A. Anaerobic Treatment of Poultry Wastewater

The anaerobic treatment process is a technique which is widely used in the treatment of high strength poultry wastewater [25]. There are advantages that come with the use of anaerobic treatment processes which range from low electricity costs, high throughput of biogas, less sludge generation, and high organic matter removal [26]. An evaluation of the performance of an up-flow anaerobic filter (AF) was used in the treatment of wastewater. The study reported a COD and BOD removal efficiency of 81% and 87% with a 15 days period [27]. In another study of the treatment of PSW effluent by using an anaerobic UASB with a hydraulic retention time (HRT) of 1 day, removal efficiencies of up to COD of 70%, BOD of 73%, and FOG of 35% were obtained respectively [28]. Yousefi [29] conducted a study of treatment of PSW effluent by using a combined anaerobic system of 3 pilot-scale anaerobic baffled reactors (ABR) in the first stage, followed by 3 anaerobic filters (AF). An evaluation of the ABR reactor used in the latter study showed a COD removal efficiency of 83% after an HRT of 18 hours, and the AF reactor showed a removal efficiency of 63%, respectively. These previous studies show a low removal efficiency and moreover, there is a need to develop a new process which would elevate removal efficiency of the stated parameters. Finally, the reactors of the 3 pilot-scale were not fitted with a heat inducing device which would regulate the temperature inside the anaerobic treatment reactors. In some cases it would be wise to explore the effect of heat has on an anaerobic treatment used in the treatment of poultry wastewater.

B. Activated Sludge Processes

Activated sludge (AS) process methods utilizes a combination of aeration and a biological floc composed of bacteria and protozoa. The AS process uses aerobic micro-organisms that can degrade pollutants and agglomerate them by flocculation [30]. A study of an evaluation of the activated process (AS) used in the treatment of PSW effluent by kinetic model simulation [31], the AS reactor at 26^0C yielded a COD removal efficiency of 93.5% up to 97.2% respectively. Carvalho [32] evaluated the role of the AS system in the removal of pollutants present in the PSW effluent. The results indicated that sorption to sludge and wastewater organic matter was responsible for the removal of drug pollutants. The study of AS reactor with 100 µg/L initial drug pollutants present in the PSW effluent yielded removal rates of up to 68% enrofloxacin (ENR) and 77% tetracycline (TET). The latter study results are not impressive as one would expect them to be, there was no information on the dosage of AS. Going forward, there would be a need to study the effect of dosage of AS on the treatment of PSW effluent.

V. Types of Bio-Reactors

There are a wide variety of anaerobic digesters which operate in different ways depending on the design specifications and material construction of each digester. Anaerobic digesters are divided into three basic categories, namely; passive systems, low rate systems and high rate system. In addition to the three categories listed in the latter, there is also an up-flow anaerobic sludge blanket (UASB), static granular bed reactor (SGBR), and expanded granular sludge bed reactors (EGSB). In the UASB the influent enters the digester from the bottom toward the top in an upward flow direction passing a sludge granule blanket which filters and treats the wastewater as it flows through it [33]. The SGBR is a new reactor which has no mixing, but rather utilizes an anaerobic biofilter coupled with granules [34]. Lastly, the EGSB is similar to the UASB reactor with a high recycle ratio of the effluent stream to the influent feed stream [35].

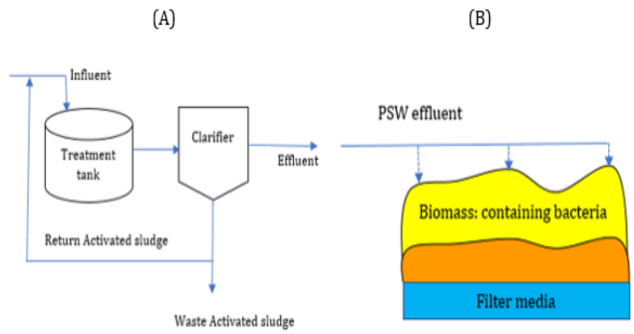

Fig. 2. Biological treatment: Suspended growth (A) & Attached growth processes (B).

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1) Up-flow Anaerobic Sludge Blanket (UASB)

In the up-flow anaerobic sludge blanket (UASB) process, the wastewater enters at the bottom of the reactor and flows upward. There are micro-organisms in the sludge layer that degrade organic matter present in the PSW effluent. In one study, an evaluation of the performance and stability of a PSW treatment plant which utilized the UASB reactor with organic loading rates of 1.6±0.4 kg COD/m3 day and velocities of 0.3±0.1 m/h was done. The results showed a total chemical oxygen demand (TCOD) and soluble chemical oxygen demand (SCOD) of up to 67% and 85% [36].

2) Expanded Granular Sludge Bed (EGSB)

The expanded granular sludge bed (EGSB) reactor is an adaptation of the UASB reactor with a distinguishing recirculation stream of the outlet effluent to the feed influent

[37]. EGSB reactors utilize a fully or partially expanded bed granules of sludge where the wastewater gets to be treated as it passes through. The recirculation stream promotes bed fluidization of the granular sludge and like-wise there are micro-organisms present in the sludge which degenerate organic matter. The performance of a rapid start-up of the EGSB reactor by using brewery wastewater as a sludge in the treatment of wastewater was conducted [38]. The results of the study depicted that the sludge could develop faster within a period of 10 days in the EGSB reactor with little detached granules. Removal efficiencies of up to 72.9% of COD with a hydraulic retention time (HRT) of 12.1 hrs.

3) *Static Granular Bed Reactor (SGBR)*

The static granular bed reactor (SGBR) is a reactor which has no mixing mechanism but rather it has a down-flow system which is fitted with static granules and sludge that serve as a biodegrading medium. The SGBR reactor has a wide range of advantages which include the simplicity of operation and the production of high quality effluent [39]. A study of the SGBR was employed in the treatment of PSW effluent with an intention of evaluating two processes using anaerobic non-granular and granular biomass [40]. The study showed that both processes were highly efficient in the removal of COD with values above 95%. Research treatment of wastewater by using a pilot SGBR reactor with organic loading rates between 0.63 to 9.72 kg/m3/d and a hydraulic retention time (HRT) of 9 to 48 hrs was performed. In the latter study removal efficiencies of COD, BOD5 above 90% and a TSS above 80% was achieved respectively [41]. Moreover, in another study of a SGBR fitted with pea gravel coupled with activated sludge from brewery proved a COD removal efficiency above 90% with a HRT range of 5 to 36 hrs [42].

VII. Materials And System Design

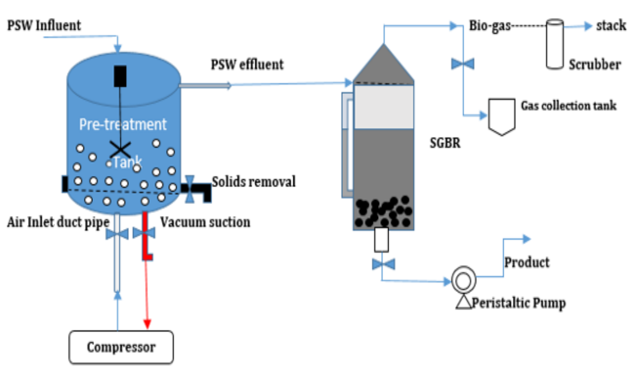

Fig. 3. Process schematic diagram of poultry slaughterhouse wastewater treatment (pilot plant).

The pilot plant is designed of the following specifications; 25 L mixing pre-treatment tank, clear PVC (SGBR) reactor of 5 L, and 5 L/hrs peristaltic pump operating at 10 Bar max. PSW influent is fed in the pre-treatment tank is treated with bacteria grown and isolated poultry effluent ponds. However, the PSW effluent product from the pre-treatment is fed in the subsequent stage of SGBR for further processing. The SGBR reactor is fitted with granules and the effluent is treated using activated sludge obtained from brewery. Analysis of influent and effluent samples before and after the pre-treatment stage and the SGBR bioreactor are performed in order to evaluate removal efficiency of COD, BOD, FOG, TSS, and pH. The reduction of the amount of FOG in the pre-treatment stage and as well as the reduction of COD in the effluent discharged by the SGBR determine the pilot plant performance. Lastly, an evaluation of how inoculated biological enzymes influence the degradation of poultry slaughterhouse wastewater is performed. The current set up of the pilot plant has been opted for against other processes because it eco-friendly, electricity costs is low, and it generates by products such as methane gas and carbon-dioxide.

VIII. Motivation for Reactor Selection

An effect of enzymatic pre-treatment by using pancreatic lipase proved to reduce pork fat present in wastewater; however, the effect enzymatic pre-treatment was never tested under anaerobic conditions [8]. In the latter study it showed that there is a remaining challenge that stems from evaluation of enzymes under anaerobic conditions. Additionally, it is worth noting that most of current designs of pre-treatment process lack a solids removal points and screens which are fitted at the bottom of the tank. It remains to be seen whether the use of a solids removal point would or would not disturb enzymatic activity after the pretreatment step. Generally, the screens serve a purpose of FOG & other large particle removal when placed under vacuum suction. Lastly, it would be interesting to evaluate how the inoculated biological enzymes, isolated from PSW ponds, influence the degradation of poultry slaughterhouse wastewater. The current set up of the pilot plant has been opted for against other processes because it is fitted with a solids removal point, it is also fitted with screens at the bottom, it is eco-friendly, electricity costs are low, and it would permit a collection of by products such as methane gas and carbon-dioxide. Anaerobic bacteria gets survival from the food or nutrients (solids) instead of oxygen, and in most cases the process is advantageous in that it produces a reduced volume of sludge, high organic matter removal and high methane gas production it as well [43]. The methane gas produced from the process, if collected, can be used as a source of energy which can make it economically viable. Effluent discharged from PSW factories can also be treated cheaply and more effectively when employing the above pilot plant set up.

IX. Conclusion

The efficiency of poultry slaughterhouse wastewater treatment is dependent on the set-up and design of process. The presented reviewed studies of different wastewater treatment processes show a diminishing removal efficiency. There is a need of the research to be conducted because of its novelty of employing, in the pre-treatment step, bacterium strains obtained from poultry ponds. Furthermore, the process of biological pre-treatment coupled with the use of SGBR inoculated with activated sludge is highly recommended.

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Derrick N. Dlamini is a member of Bioresource Engineering Research Group (BioERG), Cape Peninsula University of Technology. A South African researcher born in 16/08/1982 who has a B-Tech in Chemical Engineering (2007) from the University of Johannesburg, Gauteng, South Africa. He has worked as a Supervisor for 5 years in the production of base metals and 3 years in the sugar industry. Currently, he works at the Cape Peninsula University of Technology as a Laboratory Technician with an ambition of being a researcher.

Mr. Dlamini has won Safety awards and best MDW supervised team from his previous employment. He is currently pursuing a Master of Chemical Engineering in Chemical Engineering.