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Design and Simulation of Rotary Biological Contactor for Treatment of Industrial Wastewater using Aspen HYSYS

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ABSTRACT

*The design for the rotary biological contactor for the treatment of industrial wastewater using Aspen HYSYS was carried out. The design models were developed for the constituents of the rotary biological contactor which are primary **c**larifier, **s**econdary **c**larifier and four stage Bio disc. The models were simulated with the aid of a computer program developed using MATLAB & SIMULINK compiler. The data used for computations and simulation were obtained from the design in Aspen HYSYS simulation software which serve**d** as input to the computer program developed. The rotary biological contactor was also design using Aspen HYSYS simulation software and inputs to the design were from literatures of previous works by Tak-Wing (2000). It was observed that design results obtained after computation and simulation at various total flow**s** rate**s** gave a surface area of **2.45**m^2 for surface loading, **0.30**m for hydraulic load, **0.30**m/hr for hydraulic loading rate, **41.8**hr for hydraulic retention time, **0.66**m^3/hr/m for hydraulic load over weir and **2.29** mol/m^{2}hr for organic lording. These results would be good values of design parameters necessary for fabrication of the rotary biological contactor. Also, the mechanical design of the rotary biological contactor gave various thickness for cylindrical sections as 14.7mm for the each of the four bio disc (reactor) and **57.56**mm for primary Clarifier as well as secondary Clarifier. This thickness for cylindrical sections would be a good space for the material of construction which was carbon steel. The design cost of the rotary biological contactor gave **$91586** and **₦50372378** for each of the four bio disc (reactor) which were in dollar and naira respectively. The design also gave **$45961** and **₦25279046** for the primary and secondary Clarifiers which were in dollar and naira respectively. The design is cost effective with carbon steel as material for fabrication. Done was good and cost effective. The cost of the rotary biological contactor was cost effective. This means that the equipment(s) can be bought at cheap rate with carbon steel used as material of construction was a good one. The components treated were hydrogen sulphide, Sulphur, hydrogen chloride in waste water.*

Keywords: Rotary, Biological, Contactor, Treatment, Wastewater

1. INTRODUCTION

Wastewater pollution were a severe trouble, causing poisonous consequences to the human health and different dwelling organisms and the environment. Most pollutants ought to reason health issues at numerous level. In wastewater remedy, the biological approaches became the maximum extensively used in terms of monetary costs and environmental effect. but, the organic remedy was primarily based on suspended boom batch reactors consisting of activated sludge, trickling filters and rotating organic contractors (Ungureanu et al., 2018; Vugureanu et al., 2019).

Rotating biological systems with constant carriers were developed and used for wastewater treatment, but they were used in treating waste gasoline and fuel-liquid combinations. Wastewater remedy strategies would comply with requirements that ensure environmental protection, whilst the green to decrease socio-monetary burden (Ainger et al.,2009). The priorities for wastewater remedy (WWT) had been effluent pleasant, fee, electricity efficiency and nutrient elimination (STOWA, 2012). Regulatory organizations aim would be to improve neighborhood environmental health the use of superior kinds of WWT inclusive of biological nutrient elimination (BNR). To get exact effluent standards, conventional organic treatment became reliant on increasing power input thru extended reactor aeration or retention time (Ainger et al., 2009).

moreover, rotating organic contractors (RBC) were referred to as disc, surface, media and biofilm reactors changed into alternative to the activated sludge process. The RBC had a solid media that propel microbial growth in a static biofilm (Singh & Mittal, 2012). The RBC media changed into arranged in a series of plates or disc which rotates on a shaft through a biozone motor or air pressure (Patwardhan, 2003). The rotation results in bulk fluid blending, convection thru media pores, compound diffusion to the film, and product change with the reactor and environment (Rittman & McCarty, 2001).organic methods arise inner a set microbial biofilm, which includes components of lively and non-active biomass, biofilm extracellular matrix and debris (Arvin & Harremoes, 1990). The RBC combines bacterial boom and substrate utilization with a natural biomass separation system; the effluent excellent and manner stability turned into contingent on a sedimentation quarter.

The benefit of biofilm procedures, consisting of RBC became the mean cellular house time MCRT) was in coupled from hydraulic residence time (HRT). this could need higher natural loadings and resistance to poisonous shocks than suspended lifestyle systems (Najafpour et al., 2006 & Coprtez et al., 2008)

From the activities inside the industries, comes using water either for cooling and washing utilities or by means of the warmth exchangers for cooling plant centers. This water used generates in to waste water. also, business wastewater from numerous assets as refineries, LNG company, petrochemical flowers, and paint industries are deposited or disposed into rivers or water bodies. The disposals of wastewater generated have destructive effect at the health, flowers and fauna. therefore, the secure disposal of such waste water into land or water our bodies is the maximum tough project earlier than the engineer (Prashant et al., 2012).pollutants of both land or water our bodies from the disposal of wastewater can be decreased through the usage of processing method inside the waste remedy flora. Wastewater has unique elements which had been bodily houses such as colour, temperature, odours, and solids particles; whilst the chemical elements are surfactants, proteins, fat, oil, grease, phenol, heavy metals, pH, organic oxygen call for (BOD), chemical oxygen call for (COD), chlorides, pesticides, unstable natural compounds and many others.

additionally, biological components are animals, flowers and archaea bacteria, and many others care the radioactive elements as alpha and beta emitters. From the ingredients of wastewater we are able to classify it as low, medium exceptionally concentrated.

subsequently, wastewater is handled with number one, secondary and increase treatment strategies. The primary remedy strategies includes equalization, neutralization, screening, grit elimination, primary sedimentation, etc even as the secondary remedy technique consists of the organic and chemical treatment process. The advanced remedy process are denitrification, phosphorus elimination, carbon adsorption alternate, electro dialysis, opposite osmosis, sharpening pond, etc and the organic treatment method are: activated sludge technique, tricking filters, oxidation ditch, aerated lagoon, stabilization pond, rotating organic contactor (Met Calf et al., 2004)

The RBC changed into used for business wastewater remedy. The RBC was originated after which thousands of such units running global. RBC gadgets will be designed for each natural carbon removal and nitrification. The RBC operates for the duration of its life, besides a wreck in operation would bring interest via the operator to keep effluent consent standards. Failure to meet consent standards could have disastrous consequences for life.

The rotating organic contactor (RBC) was first installed in West Germany in 1960; it became later added to america North the us and would be used on this studies work. A rotating biological contactor changed into an cardio constant film shifting mattress organic remedy (Waskar et al., 2012).The mechanisms of the organic rotating contactor are:

I. Oxygen absorption on the liquid film flowing over the cube’s floor for the duration of the air exposure cycle.

II. Direct oxygen transfer at the air reactor liquid interface, with this diffusion being the end result of turbulence created by means of the rotating discs and

III. Direct oxygen absorption with the aid of the micro-organisms for the duration of the air exposure of the disc (Diaa et al., 2012).

furthermore, poisonous and unsafe nature of waste-water has been appreciably studied (Waskar, et al., 2012; Metcalf et al., 2004). using rotating biological contactor (RBC) in aerobic treatment of business wastewater includes decolonization, (Diaa et al., 2012); Nitrification (Vijay et al., 2004); iron oxidation (Nitin et al., 2013); and home sewage (Syed et al., 2012); has been a success enormously, due to the advantages of RBC over different forms of wastewater treatment approach which can be: high effluent nice , excessive touch time, high method balance , proof against hydraulic shock or natural loading, low sludge production, no threat of channeling; the procedure was exceptionally silent compared to dosing pumps for aeration and large energetic surface region. it's far easier to function, low fee of upkeep and really effective (Demetnos, et al., 2004; Dincer et al., 2001). An RBC includes a chain of carefully spaced, round, plastic disks this is connected to a rotating horizontal shaft. the bottom has about forty% of every disk submerged in a tank containing the wastewater to be treated. The biomass film that grows on the surface of the disks movements inside and outside of the wastewater whilst the RBC rotates. The submerged microorganisms within the wastewater take in natural and inorganic materials within the wastewater that were the impurities inside the wastewater have been absorbed because of the microorganisms submerged into the wastewater. whilst the RBC rotates out of the wastewater, they may be supplied with needed oxygen.

This study turned into intention to establish a design of rotary biological contactor for the remedy of waste water using Aspen HYSYS that might be used to explain the mode of treatment of the wastewater with the rotating biological contactor even as the contactor has 4 phases. these four phases are to make sure right treatment of wastewater such that the water can be reuse or disposed with out environmental and human effect. The layout fashions increase might be used to test if the wastewater turned into appropriate for use or safe disposal to land or sea without damaging impact to aquatic lives and human lives and the values for the design parameters appropriate for such fabrication whilst price. The land may be broken in a few scenario which may additionally call for bioremediation. This became the venture which desires pressing interest of engineers to properly layout and simulates the rotating biological contactor for treatment of industrial wastewater. The layout fashions would be advanced to attend to all business waste water the usage of enzymes in the rotating organic contactor for wastewater treatment. The photo of the rotary organic contactor changed into depicted beneath:

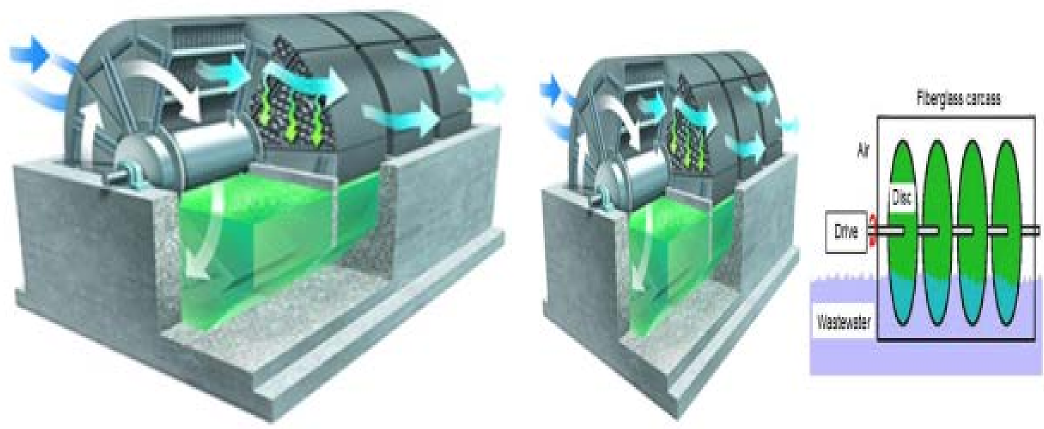

Figure 1: Picture of Rotary Biological Contactor for Treatment of Industrial Wastewater

As human population increases, industrialization also increases given rise to more of wastewater. It would be noticed that the untreated wastewater bodies would cause and pose health hazards. A lot of research had been carried out to develop process for the treatment of wastewater and such was the development of rotating biological contactor for the treatment of industrial wastewater . Other research had shown that the design and fabrication of rotating biological contactor has the ability to treat both organic and inorganic compounds in the wastewater which was cost effective.

According to Dagde *et al*., (2011) it was shown that the rotating biological contactor effectively treated phenol which was organic compound in the wastewater using four phase contactor.

In the same way, the design model for rotary biological contactor would be done with design costing that would be effective for procurement of materials that are suitable for fabrication. This rotary biological contactor design would be used to describe the treatment of wastewater suitable for use and discharge into the environment whether land or sea without causing adverse effect in such environment. The aim of the study is therefore the design and simulation of rotary biological contactor for treatment of waste water using Aspen HYSYS with the objectives to study the rotary biological contactor and its design parameters, Development of design models that would be used for the evaluations of the design parameters. The values for the design parameters of the rotary biological contactor were evaluated for the following design parameters: Surface loading, Organic loading, Hydraulic load, Hydraulic loading rate, Hydraulic retention time, Hydraulic load over weir, Use different components in industrial effluents for the chemical reaction taken place in the biofilm reactor in rotary biological contactor for the development of the design using Aspen HYSYS simulation software. Use plant data obtained from rotary biological contactor in literatures of previous works to serve as inputs into the computer program for the simulation of the rotary biological contactor. Development of computer program using MATLAB and SIMULINK compiler for the simulation and computation of design models for the values of the design parameters of the rotary biological contactor for the treatment of industrial wastewater. Mechanical design for the rotary biological contactor for treatment of industrial wastewater would evaluate the thickness which would account for the space for material of construction. Development of design costing of the rotary biological contactor for the treatment of industrial wastewater.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in the study are, Rotating biological contactor, Enzymes, Biomass and Industrial wastewater. Other materials are: Substrate, Hp computer laptop installed with Aspen HYSYS simulation software, Kinetic parameter for organic biodegradation and oxygen utilization and Operational data for rotating biological contactor for industrial wastewater.

2.2 Method

The Rotating Biological Contactors (RBCs) or simply bio discs were part of the biofilm processes. In these reactors, biofilm support material consists of discs, with a certain uniform distance between each other, coupled to a rotating horizontal shaft driven by a motor. In general, the shaft is installed above water surface level. Thus, the rotary movement causes the intermittent immersion of discs into wastewater.

The discs on which the biofilm was developed were coupled to one or more horizontal shafts driven by variable speed motors. The shaft was installed above water surface level allowing 40% of the total disc surface area to be submerged. Each reactor had several sets of discs arranged in series. In general, each set of discs represents a process stage with a reaction vessel covered to avoid inclement weather, and to minimize or improve visual impact as possible.

The biofilm oxidized organic matter from wastewater (BOD, COD) and nitrogen while the oxygen necessary to the metabolic activity of the microorganisms was ensured by discs rotation. A high process kinetics was observed due to the high biomass concentration that could be maintained on the surface of the disc, in the order of 200g (dry weight)/m, having a metabolic effect similar to that produced by a concentration of 4.000 to 6.000 mg MLSS/L in activated sludge process.

While the disc configuration was specific to each manufacturer, the design of the discs attempts to maximize the surface area, and to enhance both water mixing and aeration in the reactor. Discs were mostly manufactured of polystyrene foam, polyvinyl chloride and polyethylene. As in any biofilm process, design prevented the reactor filling clogging. At steady state, the excess biofilm was removed by continuous drag due to shear forces produced by the rotation of the discs. The excess biomass was retained and disposed through the secondary clarifier.

Since the rotary biological contactor uses biological (biomass) to treat the industrial wastewater to a harmless water for reuse or discharge to either land or sea environment, the design models would be used to evaluate the values for the design parameters of the rotary biological contactor. The processes or procedures were as follows:

2.2.1 RBC of Design Models Equations

The design models equations for the rotary biological contactor were developed using the procedures. The rotary biological contactor was used for the treatment of industrial wastewater. The diagram of the rotary biological contactor is shown.

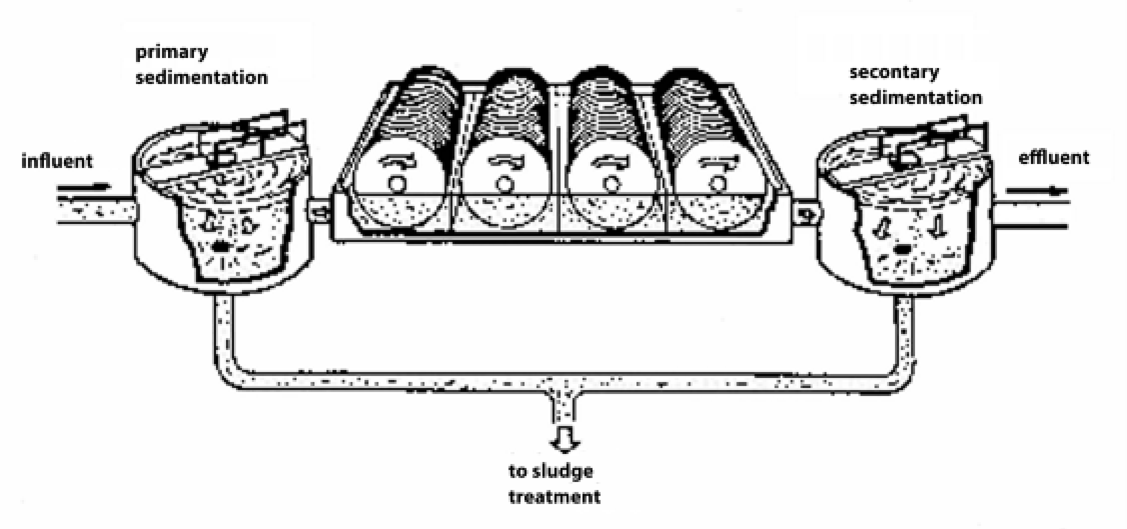

Figure 2: Diagram of the Rotary Biological Contactor for the Treatment of Industrial Wastewater

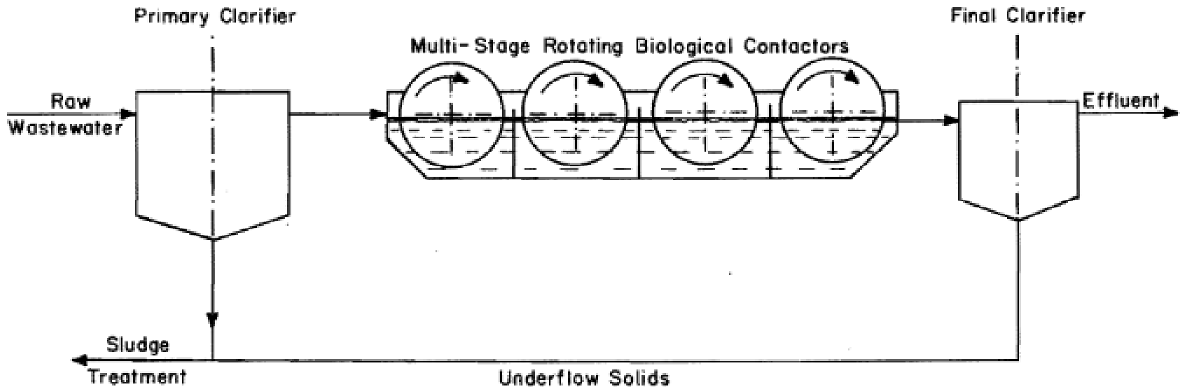

Figure 3: Schematic Diagram of Rotary Biological Contactor for Treatment of Industrial Wastewater

Also, the schematic diagram of the rotary biological contactor for treatment of industrial wastewater is as shown below.

However, the effluent were the industrial wastewater which were sent to the primary sedimentary tank for processing before it enters the bio disc rotating that treats the waste water to remove organic matter to a harmless one. After the wastewater must had passed through the four different stages then it enters the secondary sedimentary stage before it was sent as effluent which was the water free from the waste both organic and other cases inorganic matters.

2.2.1.1 Surface Loading, B_A

It was expressed in grams of pollutant applied per day and square meter of bio disc. The equation was given as:

$$B_{A,BOD} = \frac{F_{ave} L_o}{A_{BOD}} \quad (1)$$

Where

A_{BOD} = bio discs contact surface for organic oxidation (m^2)

$B_{A,BOD}$= organic surface applied load (g BOD/m^2/d)

F_{ave} = average total daily flow (m^3/d)

L_o = average influent BOD concentration without recirculation (mg/L)

2.2.1.2 Hydraulic Load, HL

The performance of RBCs has historically been correlated with hydraulic loading. Increasing the flow rate through the bioreactor reduces the liquid retention time in the system and results in a reduction in removal efficiency. In defined conditions increasing hydraulic loading also leads to an increase of attached biomass on RBC media surface. The hydraulic load was calculated (Mba *et al.*, 2007) as follows:

$$HL = \frac{F_{ave}}{A} \quad (2)$$

2.2.1.3 Hydraulic Loading Rate, HLR

The organic loading of a RBC reactor must be accurately defined during planning and designing. The variation of the organic loading rate is generally accomplished by changing the inlet flow rate or the HRT, which also results in a change in the hydraulic loading. It is based on the real flow rate through the unit that is the discharge flow through the outflow weir. The equation is given below:

$$HLR = \frac{F}{A} \quad (3)$$

Where

HLR = Hydraulic loading rate (m/h)

F = outflow (m^3/h)

A = Horizontal clarification surface (m^2)

2.2.1.4 Hydraulic Retention Time, HRT

Studies with RBC systems have revealed that longer contact times improve the diffusion of the substrate into the biofilm and its consequent removal of the influent. This trend is also verified with toxic and heavy metals substrates. Too short a HRT will result in low removal rates, whereas too long a HRT will not be economically feasible. The hydraulic retention time is calculated as follows:

$$HRT = \frac{V}{F} = \frac{Ah}{F} \quad (4)$$

Where

HRT = hydraulic retention time (Hours)

h = depth under weir (m)

V = net clarification volume (m^3)

F = F_{max} (m^3/h)

2.2.1.5 Hydraulic Load Over Weir, OW

This corresponds to the effluent flow per linear meter of outflow weir. It is calculated as follows:

$$OW = \frac{F}{L_W} \quad (5)$$

Where

OW = overflow on weir (m^3/h/m)

L_w = weir length (m)

F = maximum flow (m^3/h)

2.2.1.6 Organic Loading

Organic loading is defined as the pounds of biochemical oxygen demand (BOD) introduced into the RBC basin per 1000 square feet of the media surface area per day. The design of the media optimizes its surface area with the use of ridges and void spaces. The media surface area could be calculated. The organic loading could be increased if supplemented aeration was utilized to increase dissolved oxygen. It has the equation below:

$$Organic\ Loading = \frac{(BOD)*Flow}{Area} \quad (6)$$

Where

BOD = influent Biological oxygen demand concentration

Flow = influent flow

Area = media surface area

2.2.2 Mechanical Design for the Rotary Biological Contactor

The mechanical design of the rotary biological contactor would include estimating the thickness, the positions of the primary clarifier, reactor and secondary clarifier as well as sizes of all unit operations that constitute the rotary biological contactor. For a cylindrical shell, the minimum thickness required to resist internal pressure can be determined. If D_i is the internal diameter and t is minimum thickness required, then f is the design stress and P_i is the internal pressure. The minimum thickness required is given as follows:

$$t = \frac{P_i D_i}{2f - P_i} + e \quad (6)$$

Let's consider the cylindrical section of the RBC

2.2.3 Simulation of Design Models for the Rotary Biological Contactor

The design models developed for the rotary biological contactor for the treatment of industrial wastewater were simulated using simulation software and computer program developed. The computations and simulations of the developed design models were done using a computer program developed using MATLAB & SIMULINK compiler, the data obtained from literatures of previous works serves as inputs data for the design done for Aspen HYSYS simulation developed.

Also, operational data from the design from Aspen HYSYS simulation serve as inputs for the computer program developed using MATLAB & SIMULINK compiler. The values for the design parameters of the rotary biological contactor were evaluated for the following design parameters:

i. Surface loading
ii. Organic loading
iii. Hydraulic load
iv. Hydraulic loading rate
v. Hydraulic retention time
vi. Hydraulic load over weir

Furthermore, the thickness of the constituents of the rotary biological contactor which serve as the mechanical design was done for the primary clarifier, reactors and secondary clarifier.

Conclusively, the design costing was also done for the constituents of the rotary biological contactor which were primary clarifier, reactors and secondary clarifier.

2.2.4 Obtained Parameters for Rotary Biological Contactor

The parameters obtained for rotary biological contactor was from the literatures and works of Tak-Wing .W. (2000). This work was titled design evaluation of biological rotating contactor (RBC) treating municipal wastewater, which was a research for Bachelor in Chemical Engineering, Georgia Institute of Technology Atlanta, Georgia United States of America. The data were presented in the table below:

Table 1: Obtained Parameters for the Design of Rotary Biological Contactor

Parameters	Values	Units
F_{ave}	3.5	m^3/Hr
Lo	15.32	Mg/m^3
A_{BOD}	40.52	m^2
A	21.53	m^2
H	1.264	M

L_W	9.813	M
BOD concentration	7.578	Mol/m^3
Design Temperature	300	^0C
Internal pressure	14	bar
Corrosion allowance, e	2	mm
Internal Diameter, Di	1.5	M

However, these data obtained serves as inputs for the computer program developed which were used for the simulations of the values of design parameters of the rotary biological contactor for the treatment of industrial wastewater using Aspen HYSYS simulation software. The results from Aspen HYSYS design serve as inputs for the computer programming using MATLAB & SIMULINK compiler. The computations and simulations of the design of rotary biological contactor for values of the design parameters were presented as results in chapter 4 of this research work.

2.2.5 Design Costing for the Rotary Biological Contactor

The total cost of the design of a rotary biological contactor would be done in this section. The design costing would include cost for the purchase of primary clarifier and secondary clarifier as well as the four reactors or bio disc. The purchase design costing evaluations were as follows:

2.2.6 Design for the Rotary Biological Contactor using Aspen HYSYS Simulation Software

Step 1:

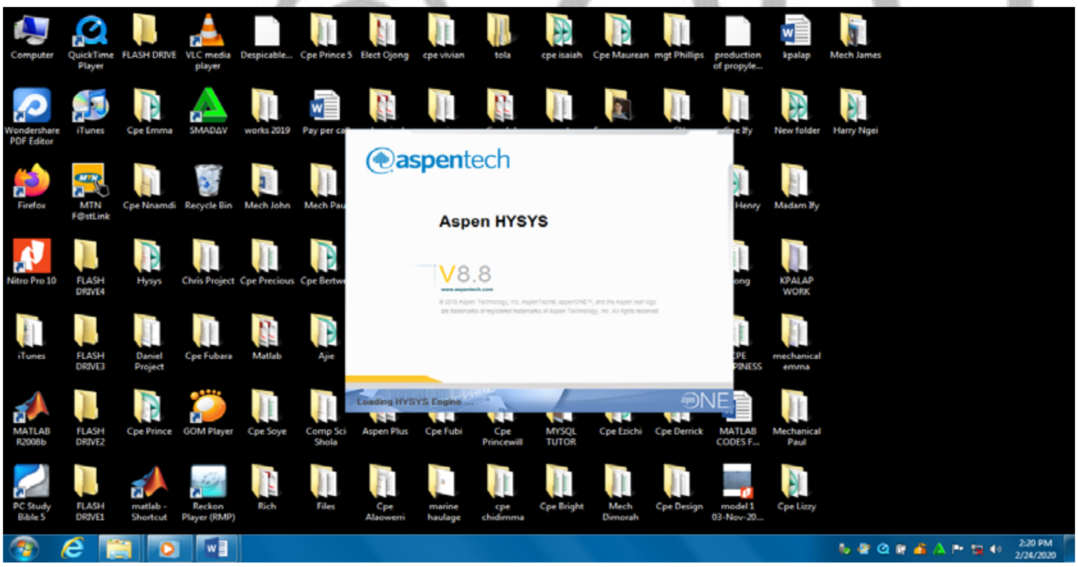

Figure 4: Opening Aspen HYSYS Simulation Environment

i. Click new to open new design environment
ii. Click on components lists and choose the components below:
iii. Carbon, Oxygen, CO_2, NO_2& N_2
iv. Choose PRSV as fluid package needed for the design after clicking on fluid package.

Step 2:

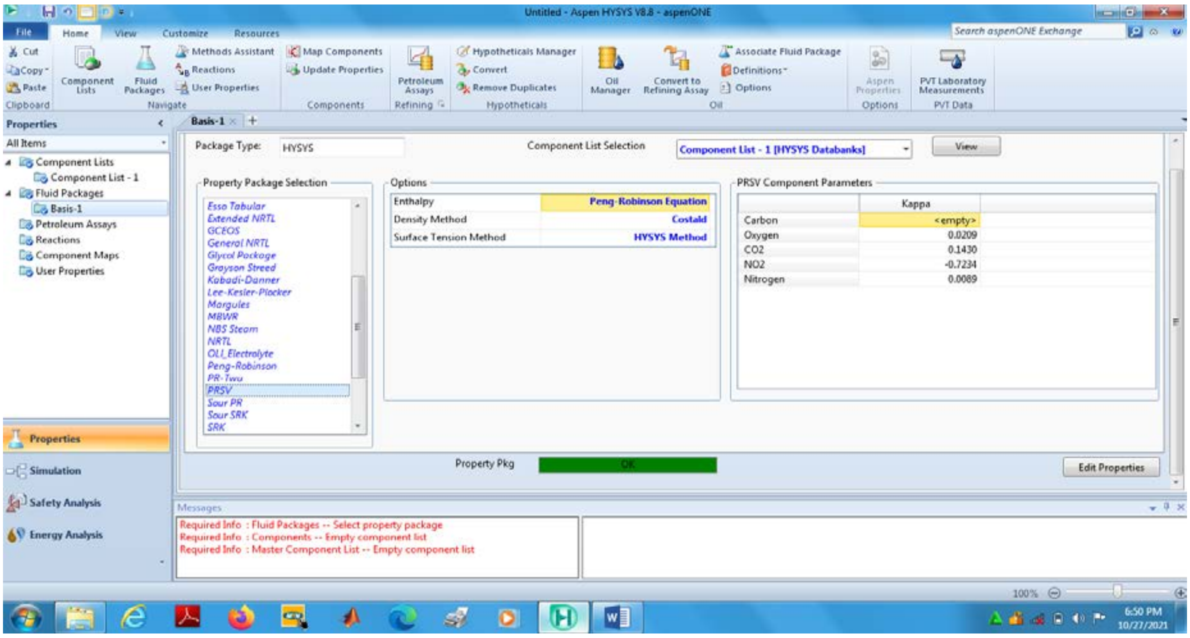

Figure 5: Aspen HYSYS Simulation Environment to Choose Fluid Package

-select the material stream and click on the Aspen HYSYS simulation environment
-double click on the material stream
-Type Wastewater for the name of the stream
-Type 70^{o}C for Temperature
-Type 60Kpa for pressure
-Type 5000Kg/hr for flow rate

Step 3:

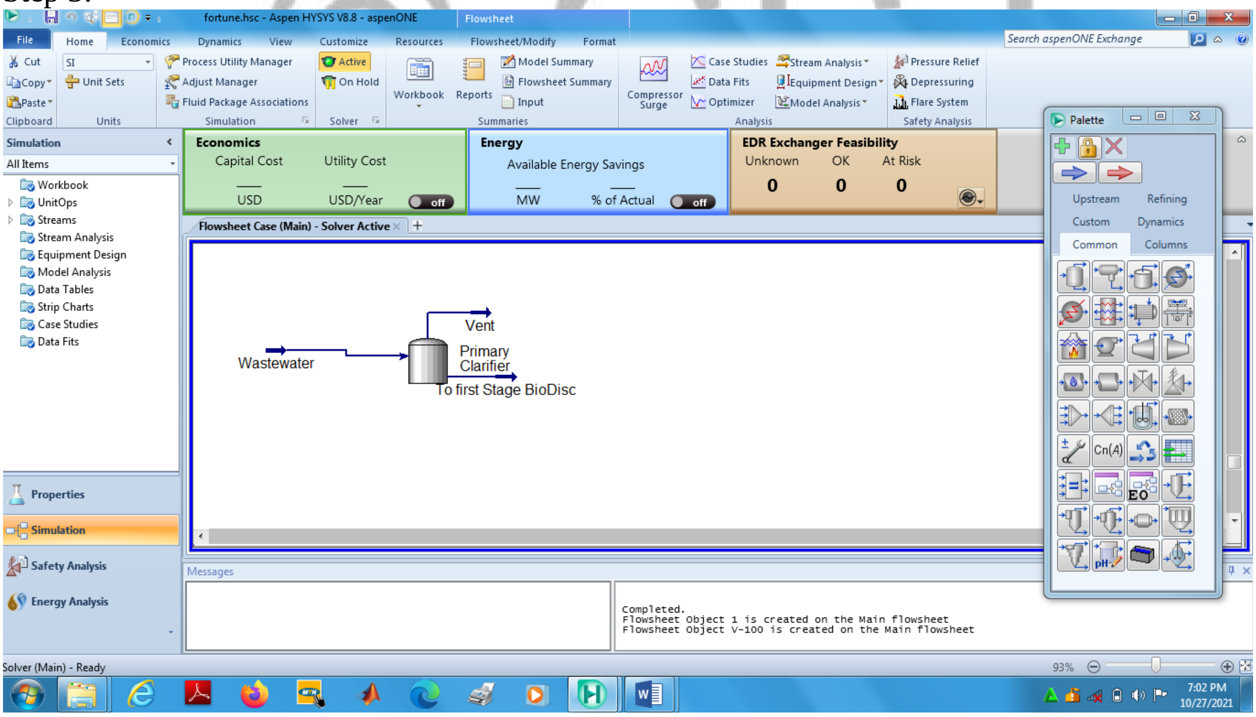

Figure 6: Aspen HYSYS Simulation Environment for Material Stream and Primary Clarifier

Step 4:

i. click on reaction
ii. click on “Add” button
iii. click on “Add Reaction”
iv. select “Kinetic” and then click the “Add Reaction”
v. select the component “carbon” and type -1 for stoichiometric
vi. select the component “O_2” and type -1 for stoichiometric
vii. select the component “CO_2” and type 1 for stoichiometric

viii. Type 2.1*e+05 in “Forward Reaction” for A
ix. Type 75362 in “Forward Reaction” for E
x. Press the Enter key and click “Balance Button”
xi. click on “Add Reaction”
xii. select “Kinetic” and then click the “Add Reaction”
xiii. select the component “carbon” and type -2 for stoichiometric
xiv. select the component “NO_2” and type -2 for stoichiometric
xv. select the component “CO_2” and type 2 for stoichiometric
xvi. select the component “N_2” and type 1 for stoichiometric
xvii. Type 2.1*e+05 in “Forward Reaction” for A
xviii. Type 75362 in “Forward Reaction” for E
xix. Press the Enter key and click “Balance Button”

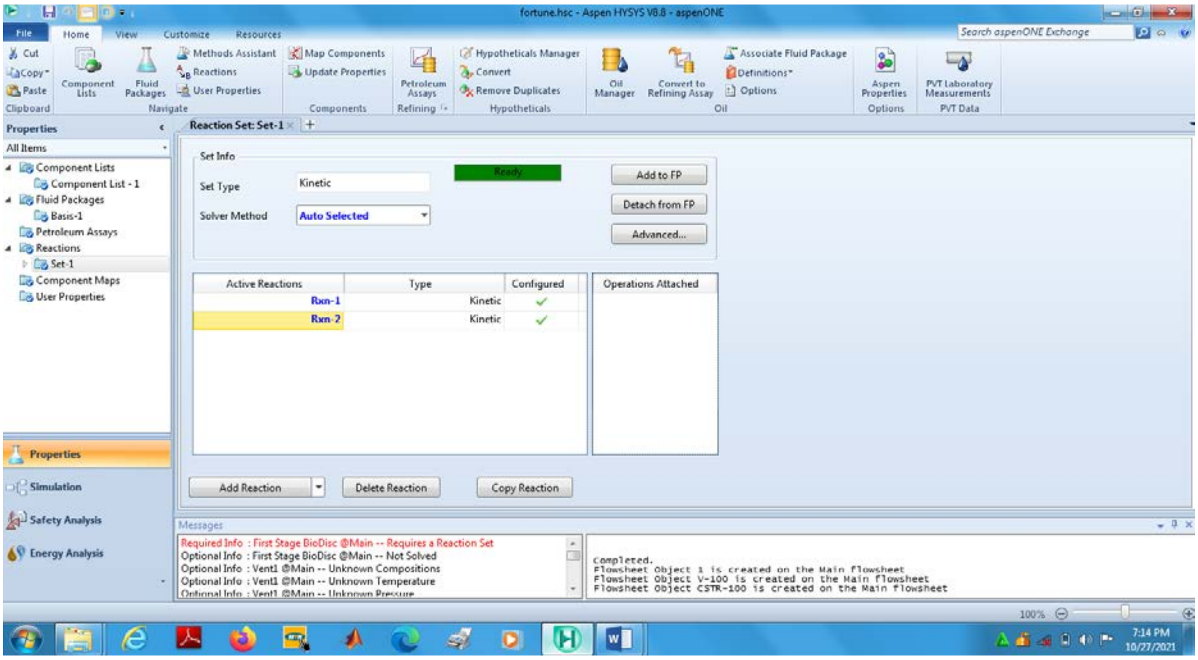

Figure 7: Aspen HYSYS Simulation Environment for Reaction Mechanisms for the Wastewater Treatment Process

Step 5:

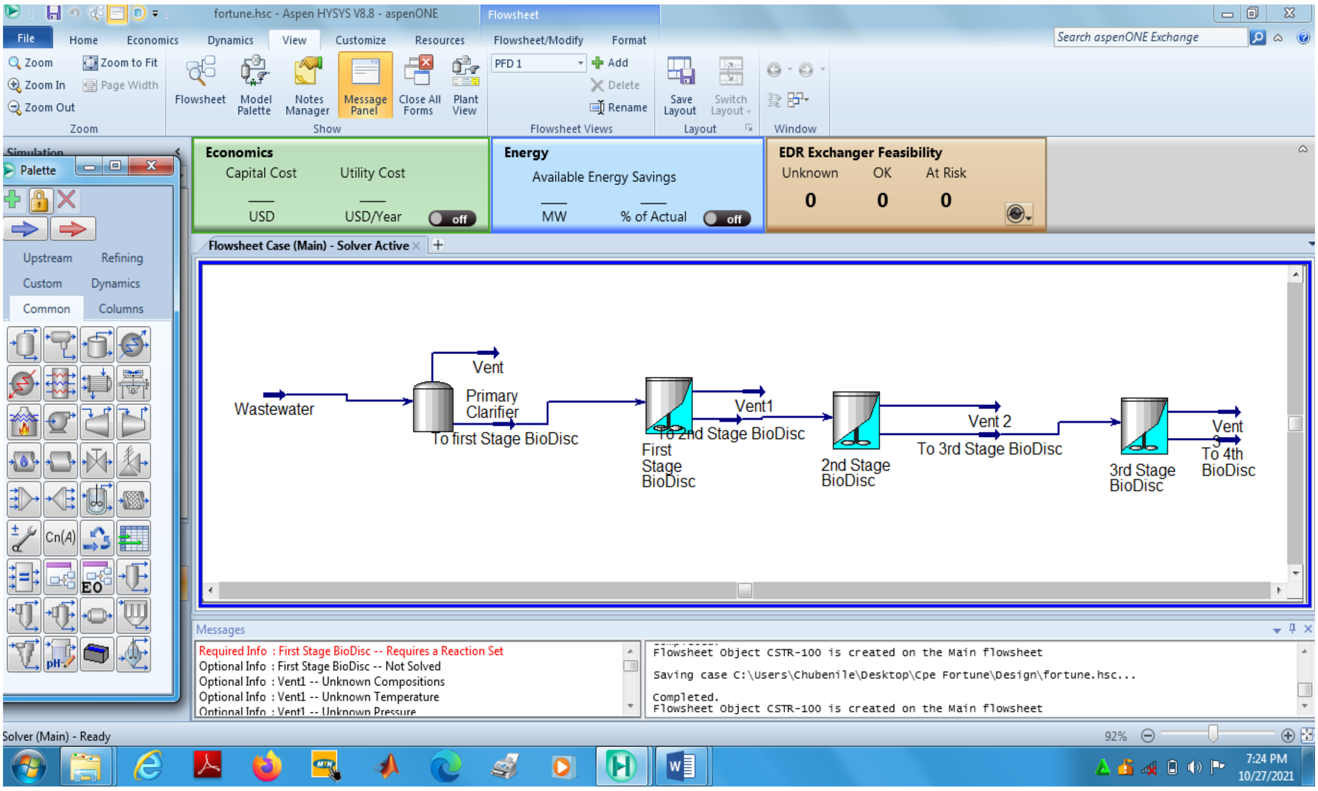

Figure 8: Aspen HYSYS Simulation Environment for the Design of four stage Bio disc in the Rotary Biological Contactor for the wastewater treatment process

Step 6:

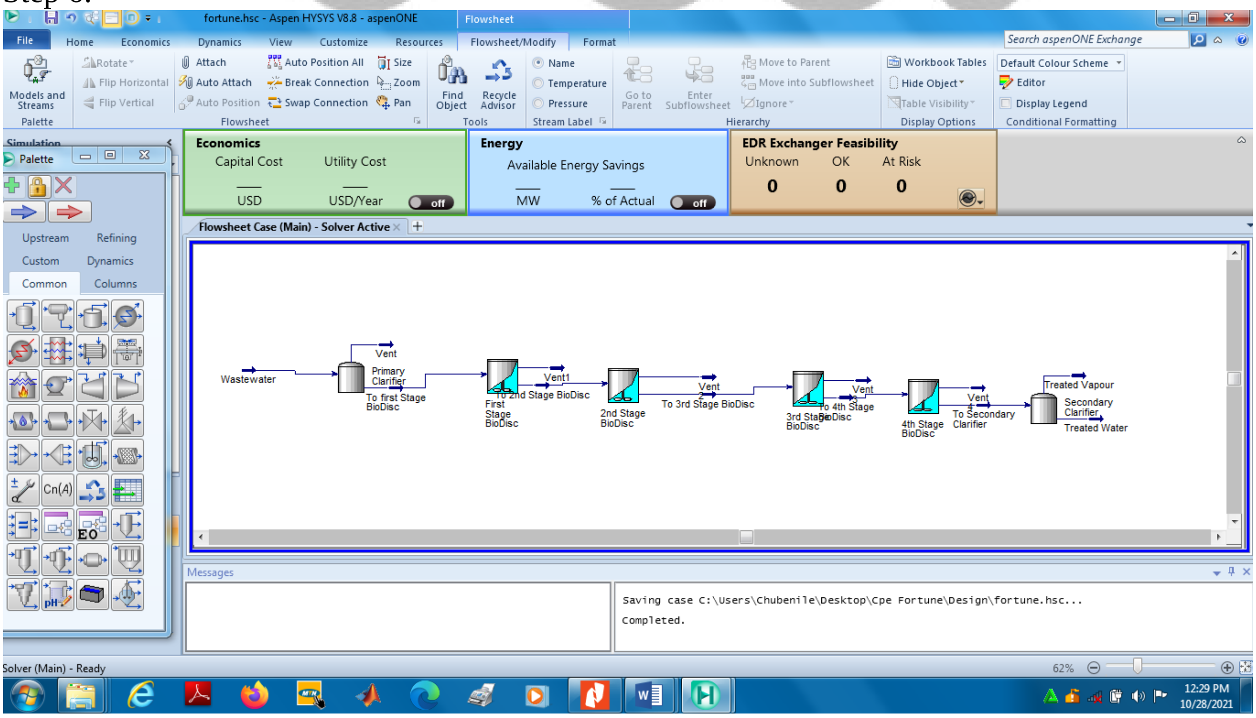

Figure 9: Aspen HYSYS Simulation Environment for the Design of Primary Clarifier, four stage Bio disc & Secondary Clarifier in the Rotary Biological Contactor for the wastewater treatment process

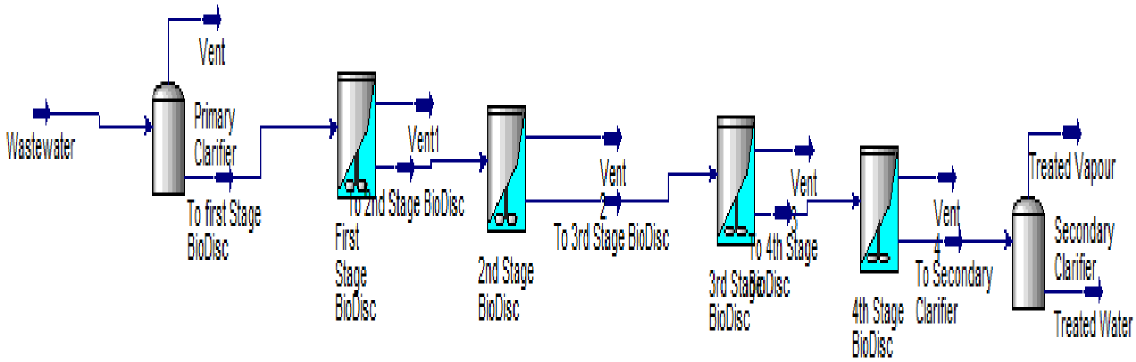

Figure 10: Process Flow Diagram for the rotary biological contactor for the treatment of industrial waste water

3. RESULTS AND DISCUSSION

The design models developed for the rotary biological contactor for the treatment of industrial wastewater were designed with Aspen HYSYS simulation software and simulated with MATLAB & SIMULINK compiler. The computations and simulations of the design models were done using computer program developed using MATLAB & SIMULINK compiler and graphs plotted with Microsoft Excel for proper results and charts. The data obtained were from the design from Aspen HYSYS which serve as input to the computer program developed. The inputs to the design from Aspen HYSYS were from literatures of previous works. The results obtained from the simulation of computer program are presented below for the design parameters.

Table 2: Design parameters of the Rotary Biological Contactor

Ba,bod (m2)	HL (m)	HLR (m/hr)	HRT (Hours)	OW (M3/hr/m)	OL (Mol/Hrm2)	Flow (M3/hr)
1.32	0.16	0.16	77.73	0.35	1.23	3.5
1.51	0.18	0.18	68.01	0.40	1.40	4
1.70	0.20	0.20	60.45	0.45	1.58	4.5
1.89	0.23	0.23	54.41	0.50	1.75	5
2.07	0.25	0.25	49.46	0.56	1.93	5.5
2.26	0.27	0.27	45.34	0.61	2.11	6
2.45	0.30	0.30	41.85	0.66	2.28	6.5

Table 3: Design Cost of Rotary Biological Contactor

Equipment	Cost in Dollar ($)	Cost in Naira (₦)
First stage Bio disc	91586.1429	50372378.64
Second stage Bio disc	91586.1429	50372378.64
Third stage Bio disc	91586.1429	50372378.64
Fourth stage Bio disc	91586.1429	50372378.64
Primary Clarifier	45961.9025	25279046.42

Secondary Clarifier	45961.9025	25279046.42
Total Cost	**458268.3766**	**252047607.4**

Table 4: Mechanical Design of the Rotary Biological Contactor

Equipment	Thickness of cylindrical section (mm)
First stage Bio disc	14.7
Second stage Bio disc	14.7
Third stage Bio disc	14.7
Fourth stage Bio disc	14.7
Primary Clarifier	57.5905
Secondary Clarifier	57.5905

Finally, the results for the mechanical design of the rotary biological contactor which evaluate the thickness of the material of construction. The material of construction was carbon steel. The results for the evaluations of the thickness was presented below:
However, the results shows that rotary biological contactor have a reactor were reactions takes place, a primary clarification tank and a secondary clarification tank to store raw wastewater and product after treatment of wastewater.
The results of computations and simulations of values for the design parameters of the rotary biological contactor have been presented. The sizes of the units would be discussed to ascertain which design parameter values gives the actual results needed for the treatment of wastewater using rotary biological contactor. These would be discussed extensively for which the values for design parameters may be needed during fabrication of the rotary biological contactor since its mechanical design and cost for the design had been presented also, these all calls for proper discussions.

Bio Disc

Design temperature = 300^0C
Hence, design stress, f = 85 N/mm^2
Internal pressure, Pi = (14 – 1)*1.1
Pi = 14.3 bar
Pi = 1.43 N/mm^2
Corrosion allowance, e = 2mm
Internal diameter, Di = 1.5m = 1.5*10^3mm

Hence,
Thickness, t = $\frac{1.43*1.5*10^3}{2*85-1.43}+2$
Thickness, t = 12.7 + 2 = 14.7mm
Thickness of cylindrical section of the Bio disc = 14.7mm

Primary Clarifier (Tank)

P_i = (95-1) x 0.11 = 10.34N/mm^2
D_i = 1396mm
F = 135N/mm^2
Hence,
Thickness, t = $\frac{10.34*1396}{2*135-10.34}+2$
Thickness, t = 55.5905 + 2 = 57.5905mm
Thickness of cylindrical section of the primary Clarifier = 57.5905mm

Secondary Clarifier (Tank)

P_i = (95-1) x 0.11 = 10.34N/mm^2
D_i = 1396mm
F = 135N/mm^2
Hence,
Thickness, t = $\frac{10.34*1396}{2*135-10.34}+2$
Thickness, t = 55.5905 + 2 = 57.5905mm
Thickness of cylindrical section of the primary Clarifier = 57.5905mm

Cost of the Reactors or Bio disc

Annual cost, c = $200{,}000\left(\frac{Volume}{100}\right)^{0.6}$ (John, 2008)
Where
Volume = 21.529*1.2637
Volume = 27.2061m^3
Hence,

Annual cost, c = $200{,}000\left(\frac{27.2061}{100}\right)^{0.6}$

Annual cost, c = $91586.1429
Cost of each Bio disc = $91586.1429
Cost of four Bio disc = $91586.1429*4
Cost of four Bio disc = $366344.5716
Annual cost in naira = 91586.1429*550
Annual cost of each Bio disc in Naira = N 50372378.64*4
Annual cost of four Bio disc in Naira = N 1465378.286

Cost of Clarifiers (Tank)

Purchase equipment cost (Ce) = CS^n

Where
S = characteristic size parameter
C = cost constant
n = index for that type of equipment
Hence,
C = 2900 for carbon steel
n = 0.6
S = 100
Purchase equipment cost (Ce) = $2900 * (100)^{0.6}$

Purchase of primary clarifier cost (Ce) = $45961.9025
Purchase of secondary clarifier cost (Ce) = $45961.9025
Purchase cost of primary clarifier in Naira = 45961.9025*550
Purchase cost of primary clarifier in Naira = N 25279046.42
Purchase cost of secondary clarifier in Naira = N 25279046.42

The design models developed were subjected to computer programming and Aspen HYSYS software design. The computer program developed was used for the computations and simulations for the values of the design parameters of the Rotary Biological Contactor for the treatment of industrial wastewater which were discussed as follows:

From Figure 11 below, the graph shows the variation of average total flow with surface loading. Increase in average total flow, shows increase in surface loading.

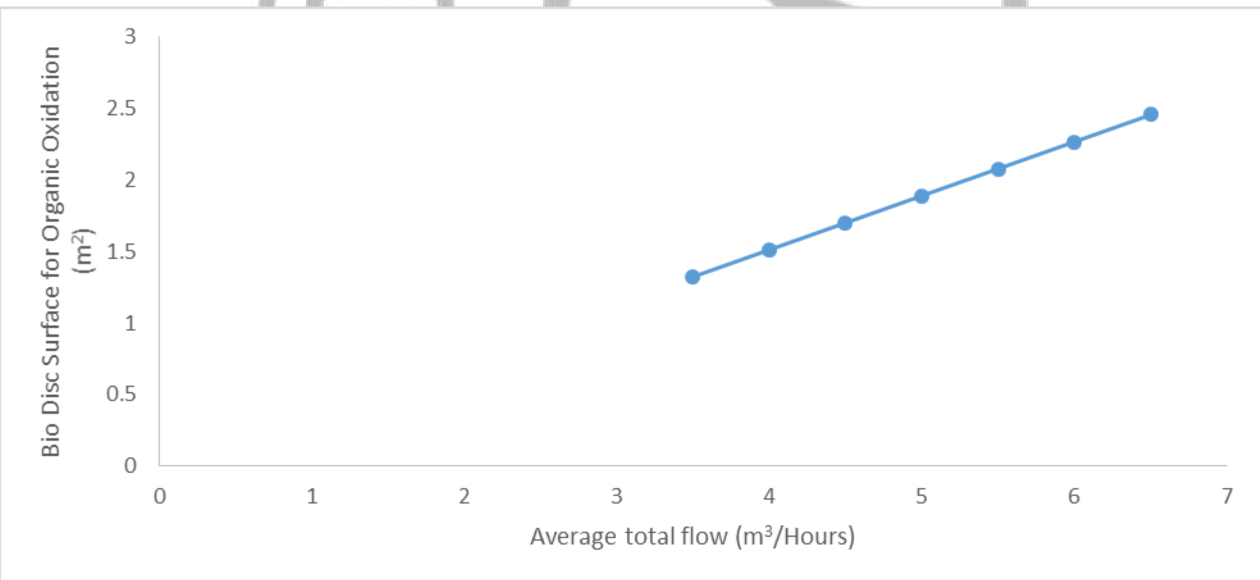

Figure 11: Effect of Average Total Flow on Surface Loading

However, as average total flow increases, the surface loading of the bio disc for organic oxidation increases to a maximum. This means that as average total flow increases, then the surface loading in the bio disc increases the organic oxidation of the contaminants in the wastewater. The organic loading of micro-organisms provides surfaces for contact between the contaminants and micro-organisms for proper utilization of the contaminants in wastewater.

However, as the surface loading of the bio disc increases the quantity of wastewater to be treated increases which enhances the treatment of more wastewater using micro-organisms. Hence, the quantity of water free from contaminants entering the secondary clarification then becomes more. More treated water would be obtained.

This increase values of surface loading would serve for the fabrication of the rotary biological contactor. The results also agree with the results from Aspen HYSYS design.

4.2.2 Effect of Average Total Flow on the Hydraulic Loading, HL

From Figure 12 below, the graph shows the variation of average total flow with hydraulic loading. Increase in average total flow, shows increase in hydraulic load.

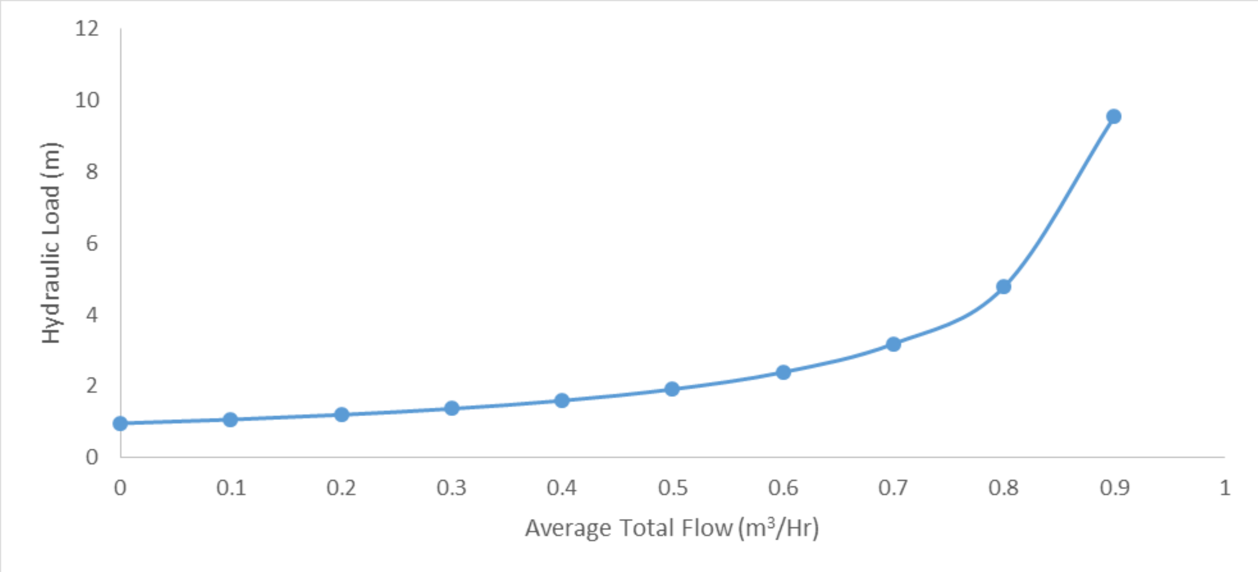

Figure 12: Effect of Average Total Flow on Hydraulic Load

However, as average total flow increases, the hydraulic load for organic contaminants utilizations increases to a maximum. This means that as average total flow increases, then the hydraulic loading increases the organic utilizations of the contaminants in the wastewater. The organic loading of micro-organisms provides contact between the contaminants and micro-organisms for proper utilization of the contaminants in wastewater. This hydraulic loading increased to an optimum value of $0.8m^3$ before it increases. This shows that at $0.8m^3$ average total flow of wastewater to the bio disc, the rotations were at peak with maximum rotational speed which provide the maximum rate of utilizations of contaminants. The optimum value also shows the point at which the highest amount of water free from contaminants were produced.

However, as the hydraulic loading increases the quantity of treated wastewater increases which enhances the treatment of more wastewater using micro-organisms. Hence, the quantity of water free from contaminants entering the secondary clarification then becomes more. More treated water would be obtained. This optimum value of hydraulic loading would serve for the fabrication of the rotary biological contactor. The results also agree with the results from Aspen HYSYS design.

From Figure 13 below, the graph shows the variation of total flow with hydraulic loading rate. Increase in total flow, shows increase in hydraulic loading rate.

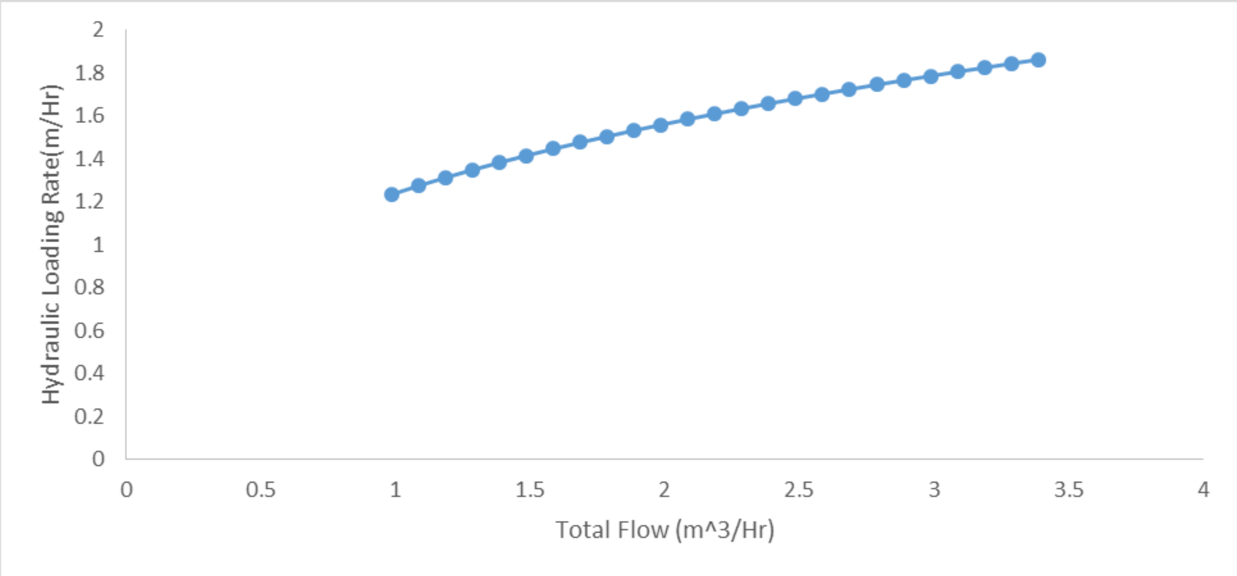

Figure 13: Effect of Total Flow on Hydraulic Loading Rate

However, as total flow increases, the hydraulic loading rate for organic contaminants utilizations increases upwards. This means that as total flow increases, then the hydraulic loading rate increases the organic utilizations of the contaminants in the wastewater from the out flow weir. The organic loading rate determines the time of micro-organisms providing contact between the contaminants and micro-organisms for proper utilization of the contaminants in wastewater from the primary clarification. This shows that total flow of wastewater to the bio disc from the primary clarification, the rotations were maximum which provide the maximum rate of utilizations of contaminants from the wastewater. The values also show the points at which the amount of water free from contaminants were produced.

However, as the hydraulic loading rate increases, the quantity of treated wastewater increases which enhances the treatment of more wastewater using micro-organisms in the bio disc. Hence, the quantity of water free from contaminants entering the secondary clarification then becomes more. More treated water would be obtained since more hydraulic loading rate. These values of hydraulic loading rate would serve for the fabrication of the rotary biological contactor. The results also agree with the results from Aspen HYSYS design.

From Figure 14 below, the graph shows the variation of total flow with hydraulic retention time. Increase in total flow, shows increase in hydraulic retention time.

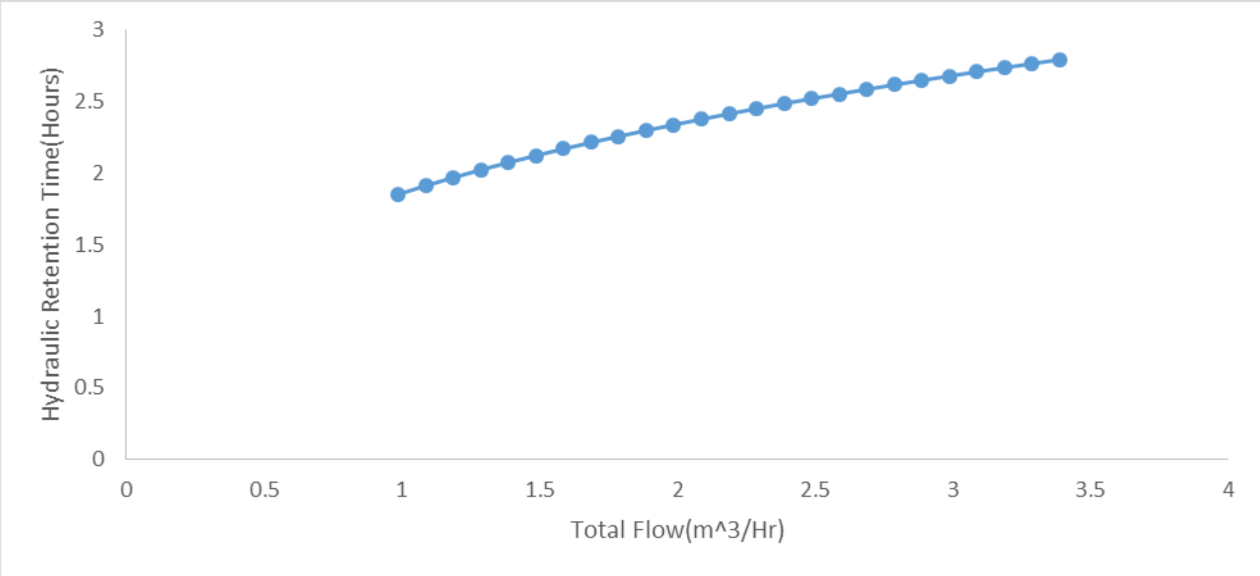

Figure 14: Effect of Total Flow on Hydraulic Retention Time

However, as total flow increases, the hydraulic retention time for contaminants utilizations increases upwards. This means that as total flow increases, then the hydraulic retention time increases the organic utilizations of the contaminants in the wastewater from the out flow weir. This shows that total flow of wastewater to the bio disc from the primary clarification, the rotations were maximum which provide time for maximum rate of utilizations of contaminants from the wastewater. When more hydraulic retention time for contaminants utilizations then the treatment becomes better as more time was given for contact between the micro-organisms and the contaminants. The values also shows the points at which the amount of water free from contaminants were produced which was higher since more hydraulic retention time was given.

However, as the hydraulic retention time increases, the quantity of treated wastewater increases which enhances the treatment of more wastewater using micro-organisms in the bio disc. Hence, the quantity of water free from contaminants entering the secondary clarification then becomes more. More treated water would be obtained since more hydraulic retention time was achieve for contact between micro-organisms and contaminants. This values of hydraulic retention time would serve for the fabrication of the rotary biological contactor. The results also agree with the results from Aspen HYSYS design.

4.2.5 Effect of Total Flow on the Hydraulic Load over Weir, OW

From Figure 15 below, the graph shows the variation of total flow with hydraulic load over weir. Increase in total flow, shows increase in hydraulic load over weir.

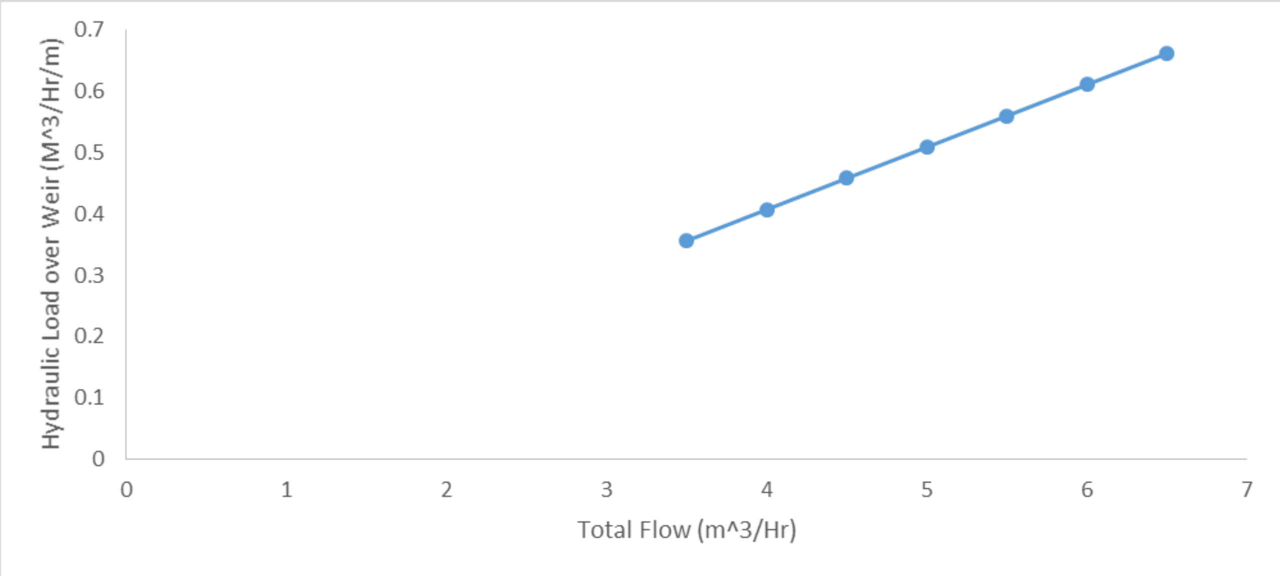

Figure 15: Effect of Total Flow on Hydraulic Load over Weir

Furthermore, as total flow increases, the hydraulic load over weir for contaminants utilizations increases upwards and flows the effluents to the secondary clarification. This means that as total flow increases, then the hydraulic load over weir increases the treated wastewater from the out flow weir to the secondary clarification before discharge to storage tank. This shows that total flow of treated wastewater from the bio disc to the secondary clarification, the maximum rate of utilizations of contaminants during the treatment of wastewater were high enough. The values also shows the points at which the amount of water free from contaminants were produced which enters the secondary clarification. The treated water was good enough for reuse or recycling purposes.

However, as the hydraulic load over weir increases, the quantity of treated wastewater increases which enhances the treatment of more wastewater using micro-organisms in the bio disc. Hence, the quantity of water free from contaminants entering the secondary clarification then becomes more. This values of hydraulic load over weir would serve for the fabrication of the rotary biological contactor. The results also agree with the results from Aspen HYSYS design.

4.2.6 Effect of Total Flow on the Organic Loading, OL

From Figure 16 below, the graph shows the variation of total flow with organic loading. Increase in total flow, shows increase in organic loading.

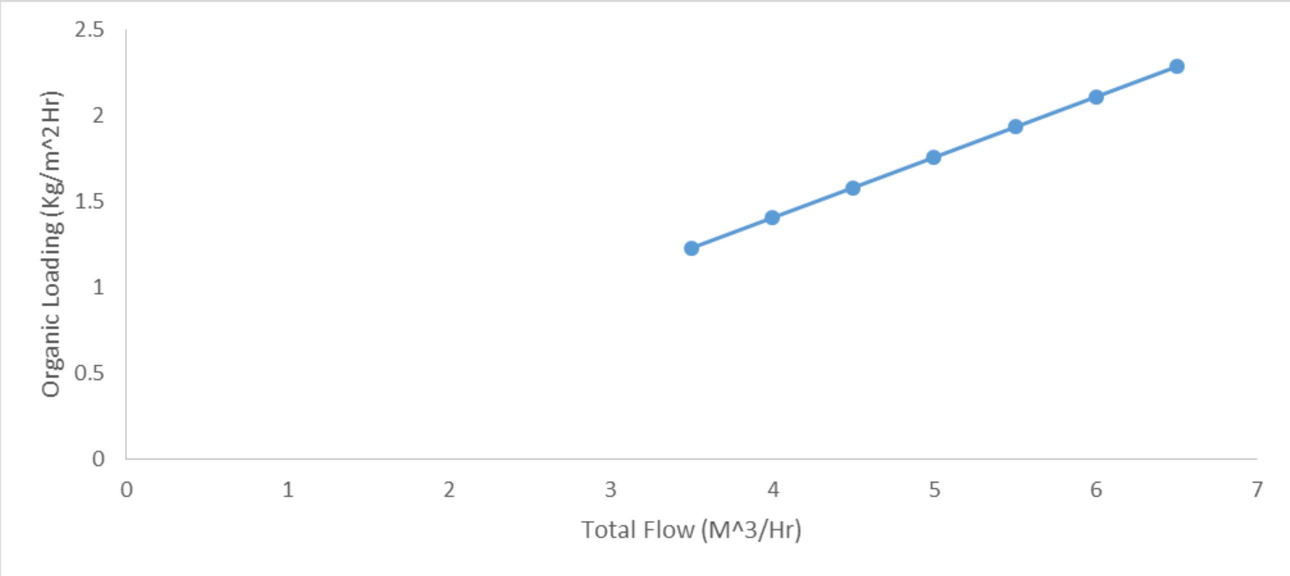

Figure 16: Effect of Total Flow on Organic Loading

Furthermore, as total flow increases, the organic loading for the contaminants utilizations increases upwards and flows into the bio disc. This means that as total flow increases, then the organic loading increases the biochemical oxygen demand introduced in the rotary biological contactor for the utilization for the micro-organisms. This shows that total flow of treated wastewater from the bio disc to the secondary clarification, the maximum rate of utilizations of contaminants during the treatment of wastewater were be high. The values also show the points at which the amount of oxygen demand by the micro-organisms for proper utilization of contaminants before entering the secondary clarification. The treated water was good enough for reuse or recycling purposes.

However, as the organic loading increases, the quantity of treated wastewater increases which enhances the treatment of more wastewater using micro-organisms in the bio disc since more oxygen demand had been introduced in the bio disc for the micro-organisms. Hence, the quantity of water free from contaminants entering the secondary clarification then becomes more. These values of organic loading would serve for the fabrication of the rotary biological contactor. The results also agree with the results from Aspen HYSYS design.

4. CONCLUSION

Model equations were developed for the rotary biological contactor using Aspen HYSYS. The design models equations were develop for the constituents of the rotary biological contactor which are primary Clarifier, Secondary Clarifier and four stage Bio disc.

The design models were simulated using a computer program developed using MATLAB & SIMULINK compiler. The data obtained were from the design from Aspen HYSYS simulation software which serve as input to the computer program developed. The rotary biological contactor was also design using Aspen HYSYS simulation software and inputs to the design were from literatures of previous works by Tak-Wing .W. (2000).

However, it was observed that design results were obtain after computations and simulations at various total flows and gave 2.4572m^2 for surface loading, 0.3019m for hydraulic load, 0.3019m/hr for hydraulic loading rate, 41.8556hr for hydraulic retention time, 0.6623m^3/hr/m for hydraulic load over weir and 2.2879 mol/m^2hr for organic lording. These results would be good values of design parameters necessary for fabrication of the rotary biological contactor. Also, the mechanical design of the rotary biological contactor gave various thickness for cylindrical sections as 14.7mm for the each of the four bio disc (reactor) and 57.5905mm for primary Clarifier as well as secondary Clarifier. This thickness for cylindrical sections would be a good space for the material of construction which was carbon steel.

Finally, the design cost of the rotary biological contactor gave $91586.1429 for each of the four bio disc (reactor) and N50372378.64 for each of the four bio disc (reactor) which were in dollar and naira respectively. The design also gave $45961.9025 for the primary and secondary Clarifiers and N25279046.42 for the primary and secondary Clarifiers which were in dollar and naira respectively. The design done was good and cost effective.

The design cost of the rotary biological contactor was cheap and cost effective. This means that the equipment(s) can be bought at cheap rate and for fabrication purposes with the material of construction as carbon steel.

Based on the design and simulation of rotary biological contactor for the treatment of industrial wastewater using Aspen HYSYS, the following recommendations were made:

i. The design of rotary biological contactor for treatment of industrial wastewater could be done using Activated sludge or trickling filter.
ii. The design of rotary biological contactor for the treatment of industrial wastewater was cheap but other suitable materials of construction can be used which were cheaper and easy to transport and maintain.
iii. The design models for the rotary biological contactor could be simulated with other software like CHEMCAD for the treatment of industrial wastewater.
iv. The compiler used was not windows based and hence the computer program cannot be installed in a computer system. However, compilers like Java, Visual Basic Dot Net, C# and C^{++}could do it better for proper computations and results which would aid suitable installations of the computer program developed to a computer system.

The research had shown that:

I. Wastewater should be treated with suitable unit operations like rotary biological contactor before it could be re-use or discharged in to the environment without causing any harmful effect.
II. Wastewater could be treated to remove pollutants or contaminants before recycling it for reuse in any industries and other usage generally since water may be scarce.

The design of rotary biological contactor must be done and simulated using simulation software like Aspen HYSYS for proper evaluations and analysis before the actual implementations of the real life treatment of pollutants in wastewater if such treatment could be a success

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