2Cl_2 + 2H_2O \rightarrow 4HCl + O_2 \quad \ldots(10)$$

Thus, the hypochlorous acid (HOCl) produced from the reversible equation is a strong disinfectant and its dissociation in water forms hydrogen ions and hypochlorite ions as shown in the (equation 11):

$$HOCl \leftrightarrow H^+ + OCl^- \quad \ldots(11)$$

Study exposed that the rate of dissociation of HOCl depends on the pH levels as well as the temperature of the water. This two parameters are determining factors based on WHO's requirement for clean water which is always at the range of 7.0 – 7.8 and 25℃ respectively [5, 13 – 15]. However, the rate of dissociation increases at a higher pH and, since HOCl is a stronger disinfectant than the hypochlorite ion, it is advisable to maintain pH at lower levels. Therefore, this was considered in the laboratory assessment of the different water samples under study.

VII. Presentation of Result

Tables 1 and 2 shows a laboratory test results presentation of the four different water samples analyzed in the illustrative water treatment plant. Also obtained data from each of the sample were compared with the required WHO's standard for further discussion. However, a detailed analysis of the fluid flow disinfectant (Chlorine) and Water (H_2O) mixture result from solidworks is presented as well.

After a complete project modeling processes, flow simulation was launched to configure the model against the basic requirement to simulate the model on the flow simulation analysis tree in order to determine how well the fluid is mixed before going through the semi-permeable membrane, its pressure drop, mass flow, and other vital thermodynamic properties of the fluid were considered and analyzed. Again, the engineering goals and flow trajectories were defined and results are presented in figures 5 – 8.

Table 1 Test Result without Treatment Technique

Samples	Temp (0C)	PH - Value	Salinity	Conductivity (uscm^{-1})	Turbidity Ntu	Total Dissolved Solid (ppm)	Total Suspended Solid ppm)	Total Alkalinity	Total Hardness	Iron (Fe)
Rain Water	17.3	4.7	0.0	17.4	0.3	34.0	0.4	5.1	1.4	0.0
River Water	17.2	4.8	0.0	25.5	13.4	78.0	2.5	1.2	2.0	0.0
borehole	16.5	4.7	0.0	86.7	10.2	253.5	0.8	5.3	2.6	0.1
Pond Water	16.8	4.9	0.0	77.5	10.3	234.0	1.8	1.0	3.8	0.1
WHO Standard	25.0	7.0	0.1	200.0	15.0	500.0	0.2	10.0	5.0	0.3

Table 2 Test Result with Treatment Technique

Samples	Temp (0C)	PH - Value	Salinity	Conductivity (uscm^{-1})	Turbidity Ntu	Total Dissolved Solid (ppm)	Total Suspended Solid ppm)	Total Alkalinity	Total Hardness	Iron (Fe)
Rain Water	26.5	7.2	0.0	26.8	0.5	52.3	0.5	7.9	2.2	0.0
River Water	26.4	7.4	0.0	39.2	20.6	120.0	3.9	1.9	3.0	0.1
borehole	25.8	7.6	0.0	119.2	15.8	360.0	2.8	1.5	5.8	0.1
Pond Water	25.3	7.2	0.0	133.4	15.7	390.0	1.2	8.1	4.0	0.2
WHO Standard	25.0	7.0	0.1	200.0	15.0	500.0	0.2	10.0	5.0	0.3

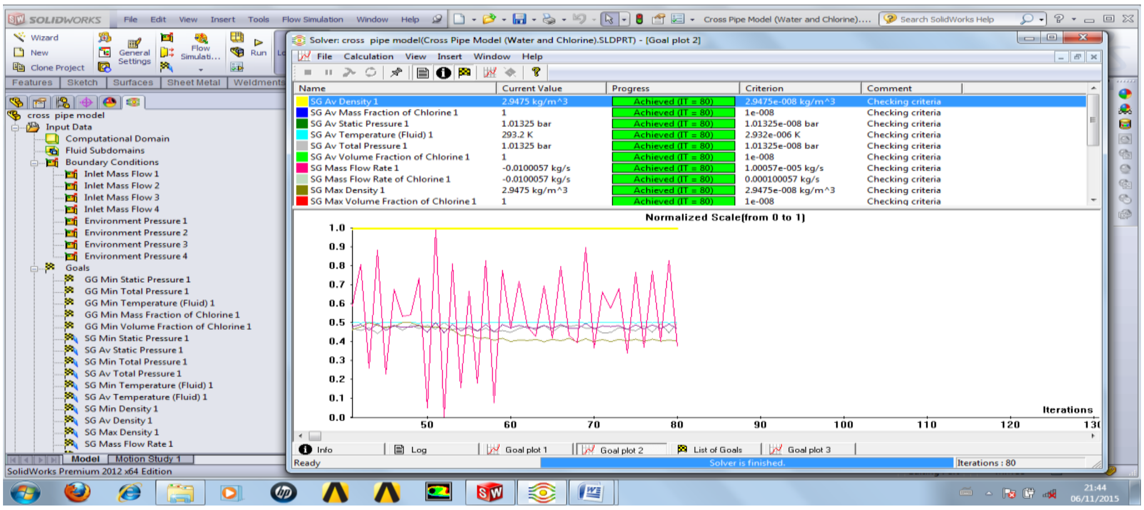

Figure 5 Engineering volume goals insertion results

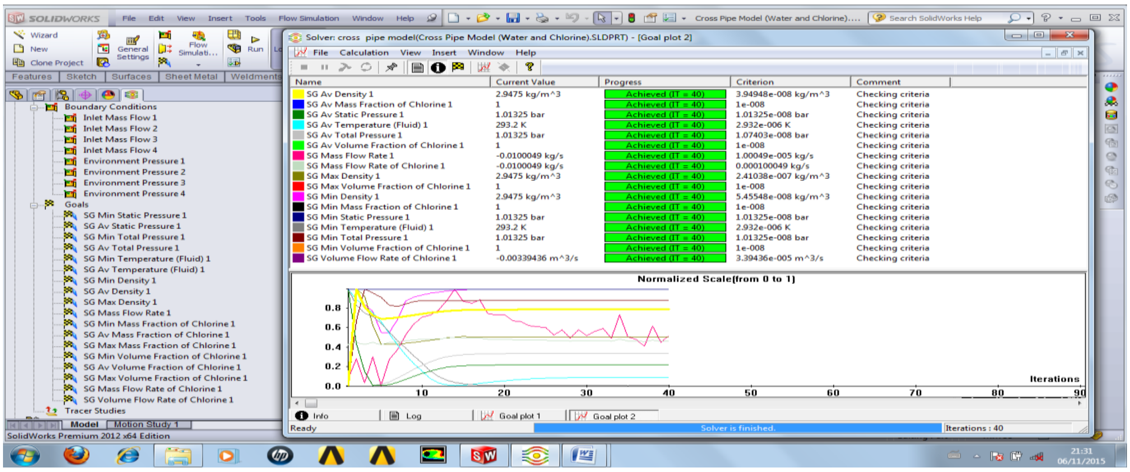

Figure 6 Engineering surface goals insertion results

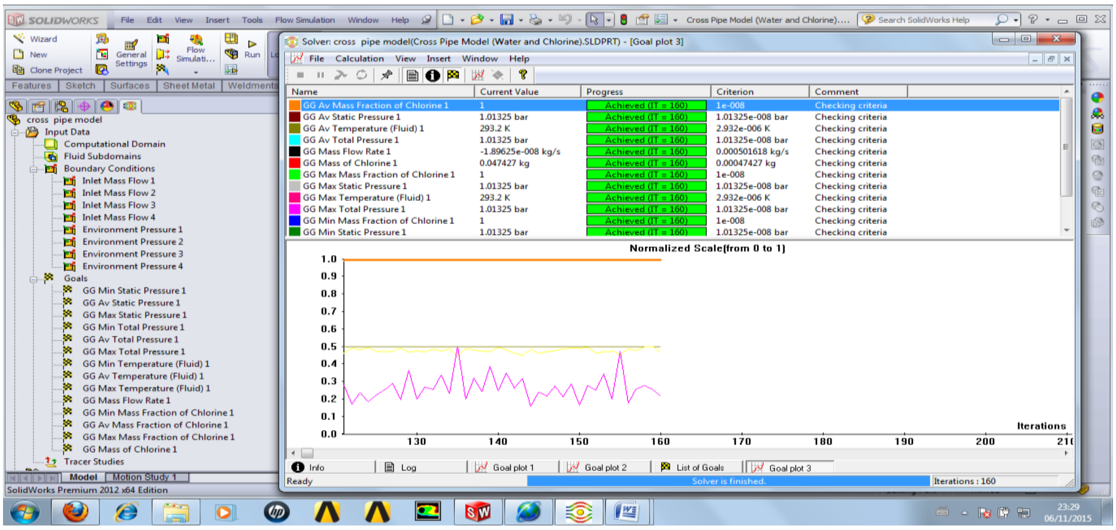

Figure 7 Engineering global goals insertion results

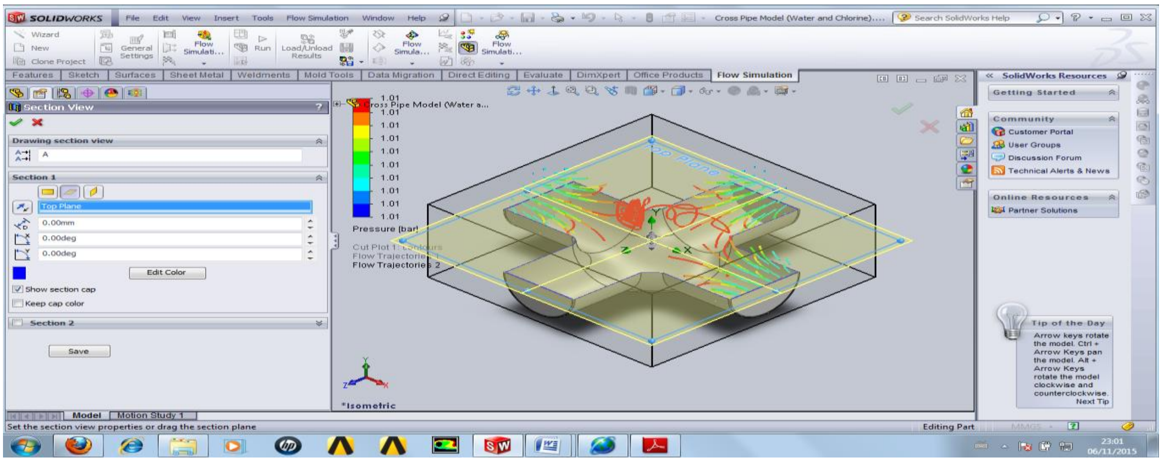

Figure 8 Engineering global goals insertion results

VI. Discussion of Results

Test results displayed for the samples in figure 9 and 10 are in terms of World Health Organization's standard for the determination of clean water. They are the temperature, P^H – value, salinity, conductivity, turbidity; total dissolved solid, total suspended solid, total alkalinity, total hardness, etc. After close comparison with the WHO's values, water sample from the borehole which seem to be the closer sample to WHO's values is about 8% more than its rival for total dissolved solid and conductivity; and over thrice more than other samples respectively. All samples seem to meet WHO's standard for water temperature, P^H –values, total alkalinity, total suspended solid, hardness, etc except rain water with a turbidity value of 0.5

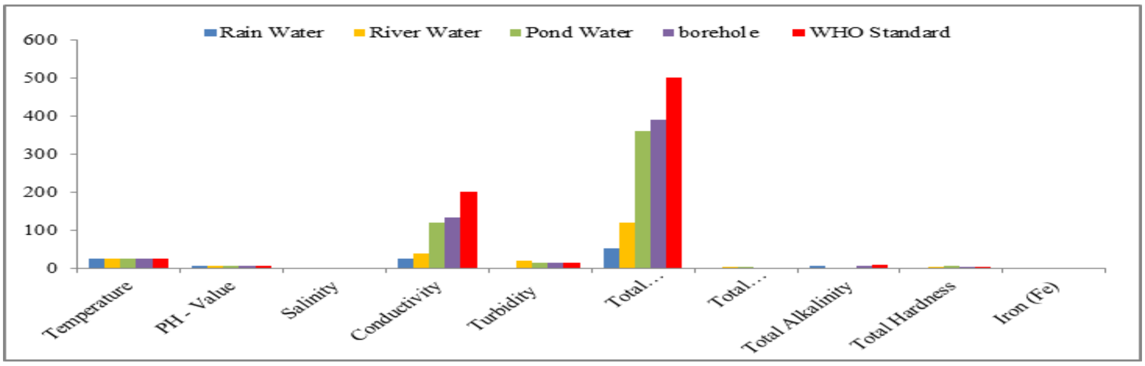

Figure 9 Test Result with Treatment Technique

Another comparison is the results without the application of treatment technique shown in figure 10; a close observation gives a clear gap between the samples and the corresponding WHO's values. Hence, the application of the technique in the study is very obvious and the effect of the process over the water samples is about 65% increment from analysis.

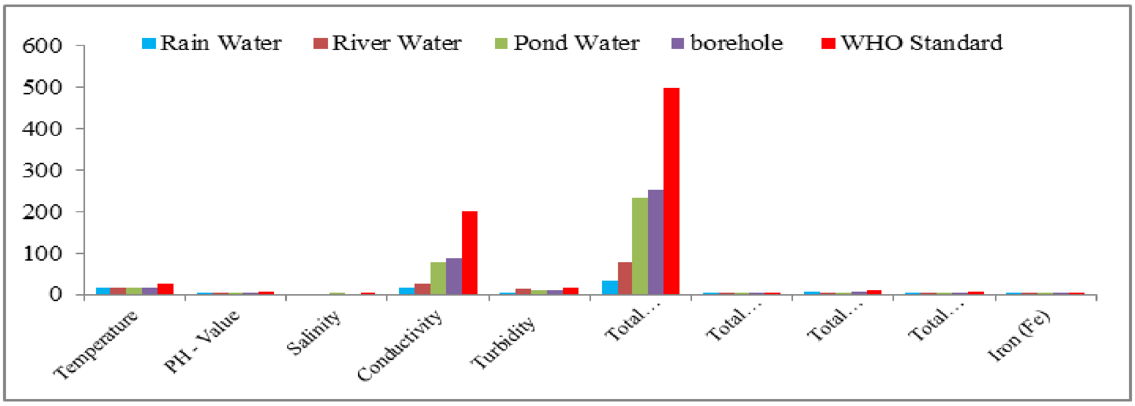

Figure 10 Test Result without Treatment Technique

From the solidworks results presented, the different goals take different number of iterations to converge. The goal-oriented philosophy of flow simulation allows the user to get the needed result in the shortest amount of time. Goal progress bar is a qualitative and quantitative characteristic of the goal convergence process. When flow simulation analyzes the goal convergence, it calculates the goal distribution. This parameter defines the difference between the maximum and minimum goal values over the analysis interval considered from the last iteration and compares this dispersion with the goal's convergence criterion dispersion, as a fraction of the goal's physical parameter dispersion over the computational domain.
Hence, results indicates 80 – iterations, 40 – iterations and 160 – iterations for volume goals, surface goals and global goals respectively which was converged with an Achieved progress bar at the end of the simulation. However, only few flow trajectories are noticed which results to low level of fluid velocity enabling good mixture of fluid. Finally, the amount of pressure drop as analyzed by the simulator is negligible as indicted in the presented spread sheet result of the thermodynamic properties of the fluid in the appendix.

IX. Conclusion

To justify the findings of the research study; results from the laboratory test for the four water samples were validated with the standard values of World Health Organization on clean water as established in the open literature. Sample from the borehole having a close match with WHO's values were analyzed in Solidworks to evaluate further performance and the compatibility of the fluid mixture with the simulation tool. The following were established:-

- The mixture of the fluid (water and chlorine disinfectant) were mixed properly to enable the disinfectant improve the microbiological quality of the consumable water by the eradication of dangerous chemical substances and metals/irons present in it.
- The pressure drop of the fluid is negligible; therefore no external pressure force needed from the storage to the distribution points.
- The temperature of the mixed fluid is considerable satisfactory based on WHO's standardization.

Therefore, the application of the simulation software to confirm that the mixture of the fluid in the enclosed pipe system is achieved, thus the effectiveness of Solidworks for analyzing fluid mixture is proven. Finally, it is suggested that in order to improve water treatment processes it is important to consider the pressure drop of the fluid and mixing rate or value of water and any disinfectant.

X. Acknowledgment

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Nomenclature

M = Molar concentration of dissolved species (molL^{-1})
R = Ideal gas constant
T = Temperature (°K)
Q = flow rate
$K(r)$ = flow coefficient
$A(r)$ = flow area
ΔP = pressure differential
n = exponent (0.5 for turbulent and 1 for laminar)
(r) = flow diameter
μ = dynamic viscosity
L = restriction length
$C(d)$ = flow coefficient (assumed to be 0.61 from experimental data
ρ = fluid density
D = minimum radial area between the seat and the sleeve
c = inside diameter of the sleeve
dia = diameter of the fluid passageway through the valve seat
a = radial thickness of the lower end of the guide sleeve wall and K_1, K_2 and K_3 are constants

References

[1] W. Grabow, Waterborne Diseases: Update on Water Quality Assessment and Control, *Water SA, 22 (2),* 1996, 193-202.

[2] N. J. Ashbolt, O.K. Willie, W. Grabow, and S. Mario, *Indicators of Microbial Water Quality Guidelines, Standards and Health*, (IWA Publishing, London, UK, ISBN: 1 900222 28 0, 2001)

[3] E. D. Morris, *Simple and Appropriate Methods for Household Water Treatment*, Utah State University, Logan, UT, MSc Thesis, 2001.

[4] H. G. Peter, Dirty Water: Estimated Deaths from Water-Related Diseases, *Pacific Institute Research Report,* 2002

[5] World Health Organisation, 2003, "Right to Water", Available at*: http://.www.whohealthorganisation.org*, (Accessed in November 2014).

[6] N.J. Ashbolt, Microbial Contamination of Drinking Water and Disease Outcomes in Developing Regions, *Toxicology, 198 (1-3),* 2004, 229-238.

[7] M.N.B. Momba, V.K. Malakate, and J. Theron, Abundance of Pathogenic Escherichia Coli, Salmonella Typhimurium and Vibrio Cholera in Nkonkobe drinking water, *Journals of Water & Health, 04*, 2006, 289-296.

[8] N. Muyima, and F. Ngcakani, Indicator Bacteria and Regrowth Potential of the Drinking Water in Alice, Eastern Cape, *Water SA, 24 (1)*, 1998, 29-34.

[9] C.L. Obi, N. Potgieter, P.O. Bessong, and G. Matsaung, Assessment of Microbial Quality of River Water Sources in Rural Venda Communities in South Africa, *Water SA, 28 (3),* 2002, 287-292.

[10] O. Hydes, European Regulations on Residual Disinfectant, *Water Works Assoc, 91 (1),* 1999, 70-74.

[11] USEPA, Optimising Water Treatment Plant Performance using the Composite Correction Program, *Environmental Protection Agency,* 1998.

[12] Anon, Surface Water for Rural Use, *Watertek Info*, 1995, 61-71.

[13] Z. Jie, E. Andrés, M.n Tejada, Z. Qiong, Developments in computational fluid dynamics-based modelling for disinfection technologies over the last two decades: A review, *J. Environmental Modelling & Software, 58*, 2014, 71-85.

[14] M. Pedram, *Fate of Chlorine in indoor Swimming Pools: A Numerical Modelling Approach*, University of Leeds, (UK), MSc.Thesis, 2010.

[15] WHO, Guidelines for Drinking Water Quality-Surveillance and Control of Community Supplies Geneva, *World Health organization,* 1997.

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