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Economic life cycle assessment of aeration blowers used in waste water treatment systems

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ECONOMIC LIFE CYCLE ASSESSMENT OF AERATION BLOWERS USED IN WASTE WATER TREATMENT SYSTEMS

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ECONOMIC LIFE CYCLE ASSESSMENT OF AERATION BLOWERS USED IN WASTE WATER TREATMENT SYSTEMS

A dissertation presented in part fulfillment of the requirements for the Degree of Master of Science in Sustainable Environmental Resource Management/ Master of Science in Integrated Science and Technology.

By

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TO MY DAD,

A. MANOGARAN

“A man's desire for a son is usually nothing but the wish to duplicate himself in order that such a remarkable pattern may not be lost to the world.”

HELEN ROWLAND

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List of Acronyms

AOR	Actual Oxygen Required
ACSA	August County Service Authority
BNR	Biological Nutrient Removal
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CO2	Carbon di-Oxide
D/N	Di-Nitrification
EPA	Environmental Protection Agency
ISO	International Standard Organization
GHG	Greenhouse Gas Emissions
LCA	Life Cycle Assessment
LCEA	Life Cycle Energy Analysis
LCEIA	Life-cycle Energy and Impact Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MG	Million Gallons
MWh	Megawatt Hours
MLE	Managed Learning Environment

MG	Million Gallons
PSI	Pounds per Square Inch
RAS	Return Activated Sludge
RH	Relative Humidity
POTW	Publicly Operated Treatment Works
SRF	State Revolving Funds
SAS	Surplus Activated Sludge
SCFM	Standard Cubic Feet per Minute
SOTE	Standard Oxygen Transfer Efficiency
SOR	Standard Oxygen Required
UV	Ultra Violet
U.S.	United States
VFD	Variable Frequency Drive
WAS	Waste Activated Sludge
WWTP	Waste Water Treatment Plant
ft	Feet
gpm	Gallons Per Minute
hz	Hertz
hp	Horse Power
kWh	Kilo Watt Hours
lbs	Pounds

mg/L	Million Gallon per Liter
mgd	Million gallon per day
psig	Pound-force per square inch gauge
rpm	Rotation per minute

ABSTRACT

By Shriram Manogaran

Economic Life Cycle Assessment of Aeration Blowers used in Waste Water Treatment systems

A substantial amount of energy is needed in water supply and treatment systems to convert the unprocessed water into safe drinking water or to purify wastewater prior to discharge to the environment. There is lot of water and energy lost in the process of collection, discharge and delivery of the treated drinking water as well. Therefore the energy and water consumption by these systems have an indirect effect on the local municipality in terms of high energy consumption and in permissive waste of water. Thus, an exhaustive research and life cycle analysis must be carried out in each process of water treatment to extenuate energy and water inefficiencies in the system. Thus new methodologies to improve the efficiency of mundane systems have to be encouraged.

This study focuses on economic life cycle analysis on water treatment systems to attain sustainability in the economic pursuit of water treatment bodies in US. Life cycle assessment concentrates on techniques to access environment impacts on system associated with all the stages of a product's life form. Life cycle assessment helps in analyzing and quantifying the flaws and recommending methods to overcome them. Thus in this study we focus on evaluating the effect on energy consumption, cost etc. for two different (competing) blower technologies used by the August County Service Authority (ACSA), Virginia. The two types of blowers are:

1. Centrifugal blowers – an older, established technology supplied by Hipon
2. Turbo blowers – a relatively recent technology (to US) supplied by Neuros

Keywords: Life Cycle Assessment, Centrifugal, Turbo, Blowers.

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Chapter 1

Introduction

A substantial amount of energy is needed in water supply and treatment systems to convert the unprocessed water into safe drinking water or to purify wastewater prior to discharge to the environment. There is a lot of water and energy lost in the process of collection, discharge and delivery of the treated drinking water as well. Therefore, the energy and water consumption by these systems have an indirect effect on the local municipality in terms of high energy consumption and on permissive waste of water. In light of an increasing realization towards exhaustion of energy and adverse impacts of fossil fuels on the environment, there is a much stronger demand for energy efficiency in all sectors. Operation and facilities of a wastewater treatment plant consume a large part of electricity required at the local government level. Lessening electricity consumption at these cities would lower costs for municipalities and/or agencies worthy for their operation. Meanwhile, the ecological footprint linked with the per capita energy consumption could be reduced. Nevertheless, energy efficiency at wastewater treatment facilities is hard to accomplish without the current patterns of energy consumption being assessed, and sources of loss or inefficiency are identified in the system. Thus, an exhaustive research and Economic Life Cycle Assessment (LCA) must be carried out in each process of water treatment to extenuate energy and water inefficiencies in the system. New methodologies to improve the efficiency of mundane systems have to be encouraged. Economic LCA of key human health and ecosystem risks analyzing the economic impacts of design alternatives and production processes which are essential in improving environmental and efficiency performance [10].

LCA is a standardized methodology for the quantification of the potential environmental impacts of processes and systems. The data provided can be used effectively to assist in decision making situations. The following attributes of LCA contribute to its overall usefulness in the decision making process:

- LCA takes a holistic approach to identifying and quantifying environmental impacts;

- LCA is data driven;
- LCA is replicable where it is based on standard methodologies (i.e. ISO 14040 and14044);
- A range of tools already exist to effectively collate, manage and report data;
- LCA provides a robust methodological framework for quantifying environmental and economic factors and over time is also likely to include social and cultural issues [11].

1.1 Background

Water is essential for human health, living and is the essence of sustainable development. Therefore, water and wastewater infrastructure is fundamental for sustainability and protecting the human population and environment. Sustainable energy is a dynamic harmony between the equitable availability of energy-intensive goods and services to all people and the preservation of earth for future generations [12]. To administer the environmental, economic, and social aspects of sustainability, decision makers will have to make assessments under highly complex and uncertain conditions. Models, methods, frameworks, and guidance for sustainability-based decision making are needed [13].

For many years, minimizing the economic impacts of products focused entirely on production processes and treatment of waste. However, it is necessary to address economic sustainability issues that consider the design, manufacture and use of product across its entire life cycle; from raw material extraction and conversion, to manufacture, distribution and reuse. This perspective of holistic life cycle helps manufacturers, policy makers and stakeholders identify possible improvements across the industrial system and through all of the product life cycle stages. It also helps in improving and identifying flaws in industrial processes and activities [14].

The main objective of thinking about processes using a life cycle perspective is to avoid burden shifting. Burden shifting is defined as minimizing the impacts at one stage of the life cycle, or a specified impact category, while circumventing unrecognized increased impact elsewhere. Considering a life cycle perspective requires a policy developer, environmental manager or product designer to foresee the impacts and irregularities within and beyond their own system, knowledge, or in-house operations. Applying a life cycle perspective can help identify opportunities and lead to sustainable solutions that help improve environmental performance, societal image, and economic benefits [14].

1.2 Rationale

Four percent of the national annual electricity in the U.S. is utilized for the treatment of water and wastewater, which includes everything from the energy required in acquiring the water all the way to discharging the wastewater [15]. In surface and ground water supply systems, the unit electricity consumption in the U.S. is estimated to be 1,400 kWh/MG and 1,800 kWh/MG respectively [16]. Furthermore, Publicly Operated Treatment Works (POTW) accounted for 21 million MWh of electricity in the year 2000 for wastewater treatment alone [17] out of a total U.S. electricity consumption of approximately 3.8 billion MWh [18]. Privately operated wastewater treatment facilities are estimated to consume more energy than the POTW [17] because of their smaller size and potentially higher input, since these facilities are generally industrial or commercial. Thus, the electrical consumption for treatment facilities as a whole in the U.S. is even greater. With these substantial amounts of electricity energy consumption figures for water treatment plants, it makes sense that approximately 80% of municipal water processing and distribution costs are for electricity [18].

The water and wastewater systems are also fundamental for any municipality in footing economic impacts outstanding to the different processes involved. Although there are evident welfares from the water and wastewater treatment plants, there are negative economic impacts as well, in the form of greenhouse gas emissions emission and treatment facility which is the heart of these facilities. For instance, emissions resulting from domestic wastewater treatment accounted for an estimated 20 million metric tons of CO_2 equivalence of global warming potential. Emissions from industrial wastewater treatment resulted in 17 million metric tons of CO_2 equivalence of global warming potential in the year 2004 [19]. The environmental emissions from these wastewater treatment plants further increase the global warming potential from water and wastewater treatment systems.

One of the most grievous forms of environmental pollution threatening both human health and sustainable development can be a result of uncontrolled municipal sewage discharge. Furthermore, inefficiencies and irregularities at different stages in water and wastewater sectors can bestow a significant amount of energy towards high energy consumption due to energy losses and consequently increased greenhouse gas emissions leading from various energy consumption. Hence, energy savings are essential to both water and wastewater sectors to meet national and international targets for decreasing greenhouse gas emissions (GHG) and to decrease dependence on imported energy resources. In order to meet the growing demands in water and energy sector, priority should be given to wise and efficient use of existing water and energy supplies. Transformation is needed at all levels - from the national policy level to innovations and efficient practices at very small scales such as the city level [20].

1.3 Thesis Statement

This study focuses on an Economic Life Cycle Assessment of aeration blowers used in wastewater treatment system to attain sustainability and to increase the sustainability of water treatment bodies in the U.S. Economic Life cycle assessment concentrates on techniques to access economic impacts on systems associated with all stages of energy consumption. Economic Life cycle assessment helps in analyzing and quantifying the flaws and recommending methods to overcome them. Thus, in this study we focus on evaluating the economic effect on energy consumption, cost etc. for two different (competing) blower technologies used by the Stuarts Draft Wastewater Treatment plant, under the authority of August County Service Authority (ACSA), Virginia.

The two types of blowers are:

1. Hibon multi- stage Centrifugal blowers – an older, established technology supplied by the Houston Service Industry, Texas

2. Neuros high-speed Turbo blowers – a relatively recent technology (to the U.S.) supplied by Houston Service Industry, Texas

1.4 Scope of Study

Research problem Justification

Globally, commercial energy consumption for treated safe drinking water accounts for 26 Quads (Quadrillion British Thermal Units) which bills for 7% of the total world consumption of electricity [1]. It has been predicted that the growth in world requirements for development of additional water supplies will range from 25% to 57% by the year 2025 [2]. According to the United States Environmental Protection Agency (EPA), approximately 56 billion kilowatt hours (kWh) are used for drinking water and wastewater services. Averaging energy sources in the U.S. across the board, this equates to adding almost 45 million tons of greenhouse gases to the atmosphere. Just 10% of energy savings in this sector could collectively save about $400 million annually [3]. In a typical biological wastewater treatment plant, the aeration blower system accounts for up to 70% of the energy usage. Today the majority of these plants use the inefficient lobe technology, a technology that has had little development since its introduction in the late 19th century. By reducing the energy usage of their aeration blower system, these plants will decrease their energy costs while operating in a more environmentally friendly manner [4]. Energy represents the main cost in the lifecycle of blowers. As energy consumption typically represents the majority of an air blower's life cycle cost, more energy efficient air blowers will have a significant impact towards preserving the environment [5]. Thus, new methodologies to improve the efficiency of mundane systems have to be encouraged. Foreseeing the depletion of sources of energy and untoward encroachment of fossil fuels on the environment has created a much stronger motive for energy efficiency sectors.

1.5 Methodology

1.5.1 Life-cycle Energy and Impact Assessment (LCEIA)

Life-cycle Energy Analysis (LCEA) is an approach to find total energy usage by reviewing the energy input of a product. These products are accounted for including all the energy inputs needed to produce components, materials and services needed for the process. The procedures of Life Cycle Analysis are a part of ISO 14000. The ISO 14040- "Environmental Management-Life-cycle Assessment – Principles and Framework" [6] – defines:

Life-cycle Assessment (LCA) as a technique for assessing the environmental aspects and potential impacts associated with a product by:

1. Compiling an inventory of relevant inputs and outputs of a product system.

2. Evaluating potential economic impacts associated with the inputs and outputs.

3. Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

The impact assessment consists of three components [7] - classification, characterization and evaluation.

- Classification- where the data from the inventory are grouped into a number of impact categories.
- Characterization- in which impacts are analyzed/quantified and aggregated within identified impact categories.
- Evaluation- in which the contributions from the different specific impact categories are weighted so that they can be compared among themselves.

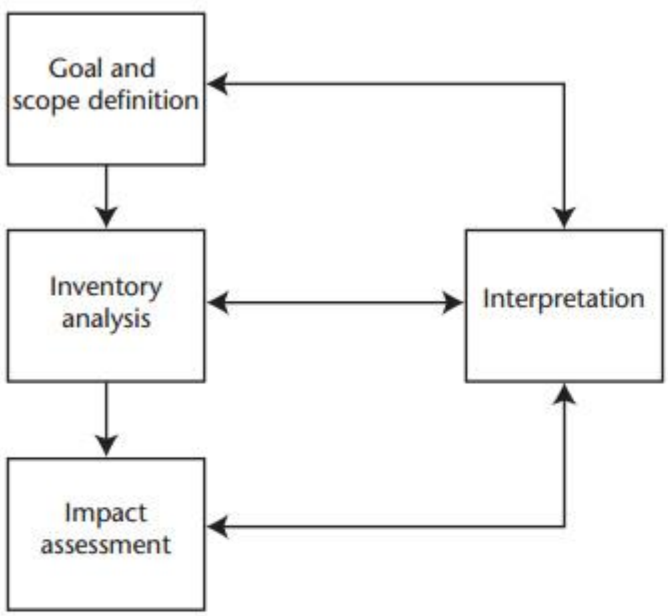


Figure 1.1: Outline of generic Life Cycle Assessment [69]

1.5.2 LCEIA Modeling and Key Parameters for Assessment

The model for LCEIA was created in Microsoft Excel, and the framework for analyzing energy consumption and environmental impacts is explicated in this section.

1. *Life Cycle Energy Analysis*

The study helps in identifying the energy consumption pattern in the two blowers, Hibon high speed and Neuros Turbo blowers. Economic Life Cycle Assessment is followed by Impact assessment. Impact Assessment [8] is a process involved in identifying and assessing the problem at stake. It helps in finding the most suitable way to achieve objectives and analyze favorable impacts.

2. *Key parameters*

This section helps in analyzing energy consumption and economic impacts experienced by the two aeration blower systems.

Total Energy Life Cycle

This section concentrates on the total energy consumption in the form of electricity, natural gas, chemicals and diesel fuel used.

i. *Electricity*

The total electric consumption in the two blowers are calculated and accounted for in terms of kWh per month. It includes all sources of electric energy consumptions.

ii. *Other Energy Consumptions*

Accounts for the amount of energy consumed in any form in the two blowers in the plant operation. It is described in the relevant energy consumption patterns per month.

Total Emission Life cycle

This study accounts for the amount of emission taking place at each process of life cycle.

i. *Electricity*

This study utilizes the information provided in a recent study by Kim and Dale - ‘Life-cycle Inventory Information of the United States Electricity System’ [9] - which compiles the emissions from one Mega Joule of electricity based on the average U.S. grid.

ii. *Diesel utilized*

The total amount of diesel utilized is accounted and reported for in all processes, including the generators.

Chapter 2

Literature Overview

About 3% of the total energy usage in the United States is used to power processing operations at drinking water and waste water treatment facilities [21]. The requirement of a safe and dependable water treatment system was recognized in the U.S. during the late 19th century to the early 20th century [22]. The commonly used methods at this time were disinfection, sedimentation and filtration. These methods were combined to provide dependable waste water treatment systems before the water was sent to storage and distribution. The locations of these plants were chosen in a way so that water flowed by gravity. In the early days these systems used less energy with simpler methods and location-suitable for these systems. Compared to those simpler methods, the existing treatment plants applying modern technologies such as ozone disinfection, ultrafiltration, microfiltration and ultraviolet disinfection require more energy. Hence, waste water treatment plants in operation in the U.S. require much greater amount of energy to operate [22].

Waste water treatment systems in the U.S. also date from the late 19th century, when septic systems were originated and became prominent in rural and urban settings. The federal funding for construction of municipal waste water treatment plants began in the year 1948, and the State Revolving Funds (SRF) were also introduced in the year 1987 amendments to the Clean Water Act. The SRF loaned the local government funds for specific water pollution control processes. To cope with more rigorous discharge limits as per the Clean Water Act of 1977, more advanced treatment technologies such as biological nutrient removal and ultraviolet disinfection came into place. The modern waste water treatment plants require significant energy for operation. The supply of drinking water and collection and treatment of waste water contribute substantially to energy requirements for municipal governments. Exploring opportunities and developing these collected resources contribute to energy conservation in the waste water treatment sector. [20]

A book contributing to energy accounting in the field of waste water treatment is "Energy in Wastewater Treatment" by William F. Owen [23] which was published in 1982. The book is substantial not only in terms of an attempt for reporting electricity consumption at various stages in the treatment process at waste water treatment plants, but also an elaborate description of energy consumption for various sources in the industry. Despite the book focusing on energy consumption for operation of water and waste water treatment, facilities ignored the consumption of other forms of energy utilized for treatment. The book "Energy in Wastewater Treatment" furnishes elaborate information and primary data about the various other energy consumption sources in these industries. Thus, even though this book does not assess waste water treatment systems using LCEA as a method of assessment, it demonstrates to be very utile for studies assessing energy consumption at waste water treatment plants.

Recently, larger amounts of research and development has been put forth examining the energy consumption patterns equating the alternative treatment process in terms of energy consumption as well as evaluating the various stages of energy consumption at the waste water treatment plants. Recently, the Community Clean Water Institute Fortuna and Water Quality Institute studied the energy consumption pattern at Fortuna Wastewater Treatment Facility in California. The results proved that the alternative energy-efficient options for operation and management can be employed at other facilities for accomplishing more energy efficiency in operations of wastewater treatment plants [24].

Life-cycle energy is becoming a common indicator of sustainability for wastewater treatment plants. For example, “Life-cycle Assessment of Water Production Technologies” by R. Gemma Raluy, Luis Serra and Javier Uche, assesses life cycle energy for different technologies currently used on a commercial scale for producing clean water [25]. The study concluded that Reverse Osmosis was environmentally more sustainable than the other two technologies in question: Multi Effect Desalination and Multi Stage Flash.

One of the main uses of electricity in the modern wastewater treatment plant is the aeration blower system. In this study, we concentrate on how two different blower technologies in the waste water treatment plant determine the overall cost of operation in the long term by exceeding the initial investment cost. The economic importance of a waste water system largely depends upon the design, day to day operation and maintenance of the aeration and process controls. The human factor and the management play a crucial role in reaching the objectives at the heart of the plant’s reality [26]. The information on the case study presented in this report is the primary information collected from the treatment facilities in a standard format. The consumption of energy is collected from the monthly electricity bill or the monthly reports of energy consumed by the blowers.

The Economic Life Cycle Assessment on these blowers used in the waste water treatment plants can systematically estimate the economic consequences and help to analyze the exchange of energy and environmental impacts. In addition, LCA can map the flow of quantitative information between different working environments. It can be used within the industry to compare and contrast the performance and efficiency between two different components in the same sector. It helps us in process improvement, technology selection and also supports marketing to inform different stakeholders groups within the product or company. Finally, it must be noted that with the help of this methodology, producers make better decisions pertaining to environmental protection and better energy efficient technologies [27].

Chapter 3

Operation of Waste Water Treatment Plant

3.1 Introduction

The main objective of a waste water treatment plant is to produce a disposable effluent without causing any harmful effects to the surrounding environment and to reduce pollution [28]. It consists of a multitude of physical, chemical and biological processes to get rid of different contaminants present in the water. The primary objective is to produce an environmentally clean and safe fluid stream (or treated effluent) and a solid waste, (or treated sludge) convenient for removal or reuse (generally as farm fertilizers). With advancement in technology, it is now possible to re-use sewage effluent for drinking water, although Singapore is the only nation to implement such advanced technology in its production of NEWater [29].

3.2 Need for Water treatment.

Waste water treatment helps in preserving rivers and streams for fishing, swimming and drinking water. The first half of the 20^{th} century, the U.S.'s urban waterways pollution resulted in natural events such as low dissolved oxygen, dying fish, algal blooms and bacterial contamination.

Water pollution regulations stopped human waste from reaching water supplies and minimized floating debris from obstructing shipping. The water pollution problems and their controls were primarily local government concerns. Since then, industrial growth and population problems have increased, while natural resources have remained stagnant. Although regulation measures and large investments in water pollution control have aided the problem, many miles of streams are still impacted by several other different pollutants, thus, resulting in the inability of people to use the water for beneficial purposes [32].

3.3 Oxygen Transfer

Oxygen transfer is the process in which the state of oxygen is changed from a gaseous to a liquid phase. This transfer of oxygen state is the most important part of any waste water treatment process. Processes like activated sludge, biological filtration and aerobic digestion depend primarily on ample quantities of oxygen. A given volume of water can be aerated based on the quantity of oxygen being transferred per unit of air introduced into the water for equivalent conditions (chemical composition of water, depth at which the air is introduced, temperature, etc.) [41].

3.4 Process overview

The methods of treatment in which the application of physical forces deal with contaminated water are known as unit operations. The method of treatment in which the removal of contaminants is brought about by chemical and biological processes, generally known as unit processes. The unit operations and processes are grouped together to provide various levels of treatment known as preliminary treatment, primary treatment, advanced primary treatment, secondary treatment (with or without nutrient removal) and advanced or tertiary treatment [30].

Treatment level	**Description**
Preliminary	Removal of waste water constituents such as rags, sticks, floatables, grit, and grease that may cause maintenance or operational problems with the treatment operations, processes, and ancillary systems.

Primary	Removal of a portion of the suspended solids and organic matter from the wastewater.
Advanced primary	Enhanced removal of suspended solids and organic matter from the waste water. Typically accomplished by chemical addition or filtration.
Secondary	Removal of biodegradable organic matter (in solution or suspension) and suspended solids. Disinfection is also typically included in the definition of conventional secondary treatment.
Secondary with nutrient removal	Removal of biodegradable organics, suspended solids, and nutrients (nitrogen and/or phosphorus).
Tertiary	Removal of residual suspended solids, usually by granular medium filtration or microscreens. Disinfection is also typically a part of tertiary treatment. Nutrient removal is often included in this process.
Advanced	Removal of dissolved and suspended materials remaining after normal biological treatment when required for various water reuse applications.

Table 3.1: Levels in Wastewater treatment [30]

3.4.1 Sludge Treatment

Now the sludge collected in the process of waste water treatment have to be handled and taken away in a secure and efficient manner. The intention of this digestion process is to minimize the amount of organic matter and the various different disease causing microorganisms present in the solids. The most common practices include anaerobic digestion, aerobic digestion and composting [45].

3.4.1.1 Anaerobic digestion

Anaerobic digestion is an array of processes in which microorganisms disintegrate biodegradable material in the absence of oxygen [46]. This is the commonly used domestic procedure to manage or dispose waste or to exonerate energy.

Process

The anaerobic digestion process involves many microorganisms, which include acetic acid forming bacteria (acetogens) and methane-forming archea (methanogens). These organisms undergo a series of metabolic processes in which they consume the initial stock converting them into intermediate molecules like sugars, hydrogen, and acetic acid, before finally being converted to biogas [47].

The survival of different species of bacteria depends on different temperature ranges. The mesophilic or mesophiles are the bacteria which survive at optimal temperature between 95º and 104º F (35º and 40º C). The thermophiles or thermophilic bacteria are the ones which can survive at hostile conditions and hotter conditions like 130º to 140º F (55º to 60º C) [21]. Methanogens hail from the archaea family, which includes species that can grow in any hot or hostile conditions of hydrothermal vents [49].

In aerobic systems, the bacteria need a source of elemental oxygen to grow and reproduce microorganisms, but in anaerobic systems there is no source of oxygen present. Any form of gaseous oxygen is prevented from entering the system through sealed tanks and physical containment [50]. Anaerobic systems access oxygen from other sources rather than surrounding air, which could be an organic material or the oxides which can be derived from the input material itself. The aldehydes, primary alcohols and organic acids with carbon dioxide could be the end products with the above reaction. The end product of methane and carbon dioxide can be formed with the presence of specialized methanogens; the end product usually contains traces of hydrogen sulfide [51]. In anaerobic systems, the bulk of chemical energy contained within the starting material is terminated by methanogic bacteria as methane [52].

The anaerobic microorganism population typically takes a substantial amount of time to grow themselves to be fully effective. Thus, to speed up the process anaerobic microorganisms are introduced into the existing materials. This process is known as “seeding” the digesters, commonly achieved with the addition of sewage sludge or cattle slurry [53].

3.4.1.2 Aerobic digestion

Aerobic digestion is a process in which the natural biological degradation and purification of bacteria is done in an oxygen rich environment, where they are broken down and digested into waste.

After the oxidation process, the pollutants are deteriorated into carbon dioxide (CO2), Water (H2O), nitrates (NO3), sulphates (SO4) and biomass (microorganisms). The aerators provide adequate oxygen supply to substantially increase the operation. Of the three sludge digestion processes, aerobic digestion is the most commonly used biological treatment throughout the world [54].

3.4.1.3 Anoxic Digestion

Anoxic digestion is a biological process in which a definite category of microorganisms are chemically treated to combine with oxygen present in nitrates and nitrites. These microorganisms support life functions by consuming these organic matters. They produce nitrogen gas, carbon dioxide and more stable solids and organisms by using the oxygen present in nitrates and nitrites in the organic matter [54].

3.4.2 Biological and chemical oxygen demand

An aerobic bacterium uses oxygen to disintegrate dissolved pollutants. A normal process involves a large amount of pollutants, thus large quantities of bacteria are required. The demand of oxygen is high. The most influential factors to be considered here are the Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

BOD is the amount of oxygen required by the biological organisms in the waste water to break down the organic material present in a given waste water sample at specific temperatures over a certain time period. This can also be referred to as the chemical procedure to determine this amount [55]. COD is the chemical oxidation process in which the quantity of dissolved organic pollutants can be removed by adding strong acids. It is expressed in mg/l. The ratio of BOD to COD indicates the amount of pollutants in the wastewater that are biodegradable [54].

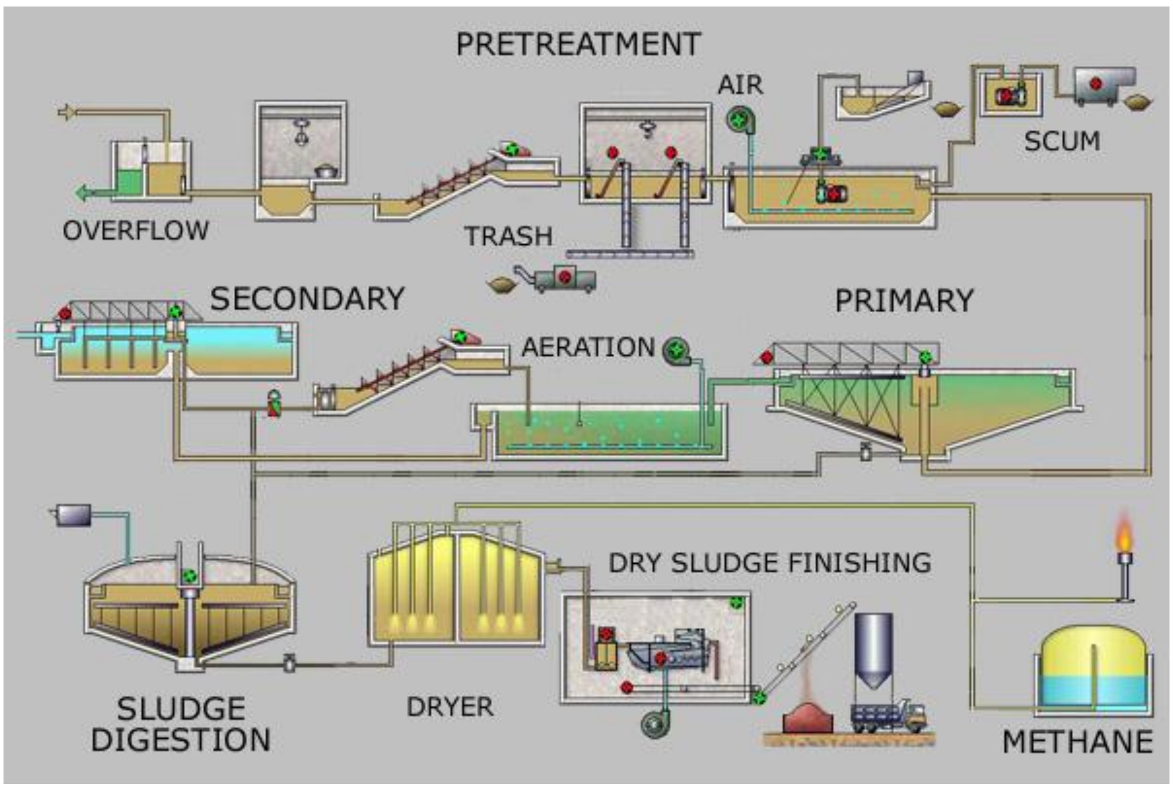


Figure 3.1Process Flow Diagram for a typical large-scale treatment plant [62]

3.5 Purpose of Aeration

Figure 3.1 represents a general process flow operation carried out in a waste water treatment plant. The influents passes through a pretreatment chamber, a primary treatment level, a secondary treatment level and passed on the chemical treatment chamber before discharge. The process of aeration takes place in the secondary treatment chamber; there are various factors to be considered for an effective aeration system.

3.5.1 Activated sludge

Presently, the most commonly used biological treatment, the activated sludge process, recirculates a certain portion of the biomass as an inherent part of the procedure. This procedure permits the microorganisms to adapt changes in waste water composition in a comparatively small acclimatization process. Thus, the procedure gives a greater degree of control over the acclimated bacteria [37].

3.5.2 Activated Sludge Systems

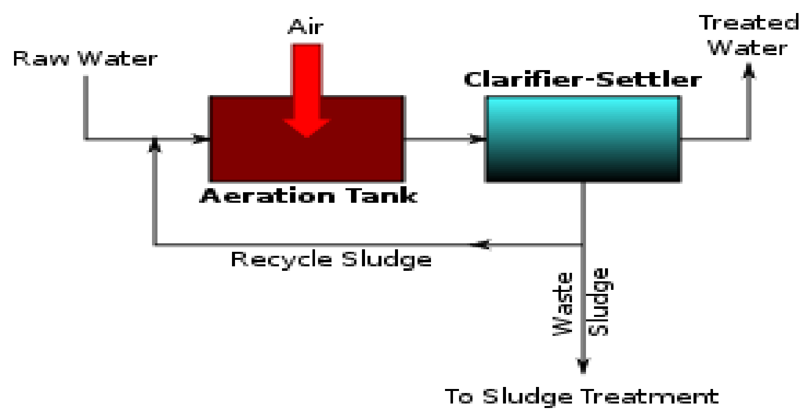


Figure 3.2 A generalized, schematic diagram of an activated sludge process [63]

Figure 3.2 shows a detailed view of an activated sludge system, where the raw waste water is sent into the aeration tank and then the treated water is sent into the clarifier settler and the remaining sludge is recycled back in the aeration tank to increase the biological activity. An activated sludge system consists of an aeration tank and a settling clarifier. All activated sludge systems include an aeration basin succeeded by a settling tank. The aeration tank receives the treated waste water from the primary clarifier as well as a mass of recycled biological organisms (recycled sludge) from the secondary settling tank- the activated sludge. The recycled activated sludge is sent back to the aeration tank to maintain the population of bacteria which helps to maintain the biological activity.

Factors affecting the performance of an activated sludge include temperature, return rates between the aeration tank and settling tank, amount of oxygen present in the aeration tank, amount of organic matter present in the aeration tank, pH of the water, rate of waste disposed, aeration time, and waste water toxicity.

Acquiring proper performance levels in an activated sludge system means maintaining a proper balance between the amounts of organic matter, activated sludge (organisms) and dissolved oxygen. A problem in an activated sludge system means there is an imbalance among these three items.

3.5.3 Activated Sludge Process Operation

The process covers different kinds of mechanisms and processes that use dissolved oxygen to promote the growth of biological flocs that considerably remove organic material [4]. In short, activated sludge is a process in which air or oxygen is forced into sewage liquor to develop biological flocs which reduce the organic content of the sewage [32].

The primary purposes of the activated sludge process are:

- To handle and treat the waste sludge;
- To treat the biologically enriched carbon matter through a process of oxidization;
- To treat the biologically enriched nitrogenous content present in the sludge and oxidize ammonium and nitrogen;
- To eliminate phosphate;
- To eliminate nitrogen, carbon dioxide, ammonia, etc. which are present as entrained gases;
- To produce floc that settles easily;

- To produce liquor which cannot suspend the material or dissolve easily [38].

The normal procedure involved in an activated sludge process for removing carbonaceous pollution includes the following requirements:

- An aeration tank where air (or oxygen) is pumped into the mixed liquor;
- A settling tank (usually referred to as "final clarifier" or "secondary settling tank") where the biological flocs are allowed to settle down, therefore the biological sludge is separated from the clear treated water.

After the primary screening is completed and the grit is removed, the waste water still has organic or dissolved constituents and inorganic constituents along with suspended solids. The suspended solids consist of minute particles which can be removed by further treatment such as sedimentation, chemical coagulation, or filtration. When the waste water enters a sedimentation tank, it slows down the suspended particles gradually sinking to the bottom. This portion of mass is called primary sludge and the various methods have been devised to remove primary sludge from the tanks [33].

Now in the activated sludge process, air or oxygen is being introduced into a mixture of primary treated or secondary screened sewage or industrial waste water combined with microorganisms to develop a biological floc which helps in reducing the biological organic content of the sewage. These biological materials found in the healthy sludge are known as the brown flocs which are largely composed of saprotrophic bacteria but also have other important protozoan flora mainly composed of amoebae and a range of other filter feeding species. In some cases of poorly managed activated sludge, a range of mucilaginous filamentous bacteria can develop Sphaerotilus natans which produces a difficult to settle sludge and can result in the decanting sludge blanket over the fences in the settlement tank which could result in severe contamination in the quality of the final effluent product. This product is often depicted as a sewage fungus [32].

The biological combination of waste water and biological mass is generally known as mixed liquor. In every activated sludge plant, the treated water from the previous process undergoes further treatment before it gets discharged. For instance, once the waste water has received adequate treatment, excessive mixed liquor is discharged into a settling tank and the treated supernatant product is sent into the runoff to confront further treatment before discharge. Now part of the settled sludge is returned into the head of aeration process to re-seed the new waste water entering the tank. The fraction of floc is called Returned Activated Sludge (RAS) and the excess sludge is called the Surplus Activated Sludge (SAS) or the Waste Activated Sludge (WAS). To keep the ratio of biomass constant to the food supplied in the waste water in balance, SAS is removed from the treatment process. Later, the SAS is treated further under anaerobic or aerobic conditions prior to disposal, which is stored in sludge tanks [32].

3.5.4 Purpose of Activated Sludge Treatment Process

The collection, processing and disposal of sludge are the most costly and complex aspect of waste water treatment. About 5% of the primary sludge is filled with a concentration of solids whereas in the activated sludge it is less than 1% and the sludge from the trickling filters has about 2%. This shows that sludge before treatment is composed entirely of water, and reducing this volume is the key to economic disposal. During the process of reducing the water content, the sludge must be stabilized so that its biological activity and putrefaction are exceedingly reduced [43].

What is it?

Activated sludge is a process to cultivate a mass of microorganism in the treatment process to break down carbon dioxide, water and other organic and inorganic compounds. The activated sludge process consists of three fundamental components:

1. A reactor consisting of microorganisms which are kept in suspension, aerated and also in contact with the waste they are treating.
2. A liquid-solid separation process.
3. A sludge recycling process in which the RAS is returned back to the beginning of the process.

There are many variants of activated sludge processes, for instance it could be differentiated with a variation in aeration method and the way the sludge is returned to the process [34].

Why to use it?

Activated Sludge removal process helps in effective and efficient removal of BOD, COD and nutrients, when designed and professionally operated to local and desired requirements. The process itself has exceptional flexibility and numerous modifications which can be tailored to meet specific local requirements, for instance Nitrogen removal. Activated sludge is the most commonly used form of secondary waste water treatment [34].

When to use it?

Activated sludge can be suitable in conditions where high removal of organic pollution is necessary, funds and skilled personnel are available for operation and maintenance, and land is scarce or expensive. The activated sludge process requires a wide availability of continuous operation of oxygen blowers, sludge pumps, and a steady energy supply. These systems need some form of pretreatment; usually processes such as screening and primary sedimentation are done [34]. The aeration blowers are the source of these systems to provide air (or oxygen) to these activated sludge basins to undergo the aforementioned process. High speed centrifugal and turbo blowers serve this purpose.

3.6 Aeration Blowers

Blowers are dynamic machines that convert the kinetic energy added to the air by the blade of the rotor into head pressure (potential static energy) in the discharge scroll. The machine is designed for worst case conditions such as lowest air density and highest compression ratio [36]. There are three types of commonly used blowers for aeration: centrifugal, rotary lobe positive displacement and high speed turbo. In waste water treatment plants, the blowers must render a wide variety of airflows under different environmental conditions and with a relatively narrow pressure range. A blower cannot satisfy a different varied set of operations at once, it can meet only one particular set of operating conditions. A blower is required to meet a wide range of air flows and pressure at a waste water treatment plant including blower system design and process control methodologies to regulate and turn down the blowers [41]. The following table discusses the general requirement specification of a centrifugal and a high speed turbo blower.

Special purpose single-stage high-speed centrifugal blower

Flow control range at constant Pressure	100% to 45% of full flow; power required is nearly proportional to the load
Most useful operating pressure Range	Compression ratio up to 2.5
Most useful flow range per unit	Standardized packages to 5000 to 70,000 SCFM (150 to 2000 m^3/min). The engineer specifying a single machines for an air flow ≥ 10,000 SCFM (>300 m^3/min), should consider a special purpose high-speed centrifugal blower for its high energy efficiency and small space requirements.
Efficiency	Highest thermodynamic efficiency. If equipped with adjustable outlet diffuser vanes and VFD driven, these machines will maintain a nearly constant efficiency over their entire flow turndown range at constant pressure.
Drive	Standard electric motor. Integral gear. Inlet guide vanes are used to adjust to varying compression ratio and inlet conditions. A VFD is not required but can be used instead of inlet guide vanes.

Table 3.2 Special purpose single-stage high-speed centrifugal blower [36]

The following Figure 3.3 is a general representation of the Hibon multi- stage Centrifugal blower used at the Stuarts Draft WWTP.

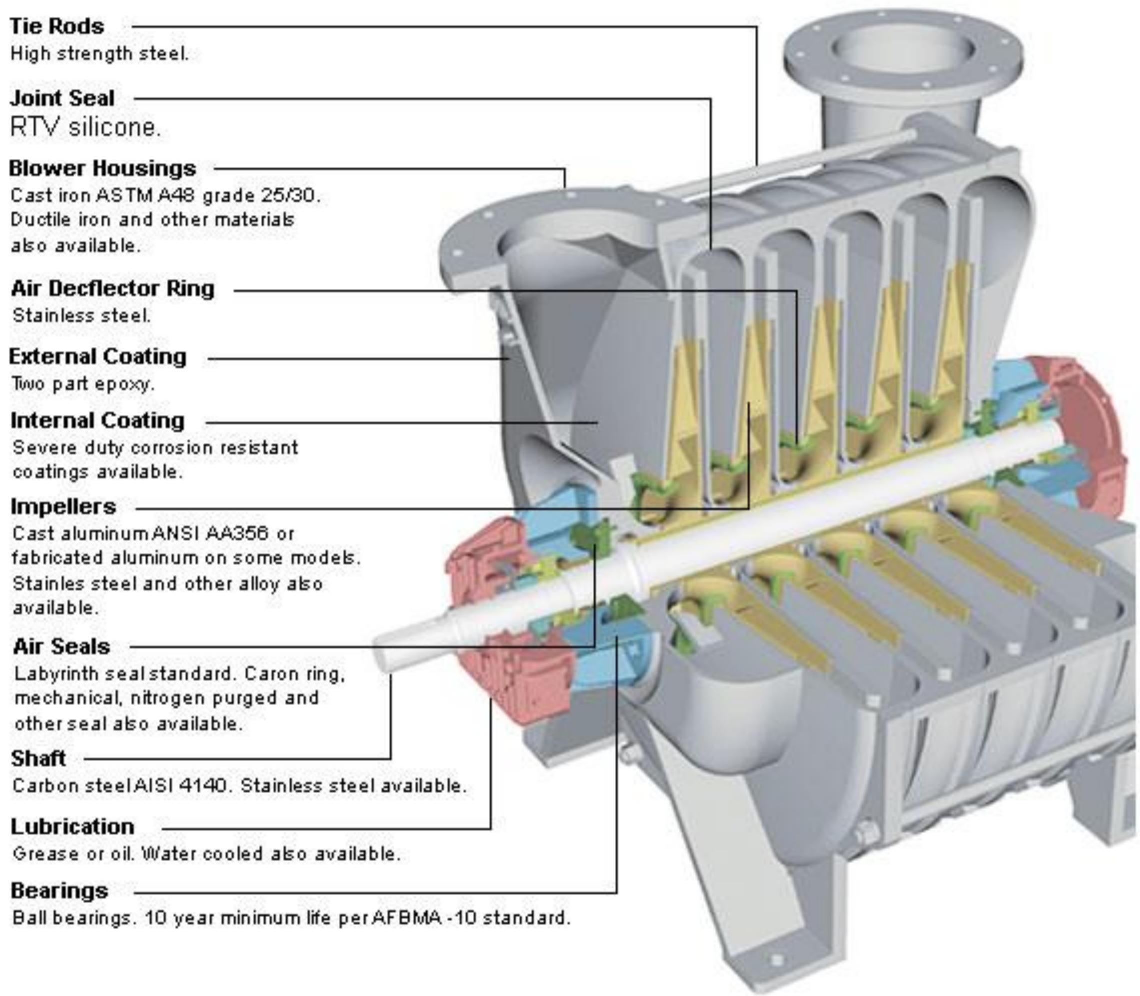


Figure 3.3 Pictorial representation of a Hibon multi- stage Centrifugal blower [64]

Standardized high-speed turbo blower

Flow control range at constant pressure	100% to 45%. Possibly narrower depending on operating vs. design point. Reduced turndown at high ambient temperature or at high pressure ratio.
Most useful operating pressure range	9 psig (~600 mbar) to 18 psig (~1.2 bar g)
Most useful flow range per package	From 350 SCFM (10 m³/min) to 6000 SCFM (170 m³/min)
Efficiency	High at the design point; drops when

	conditions differ from the design point. Power information includes all electrical and mechanical losses: “wire-to-process”
Typical efficiency difference to a specific-purpose high-speed centrifugal blower	Lower efficiency by 0% to 10% depending on operating point vs. optimum point
Drive	Direct only with high-speed proprietary permanent magnet motor. Cannot be operated without a high frequency VFD.

Table 3.3 Standardized high-speed turbo blower [36]

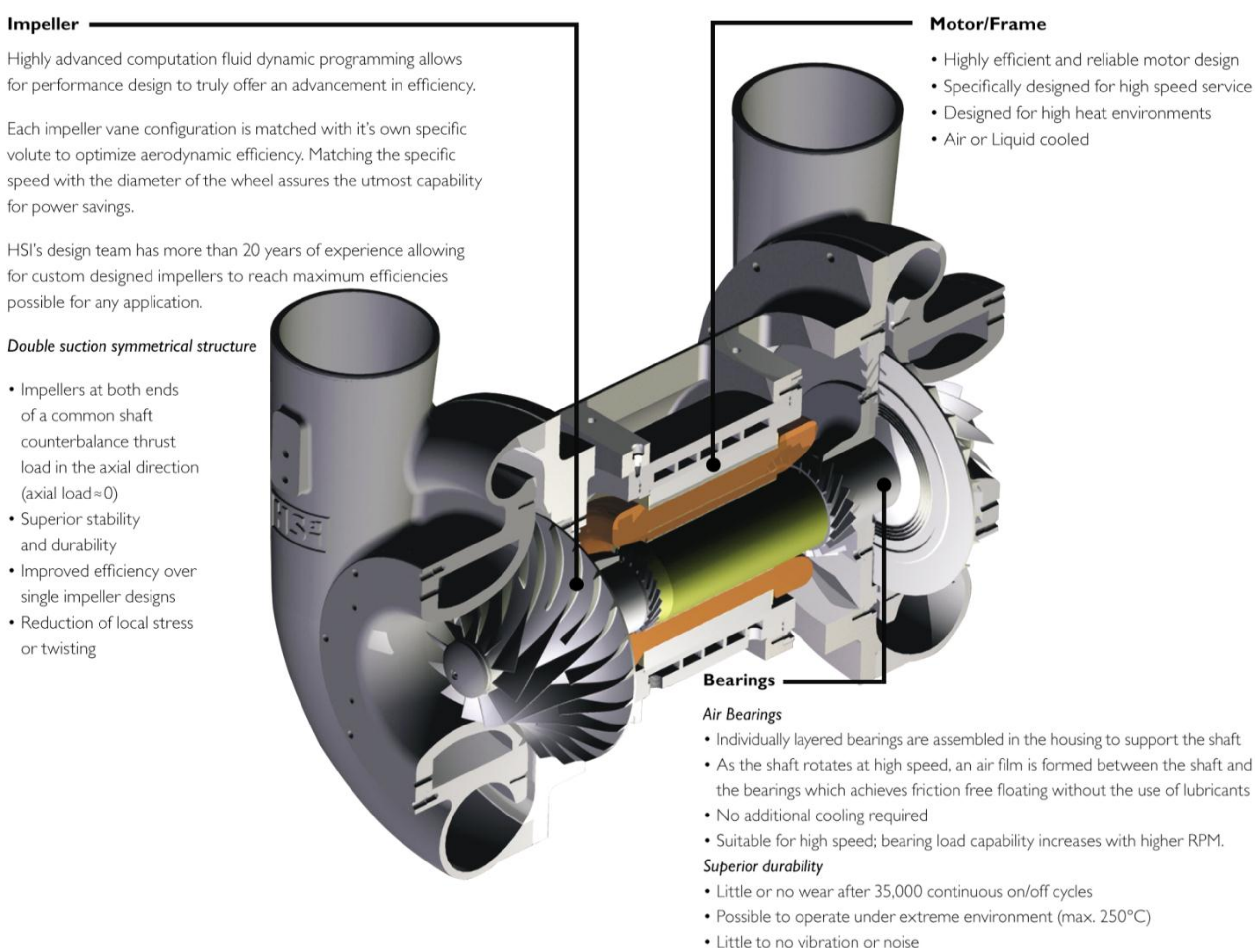


Figure 3.4 Pictorial representation of a Neuros High speed turbo blower [65]

Figure 3.4 shows a general representation of the Neuros high-speed turbo blower used at the Stuarts Draft WWTP. The aeration blowers are highly critical to these waste water systems but can consume a large amount of electricity costs required by these treatment plants. Consider some facts from the Environmental Protection Agency about energy use at waste water treatment facilities:

- The waste water treatment facilities account for nearly $3 billion each year (about 56 billion kWh) for energy costs and an added estimate of 45 million tons of greenhouse gas emissions to the atmosphere annually.

- In a typical biological waste water treatment plants nearly 70% of the facilities entire energy usage is consumed by the energy blower systems alone.

- When costs loom this large, it is easy to see that even a little savings goes a long way. Even an annual energy savings of just 10 percent in this sector could collectively save about $400 million every year. Multiply these figures by three and the impact is tremendous [35].

3.7 Variable Oxygen demand

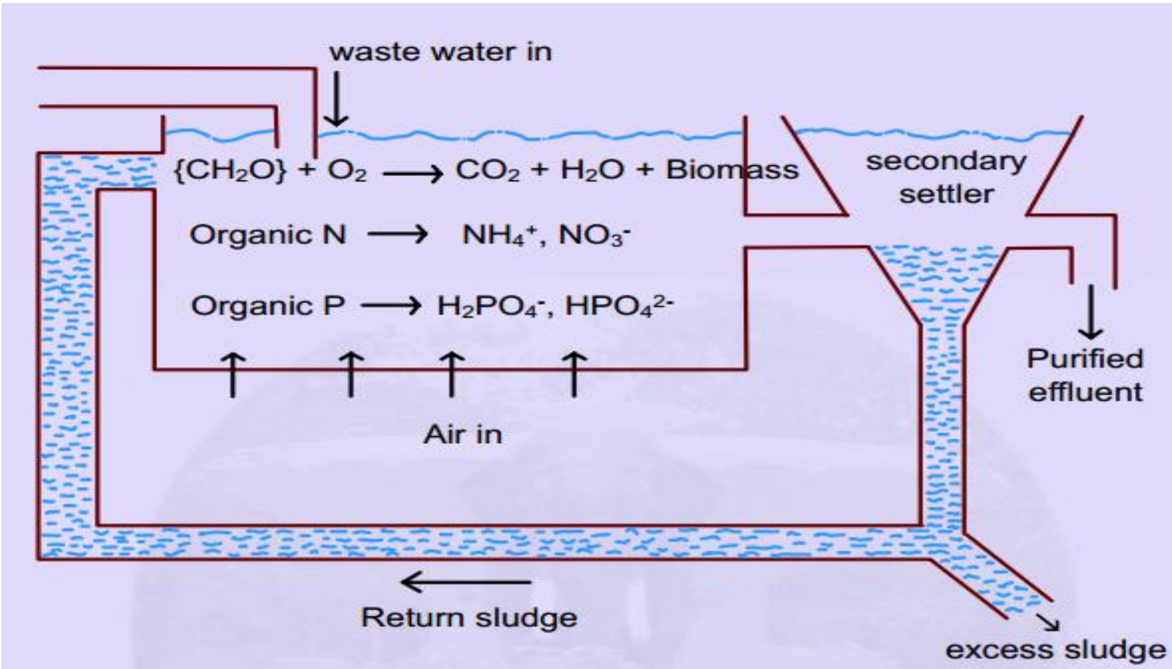


Figure 3.5 Chemical reaction of Oxygen inside Activated Sludge Chamber [66]

Figure 3.5 explains the chemical reaction taking place in an activated sludge chamber. Variable oxygen demand is one of the important criteria to be considered in a waste water treatment plant. The oxygen demand has a direct impact on the energy consumed by the plant. A correct dosage of the quantity of oxygen is needed at each step of the process. This oxygen demand can be varied with temperature, sunlight and other climatic conditions. The absorption of oxygen in the waste water is the most important parameters that influence the amount of energy used by the plant because the amount of oxygen is directly proportional to the air flow produced by the aeration blowers. To provide an accurate oxygen level at any moment requires automatic flow adjustments. Blower systems are therefore subjected to adapt to these changes in a stable and reliable way without surging [35].

3.7.1 Oxygen demand

The blower pushes the air into the tank, either in the form of bubbles through diffusers or by surface aerators. The micro-organisms use the oxygen in the air and change over the organic matter containing Nitrogen (N), Phosphorus (P) into stabilized, low energy compounds such as

Carbon dioxide (CO2), Water (H20), Nitrate ion (NO_3^-), Sulfate ion(SO2−), Ammonium ion (NH+), and Di-hydrogen phosphate ion (H2PO4). Newly synthesized bacteria cells and the effluent containing the flocculating biomass are separated from the tank. This biomass is separated out in a settler, and a fraction of them is discarded. The remaining solids are recycled as returned sludge to the aeration tank and come in contact with the new sludge. Now a varied combination of high concentration of new "hungry" cells and returned recycled sludge provides an optimal state for waste degradation [43].

In an activated sludge chamber the Biological Oxygen Demand (BOD) is separated in two different ways:

i. The organic matter in the tank is oxidized by the process of metabolism. The process follows as the organic matter is oxidized by providing energy for the metabolic reaction of the micro-organisms

ii. The other ways are synthesis and incorporation of organic matter into cell mass. In the primary footpath, the carbon is converted into a gaseous form of Carbon Dioxide (CO2), and it is removed. The alternate footpath is by removing the carbon as a biomass solid. The solid biomass portion of carbon is converted into a gaseous form of CO2 and is ventilated to the atmosphere. The remaining is a mixture of solids and water called sludge [43].

3.7.2 Chemical processes which occur in biological waste treatment

The substantial process which occurs throughout a biological waste water treatment is called nitrification. During this process, the ammonium ion is oxidized, first to nitrate by Nitrosomonas bacteria, under specific conditions.

$$2NH_4^+ + 3O_2 \rightarrow 4H^+ + NO_2^- + 2H_2O \quad \text{.......................}(1)$$

then to nitrate by *Nitrobacter*:

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad \text{.......................}(2)$$

The above reaction is a basic chemical composition exchange happening in an aeration tank of the activated sludge plant. The above reactions are favored for a long retention time, low organic loading, and a large amount of suspended solids and for high temperatures. Following that, denitrification process is induced by the action of pseudomonas in an oxygen deficient settler.

$$4NO_3^- + 5\{CH_2O\} + 4H^+ \rightarrow 2N_2(g) + 5CO_2(g) + 7H_2O \text{ ....} (3)$$

Due to the presence of oxygen deficit, bubbles are formed on the sludge floc, thus making it buoyant and floating on top. Thus, settling of sludge is prevented and organic load in the receiving waters is increased. Under a few specific conditions, advantages can be taken in removing the nutrient nitrogen from the waste water [43].

Generally, an activated sludge treatment process produces more microorganisms than essentially needed for the process. Thus, if the microorganisms are not removed, the concentration will increase more metabolic reactions, producing more clogs, thus resulting in clogging the system with solids. Therefore, some of the microorganisms have to be washed out.

3.8 Oxidation in ponds

Oxidation ponds are usually 1-2m deep, with a large shallow structure. The partially treated sewage or raw sewage is treated and decomposed by microorganisms. Similar kinds of reactions are expected in an eutrophic lake. The ponds are designed to maintain aerobic conditions throughout. The decomposition reaction taking place near the surface is aerobic while the one at the bottom is anaerobic. The ponds facilitating both aerobic and anaerobic reactions are called facultative ponds. In aerobic decomposition the oxygen is taken from surface aeration and algal photosynthesis; the other ponds which cannot be aerated naturally are artificially done. The reactions taking place in a facultative pond is shown in Figure 3.4

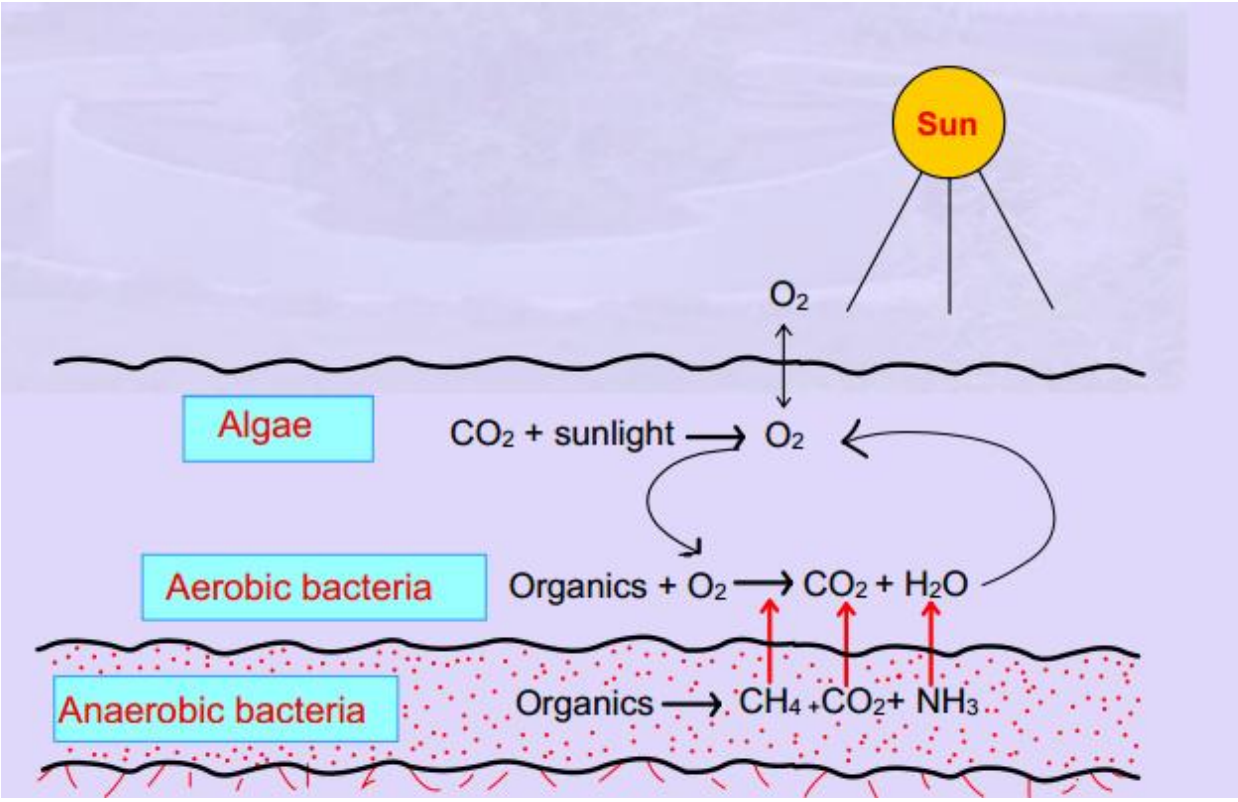


Figure 3.6 A general chemical reaction in an Oxidation pond [67]

Figure 3.6 explains the general chemical reactions taking place inside an oxidation pond. Oxidation ponds have to be large enough to provide complete treatment to raw sewage. An oxidation pond can be effectively used in small communities where land constraints are not so critical. They provide treatment and fluctuation in large flow but cost much less than the conventional biological system. However, the effluent may be filled with an undesirable concentration of algae which in winter produce unpleasant odor due to less oxygen being liberated by photosynthesis. The major disadvantage of pond oxidation is that the effluent produced may not meet the EPA secondary treatment requirement of 30 mg/L BOD and suspended solids [43].

3.9 Process control in an Activated Sludge system

Process control plays a vital role in an activated sludge process in maintaining an adequate air pressure according to the requirement in an aeration tank. There are three fundamental parameters to be adjusted to assert an efficient operation in an activated sludge process. Return Activated Sludge flows, Waste Activated Sludge flows, and dissolved oxygen levels are the three parameters. The dissolved oxygen levels are stabilized by checking the amount of air flow distributed by the diffuser in each basin. The air header pipes can be used to control the level of dissolved oxygen, for instance when the dissolved oxygen levels are too high, it can be limited using the values of the air header pipes. When the diffuser gets constipated or choked off, the air flow will drop dramatically. In those situations the diffuser can be jostled with a sudden burst of air to help clear them. Maintaining a proper dissolved oxygen level between the airflow and the basin is the vital part of maintaining an efficient operation [39].

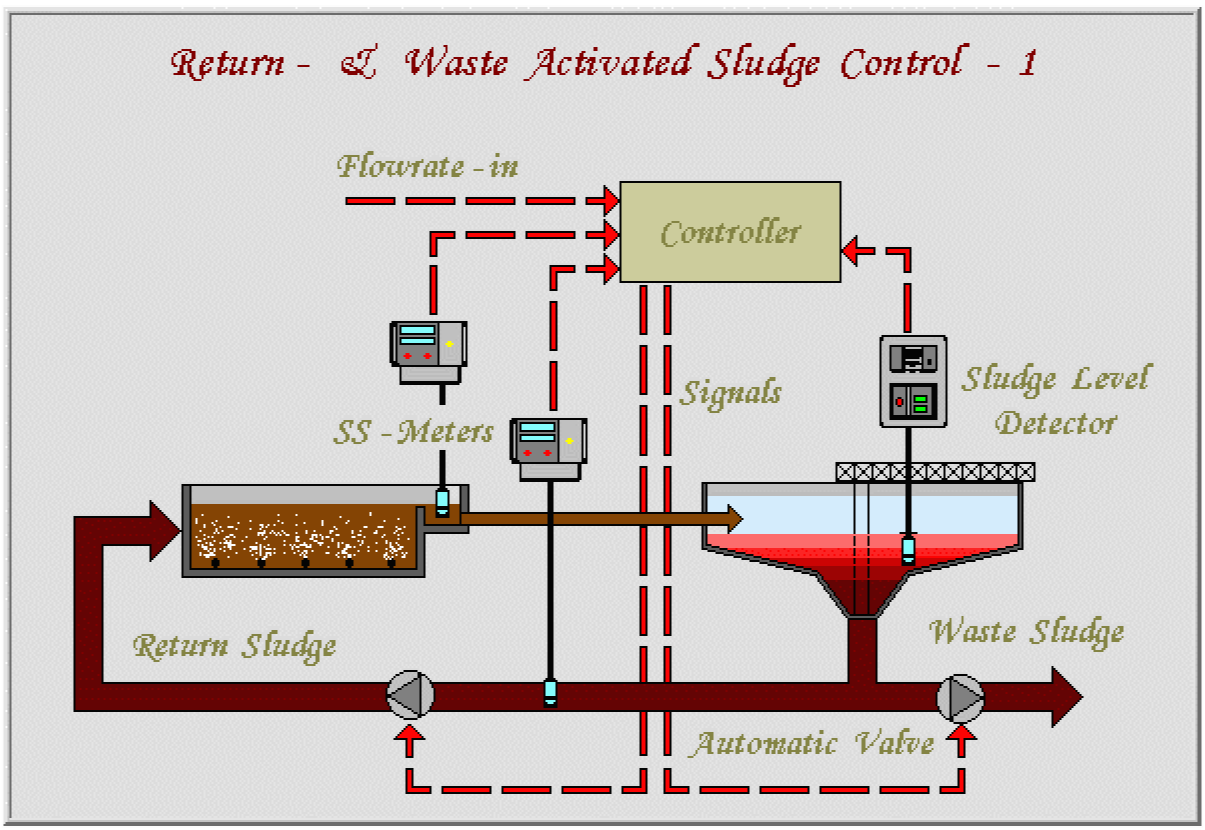


Figure 3.7 Return and Waste Activated Sludge Control Process [68]

Returned activated sludge flows are crucial because the microorganisms must be brought back to the aeration tank before they run out of dissolved oxygen. The sludge flows are suspected to spend about two hours in the clarifier throughout the average flows. In that time they consume up to 2-4 mg/L of dissolved oxygen that they had when they entered the clarifier. If the sludge is not returned to the aeration tank in time the rate in which they consume (metabolism) would fall, causing the reaction in the tank to be ineffective. The longer they stay without air the longer it will take them to build up their metabolism rate to the endogenous levels which is required to meet the F:M ratio. Returned sludge pumping capacity should be ample enough to virtually match the daily average flow rate at night. This is meant to be checked because the detention time in the clarifier gets longer as the flow drops at night. To atone the detention time in both aeration basin and the clarifier, the return activated sludge flows are increased, thus resulting in reduced depth of sludge blanket in the clarifier due to the increased return sludge flows [39].

Wasting sludge is one of the ways to maintain the F:M ratio. As the biomass eats the organics it produces more bugs. The excess must be taken out to maintain the MLSS levels. Waste activated sludge flow rates are generally 1-2% of the influent flow. The sludge age increases with the rise in MLSS levels. The older sludge is not suspected to settle, thus resulting in ashing and solid carryover out of the clarifier. When the ashing occurs the waste rate is increased to take away more solids from the system. As the light tan colored straggler floc is going over the weirs, it is commonly an indication that the sludge age has decreased. Thus, the sludge age or MCRT is increased by reducing the wasting rate [39].

Care should be taken when changing wasting rates. A sudden increase in the WAS flow can lead to an upset of the process. WAS should be removed continuously and changes in flows should be made in 1-2% increments each day to minimize the impact on the process. It is essential to remember that it takes a long time to see results from the process changes. A startup may take up to 60 days and 1 to 2 MCRT to see the results from the wasting changes [39].

Perfect measurements and precautions should be made while changing the wasting rates. An abrupt increase in the WAS flow can lead to an upset in the process. To minimize the impact on the process, the continuous changes in flow of WAS should be maintained. The change of flows should be made in 1-2% increments each day to minimize the impact. The process change does not occur immediately, it takes a lot of time to see results [39].

3.10 Diffusers

Diffused air system is a process in which air is passed through the waste water as bubbles [42]. Diffusers are the devices which release air or oxygen into the aeration tank. These days, aeration systems are classified by the physical characteristics of diffusers. They are:

i. Porous or fine-porous diffusers,

ii. Non-porous diffusers,

iii. Jet aerators, aspirating aerators, and U-tube aerators.

The other diffused air devices are described in Table 3.4

Type of diffuser or device	Transfer efficiency	Description
Porous Disk	High	Rigid ceramic disks mounted on air-distribution pipes near the tank floor.
Dome	High	Dome-shaped ceramic diffuser mounted on air-distribution pipes near the tank floor.
Membrane	High	Flexible porous membrane supported on disk mounted on an air-distribution grid.
Panel	Very high	Rectangular panel with a flexible plastic perforated membrane.
Non-porous fixed orifice	Low	Devices usually constructed of molded plastic and mounted on air-distribution pipes
Slotted tube	Low	Stainless-steel tubing

		containing perforations and slots to provide a wide band of diffused air
Static tube	Low	Stationary vertical tube mounted on basin bottom and functions like air-lift pump

Table 3.4 Type of Diffusers

The important issue to be considered is the pore size in the diffuser membrane. There are separate benefits for each kind of openings under certain circumstances. The performance of the diffuser is solely based on the material construction and size and opening of the surface of the membrane. The oxygen transfer efficiency can be improved by slightly improving the pore size, as long as the pore size is maintained at a low air flow rate. The advantage of using smaller pores and smaller flow rate is the air flow going through smaller pores gives smaller bubbles and a small improvement in oxygen transfer efficiency. The disadvantage is the small openings also create issues with pressure losses through membranes and magnify the potential for fouling and degrade in performance over time by using small membrane openings [44].

The practical difficulties of diffusers would suggest that oxygen transfer and process mixing are both primary criteria. When comparing the combination needs of those two variables it suggests that the air volume requirement for proper biological reactor performance will be an adequate substantial air flow rate per unit membrane to meet the requirement needs. At higher or elevated air flow rate, the small hole sizes have two major disadvantages:

a) In order to meet the biological needs, the air flow is increased thus causing significant pressure losses.

b) The size of the air membrane equalizes or stabilizes when the hole in the membrane increases or air flow rate per unit of membrane area increases. The small membrane openings that run at high air rate have a significant improvement in efficiency [44].

Chapter 4

Stuarts Draft's Waste Water Treatment Facilities

4.1 Background

The Stuarts Draft WWTP is operated by the Augusta County Service Authority and serves the Stuarts Draft Service Area in the south-central portion of Augusta County. The satellite image of the plant is shown in the Figure 4.1.The plant was originally constructed in 1968 as an aerated lagoon. In 1982, the plant was expanded to 0.7 mgd with the construction of two oxidation ditches. An additional oxidation ditch was constructed in 1995 to bring the plant capacity to 1.4 mgd. In 2002, the plant was converted to a BNR process and expanded again to a permitted capacity of 2.4 mgd. This project included the construction of a new aeration tank with anoxic zones, new secondary clarifiers, denitrification facilities, solids handling facilities, and U.V. disinfection facilities. The original concept was to construct a 4 mgd facility to accommodate future growth; however, due to budget restriction, portions of the expansion were deferred. The current plant configuration is designed to meet an effluent nitrogen concentration of 8 mg/l and phosphorus concentration of 1.5 mg/l on an annual average basis at 2.4 mgd.

Figure 4.1 The Google satellite image of the Stuarts Draft WWTP

4.2 Site plan and Hydraulic Analysis

4.2.1 Background

The Stuarts Draft WWTP is located at 391 Wayne Avenue in Stuarts Draft, Virginia near the South River in Waynesboro County. The site is approximately 69 acres, although a significant portion of the site is within the 100-year flood plain. South river lies to the south of the plant; the access road is from the northeast corner of the plant site. Figure 4.2 shows one of the aeration basins present in the Stuarts Draft Waste Water Treatment Plant

Figure 4.2 Stuarts Draft Waste Water Treatment Plant

4.2.2 Site plan

Section 5 of the Appendix represents the proposed plant layout with buffer zones and 100-year flood plain noted and the proposed overall site plan of the plant with new facilities noted. The purpose of this section is to establish a broader picture of the extent of work involved in Stuarts Draft WWTP during the upgrade and expansion from 2.4 mgs to 4 mgd.

The overall plant process flow diagram will not change, although additional units have been added and utilized for several processes. Section 6 of the Appendix contains the plant process flow diagram.

4.2.3 Flow projection and Hydraulic Design Criteria

After the installation of two new high speed turbo blower units, the hydraulic capacity of the plant has been increased to an average daily flow of 4 mgd to meet the intent of the 2002 expansion. After the installation of the new units, the historical flow analysis indicated a peaking factor of 3.0. This adjustment was necessary to accommodate hydraulic peaking throughout the plant. The hydraulic design criteria for the basins and interconnecting piping are 4.0 mgd at average day flows and 12 mgd at peak flows, not including recycle flows or return flows. It is anticipated that filter backwash flows during peak plant influent condition will be stored in the lagoon.

4.2.4 Hydraulic Calculation

Detailed hydraulic calculations for the plant were performed based on the criteria presented above and the location within the site.

4.3 Design Criteria

The process design of the Stuarts Draft WWTP upgrade and expansion resulted in development of design criteria for each process within the system. The pumping systems are described in Section 4.8 of this chapter. The design is being performed in accordance to the design criteria for each unit.

4.3.1 Screening

Screening will have one automatic, step by step process with an average day flow capacity of 4 mgd and a peak day flow capacity of 12 mgd. A new 5/8” manual bar rack will be provided as a bypass unit, which can process up to 12 mgd.

Design criteria for the automatic screens facility is:

1. Number of units: 1
2. Channel width (upstream): 3-ft
3. Channel depth (at screen): 4.5-ft
4. Downstream water depth: 1.0-ft
5. Downstream water depth: 3.44-ft
6. Maximum upstream water depth: 4 mgd
7. Average flow per screen (min): 12 mgd
8. Maximum flow per screen (min): 2.0
9. Motor Hp (max): 0.25- in diameter (6mm)

4.4 Aeration

The aeration tanks will have 2 operational modes, maximizing operational flexibility with variations in loading and seasonal operations while ensuring the capability to maintain nitrification during extended colder periods. The operational modes are described below in section 4.5.2. Normal operation is expected to be in Mode 1 which is a MLE mode with maximized anoxic volume in the MLE configuration.

4.4.1 General design Criteria

Diffused aeration systems shall be designed for maximum organic loading applied to the aeration basin during a six-hour period per 9VAC-25-790-690, Para.E.4. Design flow and organic loading for peak days are estimated based on the peaking factor are presented in Table 4.1 below:

	Peak day
Flow-mgd	12.0
TSS - lbs/day	21,176
BOD – lbs/day	16,825
TKN – lbs/day	2,450
TP – lbs/day	391

Table 4.1 Design Flows and Loads

Notes: Peak day organic loading is estimated from AD/MM and MM/PD peaking factors from PEP Technical Memorandum 1C.

4.4.2 Aeration Basin Sizes

The mass balance and process modeling were used to determine the required total volume to enable the process basins to meet the permit requirements at the 12 mgd peak flow. The aeration basins sizing is based on the total required volume minus the existing process basin volumes. Table 4.2 summarizes existing and proposed basins volumes:

Aeration Tank	**Anoxic Volume (MG)**	**Swing Volume (MG)**	**Oxic Volume (MG)**	**Total Volume (MG)**	**Flow Split (%)**
1	0.38	n/a	0.71	1.09	31.25
2	0.38	n/a	0.71	1.09	31.25
3	0.12	0.13	0.92	1.17	37.50
Total	0.88	0.13	2.34	3.35	100

Table 4.2 Existing and Proposed Basin Volumes

Notes: Flow split by weir at Distribution Box North.

The existing circular aeration basins have a center zone that can be prepared as either anoxic or oxic and a permanent aerobic zone in the outer annulus. The new circular aeration basin is provided a permanent anoxic center zone and a permanent outer aerobic annulus. A portion of the outer annulus will be designated as the swing zone which can be operated under anoxic or oxic conditions.

4.4.3 Aeration Basins Operating Modes

The existing center zones diffusers (Aeration tanks No1, 2, and 3) allow the flexibility of operating the system in two modes based on operator choice. The mode selected will be dependent upon influent mass loads, influent flows, seasons, and operator choice. The two operating modes are generally described as the zone volumes in each tank, as represented in Table 4.3

Aeration tank	Center zone	Swing Volume (MG)	Outer Zone
Mode 1 Normal 1	Anoxic	n/a	Oxic
2	Anoxic	n/a	Oxic
3	Anoxic	Anoxic	Oxic
Mode 3 Normal	Oxic	n/a	Oxic
	Anoxic	n/a	Oxic
	Anoxic	Oxic	Oxic

Table 4.3 Operating Modes

A volume summary of each mode is presented below in Table 4.4. Volumes are for average water depth and are in million gallons.

Mode 1	**Basin No.1 Volume (MG)**	**Basin No. 2 Volume (MG)**	**Basin No. 3 Volume (MG)**	**Total (MG)**
MLE anoxic	0.38	0.38	0.25	1.01
Aerobic	0.71	0.71	0.92	2.34
Mode 2	**Basin No.1 Volume (MG)**	**Basin No. 2 Volume (MG)**	**Basin No. 3 Volume (MG)**	
MLE anoxic	-	0.38	0.12	0.5

Aerobic	1.09	0.71	1.05	2.85

Table 4.4 Summary of Aeration Basin Volumes by Operating Mode

Normal operation is expected to be in Mode 1, which is a MLE mode with maximized anoxic volume in the MLE configuration. Currently, the plant can meet permit requirement under this mode and de-nitrification filters are used for particulate removal only. Alternatively, under peak flow and cold weather, Mode 2 may be required to maintain nitrification with supplement carbon and de-nitrification filters (D/N filters) operating under fixed growth conditions to meet permit requirements.

4.5 Aeration Diffusers

The aeration diffusers installed at the waste water treatment plant helps in providing the highest oxygen-transfer efficiency and low energy usage. The diffuser specifications help in finding out the efficiency of oxygen diffused from the aerator.

The diffuser system design criteria are summarized below:

1. Aeration design criteria:

    a) Oxygen transfer based on average water depth

    b) Blower HP based on max water depth

    c) Diffuser height from floor 0.80 ft.

    d) Diffuser submergence at average water 18.91 ft.

    e) Diffuser submergence at max water 18.11 ft.

    f) Alpha 0.65

    g) Beta 0.95

    h) Water temp 23º C

    i) Min dissolved oxygen (DO) 2.0 mg/l

j) Depth correction for saturation 0.33

2. Diffuser

a) 9-inch membranes discs

b) SOTE = 1.8% per ft of diffuser submergence (average water depth)

c) 0.41 sq ft per diffuser

d) 1.1 scfm per diffuser at average air demand

e) AT/AH between 4.0 and 40.0

f) AT = tank surface area

g) AH = area of diffuser holders (installed discs plus provided blanks)

h) Provided blank holders = 20% installed discs

3. Actual oxygen demand

Design criteria and mass balancing was performed during the process modeling. The results are summarized in Table 4.5 for warm weather air requirements and in Table 4.6 swing zone air requirements for nitrification under cold weather.

Scenario		**Actual Aeration**	**Milli Molar**	**Peak**
Influent Flow (mgd)		4	5.4	12
WW Temp (ºC)		28	28	23
	Volume, MG	**AOR [lb/hr]**	**AOR [lb/hr]**	**AOR [lb/hr]**
Total	3.35	442.61	611.89	935.87

Table 4.5 Warm Weather Actual Oxygen Demand (All basins)

Scenario		**Actual Aeration**	**Milli Molar**	**Peak**

Influent Flow (mgd)		4	5.4	12
WW Temp (ºC)		10.5	10.5	10.5
	Volume, MG	**AOR [lb/hr]**	**AOR [lb/hr]**	**AOR [lb/hr]**
Total	0.13	0	39.55	74.94

Table 4.6 Aeration Tanks No. 3 Swing Zone Actual Oxygen Demand

Based on oxygen requirements from process modeling, aeration air flows are summarized as follows:

Annual Average	**Peak day**	**Swing zone (3B)**
2932 SCFM	6200 SCFM	482 SCFM

Table 4.7 Process Modeling Aeration flow table

Diffused aeration system calculations are included in section 4 of the Appendix

4.6 Blowers

The Stuarts Draft WWTP has 3 multi- stage centrifugal Hibon blowers and 2 high-speed turbo Neuros blowers discharged into a common header which connects to a buried pipeline conveying compressed air to the Aeration Basins No. 1, 2, and 3. The blowers also discharge to a branch line to supply post-aeration air.

Unit	Capacity(SCFM)	Horse Power	Type
Hibon 60.09	1,875	200	Multi-stage centrifugal
Hibon 40.09	1,250	125	Multi-stage centrifugal
Hibon 40.09	1,250	125	Multi-stage centrifugal
Neuros NX-150	1,875	150	High-speed Turbo
Neuros NX-150	1,875	150	High-speed

			Turbo

Table 4.7 Existing Aeration Blowers

Figure 4.3 One of the three multi-stage Hibon Centrifugal blowers

The required firm blower capacity for the Stuarts Draft WWTP expansion and Equivalent Noise Resistance upgrade was calculated based on AOR requirements and adjusted for site conditions and summarized in Table 4.8. Figure 4.3 shows one of the Hibon multi-stage centrifugal blowers present at the Stuarts Draft WWTP.

	Annual Average	Maximum Month	Peak Day
AOR (lb / hr)	443	612	639
AOR (lb / day)	10632	14688	22464

SOR (lb/ hr)	24232	33476	43324
Air Required (SCFM)	2932		6200
Post Air Requirement (SCFM)			511
Total Air Required (SCFM)			6711
Est. Blower Discharge (PSI)			9.84
Existing Firm Capacity (SCFM)	2500	2500	2500
Proposed Firm Capacity (SCFM)	6711	6711	6711

Table 4.8 Process Blower Summary for Multi-stage Centrifugal blowers

Figure 4.4 The two active High Speed Neuros Blower at Stuarts Draft WWTP

The process summary for the two active high-speed turbo blowers is as follows

Proposed Process Blowers:

1. Number of blowers: 2
2. Type: High Speed and Single-Stage Turbo
3. Blower operating Conditions: 0-110 F, 85 % RH

   El. 1371.0’
4. Capacity at rated pressure: 2336 SCFM (2913 SCFM) @ 10 psi

5. Horsepower : Turbo — 200 HP for multi- stage, or 150 HP for Turbo
6. Blower Control : — inlet throttling valve for multi- stage or VFD for turbo
7. Accessories: — Weather proof enclosure, inlet filters, and discharge valve.

Detailed aeration blower calculations are included in Section 2 of the Appendix

4.6.1 Aeration Basin Mixers

The existing two basins anoxic zones are each provided with a 15 hp vertical mixer, designed to suspend the bio mass at the maximum MLSS concentration of 4000 mg/ L. The volume of each existing anoxic zone is 380,000 gallons (50,800 cf). The existing mixing energy is approximately 0.30 hp/1000 cf.

The third basin has an anoxic zone of 120,000 gallons (16000 cf) and a swing zone of 130,000 gallons (17,400 cf). A fixed vertical mixer (similar to the other two) provides the center anoxic zones and a submersible mixer will be provided for the swing zone. The anoxic zone mixers are summarized as follows:

Aeration Basin No. 3 Anoxic Zone Mixer

1. Number required: 1
2. Type: vertical, fixed
3. Horse power: 5HP
4. Motor speed: 1200
5. Power supply: 480v /3ph /60 hz
6. Impeller Speed: 30 rpm
7. Impeller Submergence: 15ft

Aeration Basin No.3 Swing Zone Mixer

1. Number required: 1
2. Type: submersible
3. Horse power: 5.6HP
4. Motor speed: 1680 rpm(constant speed)
5. Power supply: 480v /3ph /60 hz
6. Impeller Speed: 24 rpm
7. Flow circulation capacity: 9100gpm

Figure 4.5 A view of the Aeration basins At Stuarts Draft WWTP

4.6.2 Internal Recycle Pumps

The aeration basins numbers 1 and 2 have vertical propeller type pumps which are difficult to control and maintain. The aeration basin number 3 has new low head submersible type pumps will be provided to recycle MLSS in the aeration tanks.

The nitrate recycle rate of 4Q has been established. At an average design flow of 4.0 mgd, the total nitrate recycle rate would be 16 mgd. Based on the flow split to the basin, the maximum nitrate recycle rate would be 5 or 6 mgd.

4.7 Process Pumps

This section is intended to present the basis and the design and hydraulic calculations for the process and chemical pumps that are installed at Stuarts Draft WWTP.

The Stuarts Draft WWTP includes the following process pumps:

Liquid Process Pumps

- Influent Pumping Station
- Internal Recycle Pumps
- Return Activated Sludge Pumps
- Plant Effluent – Non Water Pumps

Chemical Pumps

- Alum Pumps
- Methanol Pumps

4.7.1 Influent Pumping Station Pumps

The existing facility has three variable speed, 30-HP, submersible wet-well pumps rated each for 2.4 mgd (1667 gpm) at 52 feet. The expansion in 2009 resulted in an additional parallel pumping station. The additional discharge head caused by higher flows in the force main, inclusive of the required discharge head for a future grit removal unit, reduces the firm pumping capacity of the existing pumps to 1.9 mgd (1320 gpm) each. The pumping station consists of five pumps that provide 12 mgd (8340 gpm) firm pumping capacity.

Design Criteria of the Influents Pumping Station Pumps are:

1. Number of units : 5
2. Type : submersible wet-well
3. Capacity :2,200 gpm@ 57ft
4. Motor and Speed : 50 HP at 1200 RPM max

4.7.2 Internal Recycle (IR) Pumps

The internal recycle pumps are designed to recycle mixer liquor from the last section of the outer oxic zone back to the center anoxic zone. As part of the MLE process, this recycle flow assists in the reduction of effluents TN. The pumps are designed to convey a maximum of four times the average day (AD) influents flow proportionally split to each basin.

The three existing recycle (1 per basin) propeller pumps present in the aeration basins are:

Design Criteria of the Internal Recycle Pumps

1. Number of Units: 3 (1 per basin)
2. Type: Through-wall mounted propeller
3. Service: Mixed Liquor Recycle in Aeration Basins
4. Capacity: 1×4166-gpm at 1.5 feet
   2×3500-gpm at 1.5 feet
5. Motor and Speed: 4 HP at 855 max

The pumps shall have a direct motor equipped with a variable frequency drive controller.

4.7.3 RAS Pumps

The existing facility has four horizontal centrifugal, non-clogs, return activated sludge (RAS) pumps, which return RAS from the clarifiers to the aeration basins. Each 20-HP pump has a capacity of 1,388-gpm at 33.3feet. The design RAS flow requires all three units in service to provide a minimum RAS return rate of 100% of an average day design flow or 4.0 mgd. As such, the expansion requires one additional pump as a spare unit to meet regulatory requirements

1. Number of Units: 3
2. Type: horizontal, centrifugal, non-clog
3. Capacity: 1,388 gpm at 33.3 ft

4.7.4 Plant Effluents Non-Potable Water System

A packaged plant booster water system will be provided to supply non-potable service water to plant processes including bar screening, secondary clarifiers, belt filter press and yard hydrants. The booster station suction will be from plant effluent at the UV basin and discharge will connect to the existing NPW line.

Design Criteria for the NPW are:

1. Number of Units: 3
2. Type: vertical turbine
3. Capacity: Two pumps rated 120 gpm at 75 psi

   One pumps rated 60 gpm at 75 psi

4.8 Master Blower Control

The operator shall be able to select one of the five blowers which one is lead, lag1 and lag2, lag3 or lag4. If a blower fails or does not start, the computer shall go to the next blower in the sequence. The operator shall be able to change the blower selection at any time. When a VFD blower is used it shall always be used as a lead or lag1 blower.

4.8.1 Neuros and Hibon blowers control

Normally the Neuros blowers will be selected as lead and lag1. When these blowers are running the SCADA computer will control the speed of the VFD for the blowers through PID software loop. The blowers are started and stopped by where the speed feedback for those blowers is.

The pressure controller output shall be used and converted to a speed set point between 0-100%. The output to the blower shall be the same regardless whether one or two blowers are running. Once placed in auto, the first blower in the sequence shall start. As the first blower comes on, it shall control the pressure by itself until the speed feedback signal for that blower reaches 95%. Once 95% speed is reached, the second blower shall come on. The first blower shall ramp down and the second blower shall start to ramp up from its minimum load position until both pumps are running at the same speed. Both blowers shall remain running until the speed feedback of both pumps gets to 5% above the minimum load position. Where this happens, the last blower running shall stop and only the speed of the first blower shall be controlled by the pressure controller.

If both VFD blowers are still running and the speed feedback signal for both of VFD blowers reach 95%, a constant speed blower shall come on and the computer shall set its inlet valve to a 50 % position. The pressure control loop will adjust the speed of both the VFD blowers. When the speed of both of the blowers gets to 5% above the minimum load position, the computer will stop the constant speed blower and the pressure will be controlled by the two VFD blowers.

If both VFD blowers are still running and the speed feedback signal for both of VFD blowers reach 95% and a constant speed blower is already running, a second constant speed blower shall come on. The computer shall set its inlet valve to a 50 % position. The pressure control loop will adjust the speed of both the VFD blowers. When the speed of both of the blowers gets to 5% above the minimum load position, the computer will stop the last constant speed blower to come on and tie pressure will controlled by the two VFD blowers.

Finally, if both VFD blowers are still running and the speed feedback signal for both of VFD blowers reach 95% and two constant speed blower are already running, a third constant speed blower shall come on. The computer shall set its inlet valve to 50% position. The pressure control loop will adjust the speed of both the VFD blower and when the speed of both of the blowers gets to 5% above the minimum load position, the computer will stop the last constant speed blower to come on and the pressure will be controlled by the two VFD blowers.

If only one of the VFD blowers (No.4 or No.5) is running and one of the constant speed blowers (Blower No.1, No.2 & No.3) speed the inlet valve for the constant speed blower with go to a set inlet valve position. The VFD blower will always be the lead blower.

The VFD blower shall start once this selection is made. When the speed feedback of the blower gets to 95 %, the computer will start one of the constant blowers and set its inlet valve to a 50 % position. The pressure control loop will adjust the speed of the VFD blower. When the speed gets to 5% above the minimum load position, the computer will stop the constant speed blower.

If both the VFD and constant speed blowers are still running and the speed feedback signal for VFD blower reaches 95%, a second constant speed blower shall come on and set its inlet valve to a 50 % position. The pressure control loop will adjust the speed of the VFD blower. When the speed gets to 5% above the minimum load position, the computer will stop last constant speed blower to come on.

If the VFD and two constant speed blowers are still running and the speed feedback signal for VFD blower reaches 95%, a third constant speed blower shill come on and set it's inlet valve to a 50 % position. The pressure control loop will adjust the speed of the VFD blower. When the speed gets to 5% above the minimum load position, the computer will stop last constant speed blower to come on.

If all four blowers are running and the VFD reaches 95 %, the computer shall set all the inlet valves to 75 %. It shall then adjust the VFD based upon the pressure control loop. If the VFD blower reaches 95 % after adjusting the constant speed to 75 % the computer will put the inlet valve to 90%. The pressure control loop will adjust the speed of the VFD blower, If the VFD gets to 5% above the minimum load the computer shall lower the inlet valves back to 75 %.The pressure control loop will adjust the speed of the VFD blower. If the VFD gets to 5% above the minimum load after adjusting the inlet valve positions to 75%, the computer shall lower the inlet valves back to 50 %. The pressure control loop will adjust the speed of the VFD blower.

If none of the VFD blowers are running or chosen to run, then the blowers are start/stop by position of the inlet valve position and the pressure loop will control the inlet valve position.

The pressure controller output shall be used and converted to a valve position set point between 0-100%. The output to the blower inlet valves shall be the same regardless whether one, two, or three blowers are running. Once placed in auto, the first blower in the sequence shall start. As the first blower comes on its valve position shall go to 50%. It shall control the pressure by itself by adjusting its inlet valve between 50-95 %, until the valve feedback signal for that blower reaches 95%. Once 95% valve position is reached, the second blower shall come on. The first blower inlet valve shall start closing and the second blower inlet valve shall open to 50% and then slowly ramp open until both blowers inlet valves are roughly at the same position. Both valves shall remain running until the inlet valves of both the blowers get to 40%. When this happens, the last blower running shall stop and only the inlet valve of the first blower shall be controlled by the pressure control loop. If both blowers are still running and the inlet valves feedback signal for both valves reach 95%, the third blower shall come on. The first and second inlet valves shall start closing and the third blower shall open to 50% and then slowly ramp open until all the blowers inlet valves are roughly at the same position. All three pumps shall remain running until the inlet valves feedback of all three blowers gets to 40%. When this happens, the last pump running shall stop and only the inlet valves of the first and second blowers shall be controlled by the pressure controller.

Chapter 5

Comparative assessment of blower technologies

5.1 Introduction

Opting for the best suitable methodology for any application depends on a range of technical and economic factors. For instance, if we need to pick two bulbs between fluorescent bulbs and incandescent bulbs, we need to consider the cost, efficiency, lifetime, functionality and durability. This protocol applies to all the material sciences. An increasingly important factor in a world where sustainability is a key issue is the eco-friendly economic and environmental performance from the point of manufacturer and product performance.

Economic LCA provides a universal methodology to calculate the economic performance by considering the probable impacts from all stages of the product, from manufacturer, product use and decommission phase.

Economic LCA usually includes four key modules:

• Goal and scope phase;

• Life Cycle Inventory (LCI) – data collection and calculation of an inventory of energy and emissions related to the system being studied;

• Life Cycle Impact Assessment (LCIA) – analysis of data to evaluate contributions to various environmental impact categories;

• Interpretation - where data are analyzed in the context of the methodology, scope and goals and quality of the system is assessed [56].

In this LCA, we evaluate the effect on energy consumption and cost for two different (competing) blower technologies. The case study: Stuarts Draft WWTP primarily consists of three aeration blower units, namely Hibon multi- stage centrifugal blowers. In the month of July 2010, the treatment plant authorities installed two new aeration blower units, namely Neuros high-speed turbo blowers. Therefore, the Stuart Draft WWTP has three centrifugal blowers and two turbo blowers which are all active and in good maintained conditions.

5.2 Goals

The primary objective of this study is to compare the energy and cost involved in operating and maintaining the two aeration blower systems installed at the Stuarts Draft WWPT in accordance with the ISO 14040- "Environmental Management- Life-cycle Assessment – Principles and Framework." Thus, in this study, we determine the best technology which could be cost efficient and energy saving on a long term basis.

5.3 Scope

The aeration blowers are economically precarious to any waste water treatment system. It is important to consider the energy used by these blower units in any waste water treatment system because the Environmental Protection Agency of the U.S. states that energy used at waste water treatment facilities total near three billion dollars each year for energy costs. A typical aeration blower system in a biological waste water treatment plant consumes nearly 70% - 80% of entire energy usage. When the expenditure of energy is raising this much, an eventual saving of 10% in this sector could save about four hundred million dollars every year nationally [57].

5.4 Methodology

The eminence and significance of LCA and LCI processes are applied and interpreted to an extent that depends favorably upon the procedure used. It is important that the methodology is crystal clear and well detailed. The ISO has developed standard guidance on documentation choices and set down guidelines for transparency and reporting. The appropriate ISO standards are:

• ISO 14040: 2006 – Environmental management – Life cycle assessment – Principles and framework

• ISO 14044: 2006 – Environmental management – Life cycle assessment – Requirements and guidelines [56].

The objective involved in collecting the past database of energy consumed by the waste water treatment plant helps in assisting the range of emergent impact assessment approaches for upcoming studies.

The LCI processes for the given scenario have been carried out in accordance with ISO 14040 and ISO 14044. The data collected under previous observation of energy consumption undertook a critical analysis from a learning perspective as well as a specialist perspective. This methodology enhanced the reliability and aided to the improvement of the study.

5.5 System description overview

The constraints involved in this LCA study are defined in ISO 14044 and amongst further outlines and considerations such as functional units, system boundary and cut-off criteria of the study. These considerations are outlined in the following sections.

5.5.1 Functional Units

The life cycle energy consumption for operation of any waste water treatment plant under the standards of ISO 14044 has to be reported in terms of giga joules of energy. It is noted that all results are represented on the basis of million gallons of waste water treated and discharged in case of the waste water treatment plant. The cost of electricity consumed is reported in terms of American dollars.

5.5.2 Data quality and key assumptions

The information presented in this Economic LCA is the primary information collected from the Stuarts Draft WWTP facilities in a standard format. The consumption of electricity is calculated from the detailed report provided by the Stuarts Draft WWTP facilities. It is calculated from the monthly electricity bills reported by the Dominion Virginia Power. The energy consumption data is collected on a monthly basis for the period accounting for May 2008 to July 2012. The energy consumption data was primarily reported in two variables. The first variable is the energy consumed by the Reverse Activated Sludge (RAS) end, where the aeration blower units are installed and operated. The second variable is the Head work end where the primary control units of the whole treatment system are maintained and operated. Hence, the results presented in this study apply to the time period for which the data was presented by the Stuarts Draft WWTP authorities. Also certain assumptions were made for calculations where exact data was unavailable or unpredictable.

The key assumptions and factors adopted and assumed for the purpose of homogeneity in calculations for this study are listed below.

- The data provided by the Dominion Power Virginia for the rate of electricity per kW used was not able to be interpreted by the Stuart Draft WWTP facilities. Thus, after critical review, expert advice and a series of considerations from the power bill for the last calendar year it was concluded that the Dominion Power Virginia charged the treatment plant $0.075 per kWh.

5.5.3 System Boundaries

This study is a cradle to gate LCI study, without the end of life recycling of the blower units present at the waste water treatment plant. That is, it covers the product life cycle from the factory gate to the end of his lifetime (i.e., when the product is totally worn out and cannot be repaired or maintained). The disposal phase of the product is omitted in this case. Cradle to gate assessments are occasionally used for the basis of Environmental Product Declaration (EPD) or may be termed as business to business EDP's.

Thus, the cradle to gate inventories does not include criteria like Resource and Development, business travel, production, cleaning and legal services, marketing and operation of administration [56]. While declaring the system boundaries there are other sources to be considered, like technology coverage of the systems under study, geographic coverage of the case study site and time coverage of the study.

5.5.3.1 Technology Coverage

Currently, there are three Hibon multi- stage centrifugal blowers and two Neuros high speed turbo blowers in use at the Stuarts Draft WWTP. The minimum requirement to successfully run an aeration system in a waste water treatment plant is only one blower unit. But only at worst case or at extreme supply load situations two blowers are used.

There are two working models of Hibon blowers installed, namely two Hibon 40.09 blowers and one Hibon 60.09 blower. So, there are a total of three Hibon multi- stage centrifugal blowers at the plant. The model Hibon 40.09 has a capacity to withhold a minimum of 1,250 Standard Cubic Feet per Minute (SCFM) and it has a maximum working range of 125 Horse Power (hp). The model Hibon 60.09 has a capacity to withhold a minimum of 1,875 SCFM and has a maximum working range of 200 hp.

There are two Neuros high speed turbo blowers installed at the plant which are of the same model, namely Neuros NX- 150. The Neuros NX- 150 has a capacity to withhold a minimum of 1,875 SCFM and a maximum working range of 150hp. The maximum operating range of both the blowers is 2,336 SCFM.

Based on the operation at 2,100 SCFM, which is the stable withholding capacity of each blower and at different current peaking conditions, these blowers' performance differs. At a current peak of 45% to 60% at any point of the day, the Hibon blowers require 100 hp to run the aeration system without any issues, whereas the Neuros blowers require just 68 hp. At any given point of the day with 80% current peak, Hibon blowers require 132 hp, whereas the Neuros are capable of running efficiently at 83 hp. At a maximum current peak of 100%, the Hibon blowers would need 152 hp, whereas the Neuros require just 105 hp. At a given 80% to 100% current peak, the model Hibon 40.09 would not be able to work because it has a maximum working capacity of only 125 hp, whereas for an efficient running, the centrifugal Hibon blowers require 132hp to 152 hp. This adjustment in not needed in the Neuros turbo blowers because they have a maximum working range of 150hp and the maximum current requirement does not exceed 105hp.

5.5.3.2 Geographic coverage

The Stuarts Draft WWTP is located at 391 Wayne Avenue in Stuarts Draft, Virginia near the South River. The site is about 69 acres widespread, although a significant portion of the site is within the 100-year flood plain. South river lies to the south of the plant; the access road is from the northeast corner of the plant site. The treated water is discharged into the South river which lies south of the plant. There aren't any environmental hazards to be considered with or around the plant coverage.

5.5.3.3 Time Coverage

The data collection is organized and reported on a per-month basis, starting from August 2008 to July 2012. An average blower can run continuously for 3 days. After that point, the working blower unit has to be rested and responsibility has to be shifted to the unused blower.

5.6 Selection of Application of LCIA categories

The objective of the study is to provide the LCI profilers an energy analysis on the two different blower technologies installed. The cost, working production and end of phase are included in it. In addition, normalization, grouping and weighting can also be applied if there is more information provided with a complex order of data collection.

The following LCIA classifications have been chosen as examples and will be applied to the LCI data:

- Electricity utilization by the Hibon multi stage centrifugal blowers for a period of May 2008 to July 2010.
- Electricity utilization by the Neuros high speed turbo blowers for a period of August 2010 to July 2012.

For a full assessment, there are other impact categories that need to be considered, for example human toxicity, eco-toxicity, ozone depletion potential, acidification potential, eutrophication potential, global warming potential, photochemical oxidant creation potential, etc.

5.7 Data collection

The authentic data was collected from the Stuarts Draft WWTP and cross checked with the electric bills provided by Dominion Power Virginia. Primary information was collected regarding the specific topic before collecting the data from the faculties. A data collection plan was organized a week before collecting the data from the treatment plant authorities. Data collection plan helps us in accomplishing an objective by giving a flawless, judicious and precise solution. A data collection usually includes a pre-collection activity, collection of data and present findings [58]. The pre-collection activity includes objectives on reaching the goal, finding the target data, defining methodologies to reach the goal and methods in which the data are going to be analyzed. The collection of data includes a particular kind of data that needs to be accessed to define a proper a conclusion to the analysis. The present finding process includes operations like sorting the data, summarizing the obtained data, and defining a rough trend analysis to get a picture on the working data. The present finding operations can be represented either numerically or diagrammatically [59].

Exploiting a data collection plan before starting an evaluation would help to locate data that can be used in a program to ensure that the representative of the process is sufficient enough to arrive at a conclusion and help in effective decision making.

After the data collection was successfully sorted out, the data was collected from the treatment plant authorities. The data was complete, efficient and had no missing values or gaps. The collected data was charted out in a Microsoft Excel sheet on a monthly and as well as yearly basis. Once the data was provided and sorted out, basic checks were carried out on energy consumed for each technology. The data was then exported into two separate documents, one for the Hibon and the other for Neuros.

5.7.1 Transport

The environmental and energy burden of internal and external transport for this evaluation is very small. The transport and shipment of goods is included in the price list of the aeration blowers so the functional units and cost of transportation are not considered for this process.

5.7.2 Energy and Fuel

All energy units which contribute for the successful running of the aeration systems are taken into consideration. As per the data provided by the treatment plant authorities, there was no additional energy source involved in the operation of the blower units other than electricity.

5.7.2.1 Electricity

The electric power supply was provided by Dominion Power Virginia. There wasn't any grid electricity production associated with the treatment plant. Therefore, the plant did not show any significant effect on LCI with regard to CO2 emission.

5.7.3 Emission to air, water and soil

A list of all known air, water and soil emissions were defined and checked as per the LCI for environmental emission in a process defined in the ISO: 14040. The aeration system's only energy supply was electricity and the plant did not have a power grid production. Thus, this part can be concluded by saying that the aeration blower activity didn't show any emissions being sent into the air, water or soil.

5.8 End of life phase

The aeration blowers do not have a total end of life phase. Both aeration blowers do not meet the end of life phase requirements. When the blower unit meets the worn out phase, it can still be used by totally replacing the rotor section of the blower which is responsible for kinetic energy added to the air by the blades.

5.9 Interpretation

The outcomes of the LCI/LCEIA are referring to the aim, objective and possibility. The analysis reports the following topics:

- Energy analysis: energy consumed by both blowers during the time in which they were active.
- The blower unit which is more stable in consuming energy regardless of any given temperature or pressure.
- Decisions, boundaries and endorsements of the appropriateness of the definition of the system model, functional units and system limitations.

Chapter 6

Results and analysis

After a series of data collection plans, data quality checks, sorting and evaluations, this chapter provides the assessment of blower technologies present in the Stuarts Draft WWTP. The assessment was based on a cradle to gate methodology which included the working and maintenance of the process and excluded the end of life phase recycling.

6.1 Scoping

The prices of the two aeration blowers were quoted by the CDM engineering design memorandum that analyzed and installed these blower units at the Stuarts Draft WWTP. The CDM design memorandum states that the cost comparison between the multi stage centrifugal and high speed turbo blowers was revised to reflect the expanded blower system operating at current plant demands and updated vendor pricing. Based on the current process needs, the multi stage centrifugal blower would require between 125- 200 hp, meanwhile, the high speed turbo blowers would require between 68- 105 hp. Before the installation of the high speed turbo blowers, a summary of the capital and operating cost at current plant flows and loadings was recommended by the CDM design memorandum engineers in table 6.1

	Neuros High- speed Turbo	Hibon Multi-stage Centrifugal
Equipment cost	$ 212,160	$214,000
Annual Cost of Borrowed Money	$ 14,260/ year	$ 14,384/ year
Estimated Annual PM Cost	$ 4,243/ year	$ 4,280/ year
Estimated Annual Power Cost	$ 32,626/ year	$ 48,350/ year
Estimated total Annual Cost	$ 51,129/ year	$ 67,043/year

Table 6.1 Summary Stuarts Draft WWTP Blower Comparison

Assumptions made by the CDM design memorandum:

- The equipment cost refers to the cost of affording two Neuros NX- 150 or two Hibon 60.09.
- The annual cost of borrowed money is based on a 20 year scale at a 3% rate of interest.
- The annual maintenance cost of both these blowers was estimated at 2% of the equipment cost.
- The annual power consumption is based on the operation at 2,100 SCFM and at 8.5psi:
    - 45% current peak, 75% of the year requires: 100 hp Hibon vs 68 hp Neuros
    - 60% current peak, 10% of the year requires: 100 hp Hibon vs 68 hp Neuros
    - 80% current peak, 10% of the year requires: 132 hp Hibon vs 83 hp Neuros
    - 100% current peak, 5% of the year requires: 152 hp Hibon vs 105 hp Neuros
- The estimated annual power cost of the electricity was based on $ 0.07 kWh.

The equipment cost difference between the turbo blowers and the multi- stage centrifugal blowers were minimal. Therefore, the energy savings from the turndown efficiency of the turbo blowers would result in an immediate and future comparative cost savings over multi-stage centrifugal blowers estimated at approximately $16,000 per year.

Although high speed centrifugal blowers are less expensive, Neuros blowers are within 100k of the Good Manufacturing Practice (GMP) estimated amount of $ 226,000, and CDM believes the reliability and experience of Neuros are worth the additional cost. Thus, CDM recommended the Neuros based on experience with these waste water treatment systems, the ease of installation, the support they have provided in the past and the recommendation of the design committee investigating the high efficiency blowers. The calculation and data sheet recommendations provided by the CDM design memorandum are included in Section 7 of the Appendix.

6.2 Inventory Analysis

The total energy consumed at the RAS end of the plant is concluded by the data collected from the treatment plant authorities.

6.2.1 Electricity charges

Before exploring the energy and cost under the LCI process, the explanation of electricity charges are detailed. The Dominion Power Virginia categorized the Stuarts Draft WWTP under large general service as they receive more than 500 kW of electricity supply service and electricity delivery service from the company.

Electricity Supply (ES) Service Charges

Electricity supply contract demand charge all kW of ES contract demand	$ 0.075 per kWh
Generation Adjustment Demand Charge for primary voltage customer at first 5000 kW of demand	$ 0.421 per kWh
Generation Adjustment Demand Charge for Primary voltage customer at additional kW of	$0.318 per kWh

demand	
Generation Adjustment Demand Charge for Secondary voltage customer for all demand	$0.640 per kWh

Table 6.2 Electricity Supply Service Charges

6.2.2 Energy Analysis

The electricity consumed and the charges applied can be divided into two periods, the period where Hibon multi speed centrifugal blowers were in use and the period where Neuros high speed turbo blowers were in use. The electricity consumed and the charges calculated for both of these periods correspond to the data collected from the RAS end of the waste water system. The energy consumed is reported in kWh and the cost of electricity per month is reported in American dollars and the total cost of electricity is accounted at $0.075 per kWh.

6.2.3 Energy analysis at RAS end before Neuros

The data has been collected starting from May 2008 till July 2010. So, the report has a total number of 27 months of energy consumed by the Hibon multi- stage blowers. A keen look at the energy consumed by these two blowers on an annual basis gives a clear picture on energy fluctuation caused by the seasonal changes and weather conditions.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Energy Consumed (kWh)	NA	NA	NA	NA	86100	96900	98100	86400	99600	88200	87600	85200
Cost of electricity per month ($)	NA	NA	NA	NA	6457.5	7267.5	7357.5	6480	7470	6615	6570	6390

Table 6.3 Energy consumed and Cost of Electricity per month by the Hibon blowers during 2008

The above table represents the energy consumed by the Hibon blowers at the RAS end of the plant during the year 2008. The months January, February, March, and April were not available to treatment plant authorities to be reported. The Hibon blowers consumed a total of 728,100 kWh during the year 2008 (May-Dec) averaging about 91,012.5 kWh per month. Thus, the total cost of electricity at $0.075 accounted for $54,607.50 with an average of $6,285.94 per month.

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Energy consumed (kWh)	94500	84600	82800	96000	80700	84300	95400	83100	82800	86400	87000	97800
Cost of electricity per month ($)	7087.5	6345	6210	7200	6052.5	6322.5	7155	6132.5	6210	6480	6525	7335

Table 6.4 Energy consumed and Cost of Electricity per month by the Hibon blowers during 2009

The above table represents the energy report for the year 2009. The Hibon blowers consumed a total of 1,055,400 kWh for the calendar year 2009 resulting in a total annual cost of $79,155. This is the highest recorded annual consumption and cost for the last five years, averaging about 87,950 kWh per month with a cost of $6,596.25. The months of January and December resulted in the most consumed energy with 94,500 kWh and 97,800 kWh respectively.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Energy consumed (kWh)	104100	109200	84900	100200	87900	82500	86100	NA	NA	NA	NA	NA
Cost of electricity per month ($)	7807.5	8190	6367.5	7515	6592.5	6187.5	6457.5	NA	NA	NA	NA	NA

Table 6.5 Energy consumed and Cost of Electricity per month by the Hibon blowers during 2010

The above table represents the energy consumed by the Hibon blowers during the year 2010. It is reported from January till July when the Hibon blowers were in use before been replaced by the Neuros turbo blowers. The Hibon blowers consumed a total of 654,900 kWh during the year 2010 (Jan-Jul) averaging about 93,557.14 kWh per month. Thus, the total cost of electricity accounted for $49,117.50 with an average of $7,016.79 per month. For the year of 2010, the highest energy consumption is reported for the months of January and February with 104,100 kWh and 109,200 kWh respectively. Thus, the Hibon blowers showed a similar consumption pattern with the coldest months of the year consuming more energy than the other ones.

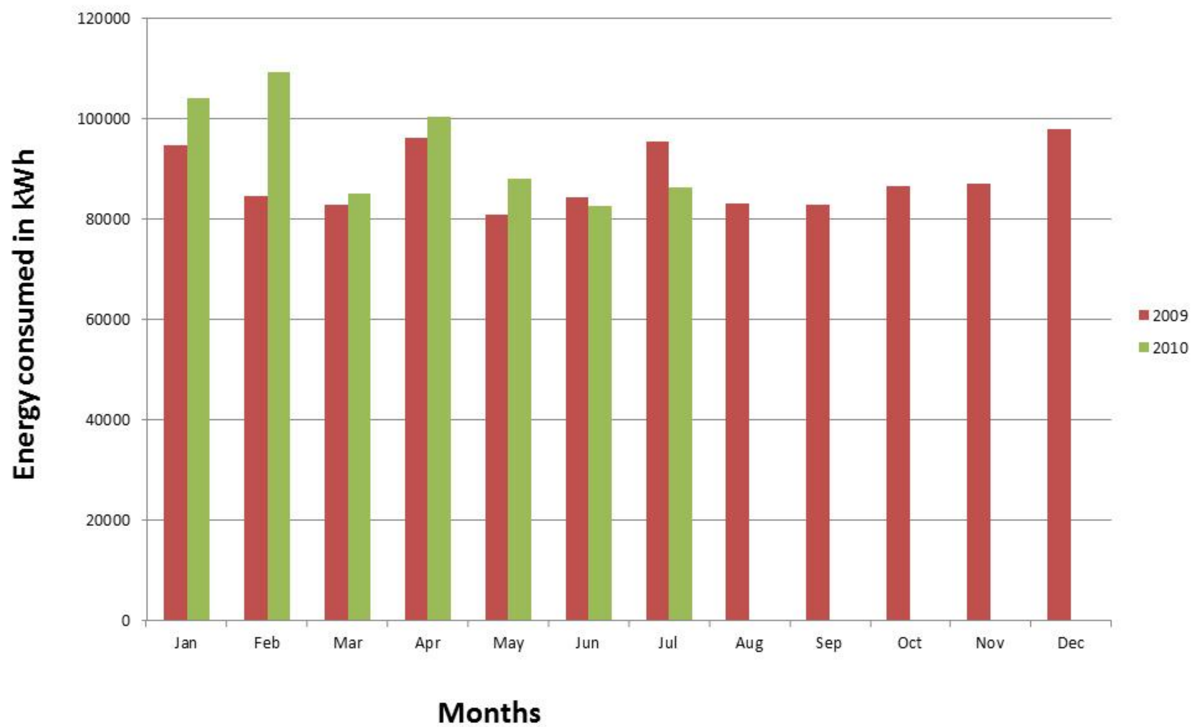


Figure 6.1 Annual Energy consumption Chart for Hibon blowers.

The above bar chart shows the energy consumed by the Hibon blower at the RAS end of the plant during the recorded time period (2008, 2009, and 2010). As explained above, the coldest months of the year have the highest energy consumed bars for that year. The chart shows a minimum of 80,000 kWh consumed every month.

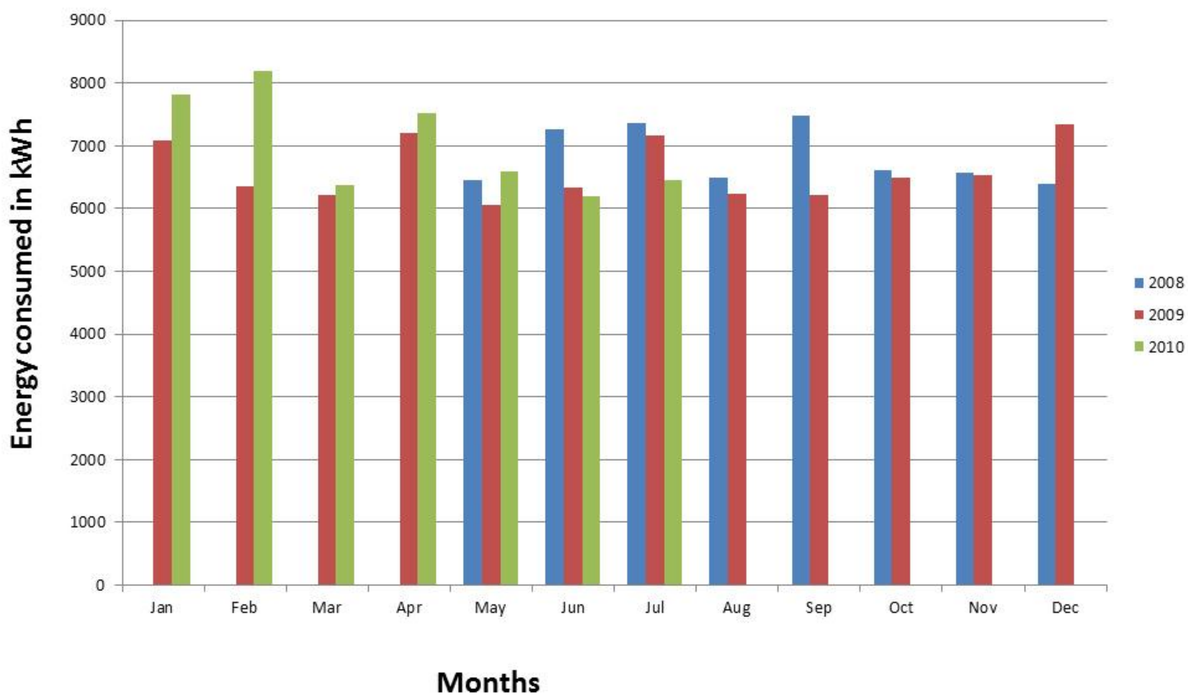


Figure 6.2 Yearly Cost of electricity consumed chart for Hibon blowers.

The above chart shows the cost of electricity for the years 2008, 2009, and 2010 when the Hibon blowers were in use.

6.2.4 Energy analysis at RAS end with Neuros

The data was collected at the RAS end during the period in which Neuros high speed turbo blowers were active starts from August 2010 to July 2012. So, the report has a total of 24 months of energy consumed by the Neuros blowers.   Similar to the Hibon blowers, the Neuros blowers showed a similar consumption pattern as well.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Energy consumed (kWh)	NA	NA	NA	NA	NA	NA	NA	89700	83400	91500	108000	108000
Cost of electricity per month ($)	NA	NA	NA	NA		NA	NA	6727.5	6255	6862.5	8100	8100

Table 6.6 Energy consumed and Cost of Electricity per month by the Neuros blowers during 2010

The above table represents the energy report for the year 2010 for the months August till December. The Neuros blowers consumed a total of 480,600 kWh, resulting in a total annual cost of $36,045, averaging about 96,120 kWh per month with a cost of $7,209. The months of November and December resulted to be the most consumed with 108,000 kWh each.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Energy consumed (kWh)	89700	95100	87600	83100	89400	87300	77700	79500	87300	83700	85500	84300
Cost of electricity per month ($)	6727.5	7132.5	6570	6232.5	6705	6547.5	5827.5	5962.5	6547.5	6277.5	6412.5	6322.5

Table 6.7 Energy consumed and Cost of Electricity per month by the Neuros blowers during 2011

The above table represents the energy report for the year 2011. The Neuros blowers consumed a total of 1,030,200 kWh for the calendar year 2011 resulting in a total annual cost of $77,265, averaging about 85,850 kWh per month with a cost of $6,438.75. The months of January and February resulted to be the most consumed with 89,700 kWh and 95,100 kWh respectively.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Energy consumed (kWh)	88500	80400	80100	99600	82200	78600	91200	NA	NA	NA	NA	NA
Cost of electricity per month ($)	6637.5	6030	6007.5	7470	6165	5895	6840	NA	NA	NA	NA	NA

Table 6.8 Energy consumed and Cost of Electricity per month by the Neuros blowers during 2012

The above table represents the energy consumed by the Neuros blowers during the year 2012 from January till July. The Neuros blowers consumed a total of 600,600 kWh during the year 2012 (Jan-Jul) averaging about 85,800 kWh per month. Thus, the total cost of electricity accounted for $45,045 with an average of $6,435 per month. The year 2012 was no exception for the energy consumption pattern, which has been followed for the last 5 years besides an unusual raise in the months of April and July. During the month of July a technology assessment was analyzed between the Neuros and the Hibon, in which Hibon blowers were active during the period of the 25th to the 30th of July. Thus, with an exception to 2012 the Neuros blowers showed a similar consumption pattern with the coldest months of the year consuming more energy.

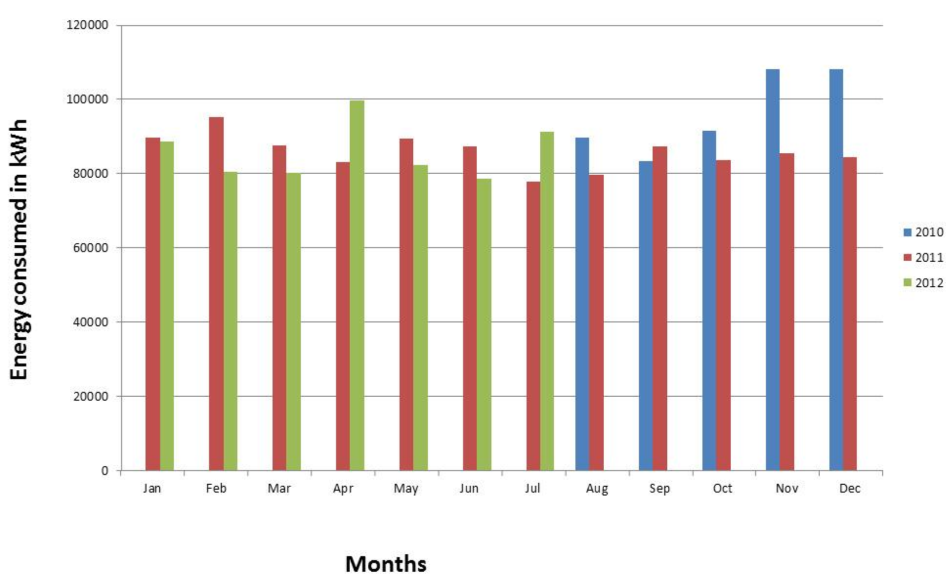


Figure 6.3Annual Energy consumption Chart for Neuros blowers

The above bar chart shows the energy consumed by the Neuros blower at the RAS end of the plant during the recorded time period (2010, 2011, and 2012). As stated in the individual analysis, the coldest months of November, December, January and February showed the highest consumed bar for that year. As similar to the Hibon blowers, the minimum energy consumed for a month remained at 80,000 kWh with a few exceptions.

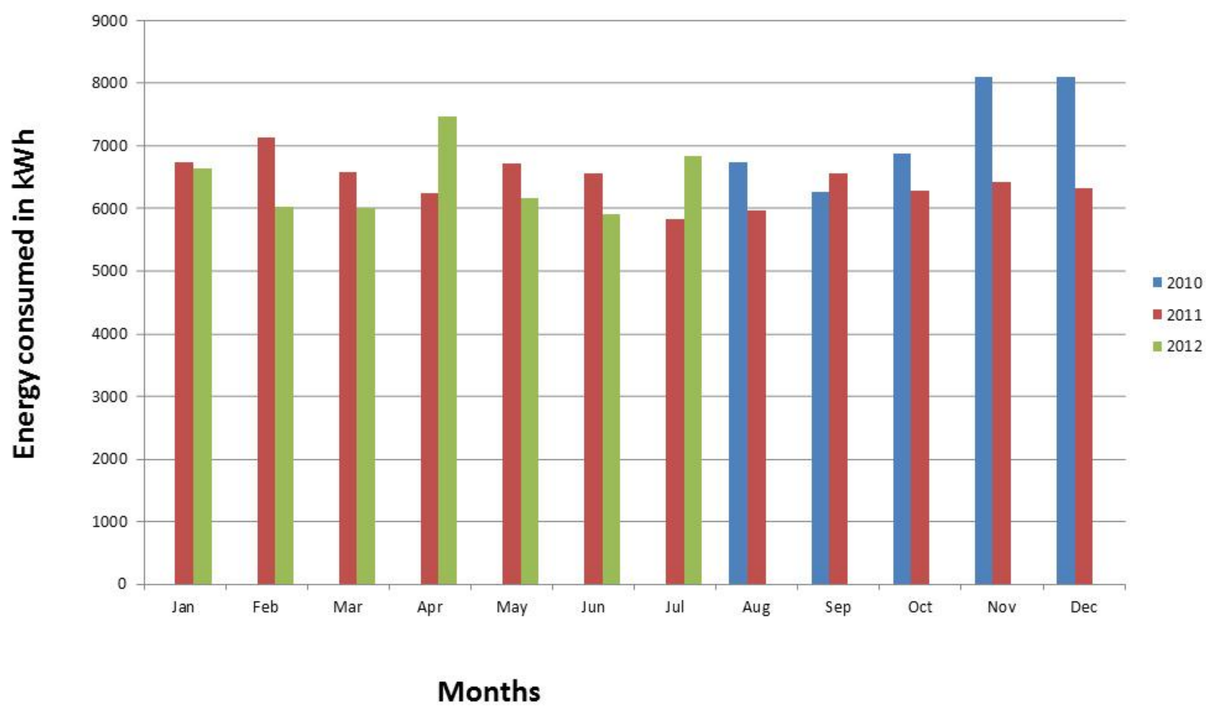


Figure 6.4 Yearly Cost of electricity chart for Neuros blowers.

The above chart shows the cost of electricity for the years 2010, 2011, and 2012 when the Neuros blowers were active.

6.2.5 Repair and Maintenance services

As per the data acquired from the Stuarts Draft WWTP, the Hibon blowers repair and maintenance cost includes oil change twice a year, which is $80 to grease the motors. It takes about 6 hours to grease these motors, so if 2 people are involved in this manual labor for a maximum 6 hours, the manual labor cost would be $ 150 each ($25*6 hours). This process of greasing the Hibon blowers has to be done twice a year. So the total cost involved in this process could be:

Cost of greasing: $ 80

Manual Labor cost: $300

Total Annual cost: (80*2times) + (300*2 persons)*2'year = $1360

The Neuros blowers repair and maintenance cost includes the cleaning and replacing the new filters every two months. The costs involved are $75 a piece and we need 6 of them. Once again a manual labor involved in this process would be $150 each, but this is done 6 times a year. So, the total cost involved in this process could be:

Cost of air filters: $450

Manual labor cost: $300

Total annual cost: (450*6) + (300*2)*6 = $ 6300

6.2.6 Decommission

The Hibon and the Neuros blowers are primarily composed of Stainless steel with less quantity of copper involved in joints and screws. So, the cost involved in decommissioning and recycling this stainless steel machine involves $0.45/ lbs. There are no other costs involved in them.

The cost involved in decommissioning a Hibon blower is:

Weight of the Hibon blower: 5750 lbs.

Cost involved in decommissioning one Hibon blower is $2587.50

Thus, cost involved in decommissioning three Hibon blowers is $7752.50

The cost involved in decommissioning a Neuros blower is:

Weight of the Neuros blower: 1768 lbs.

Cost involved in decommissioning 2 Neuros blowers is $795.60

Thus, the cost involved in decommissioning 2 Neuros blowers is $1591.20

6.3 Life Cycle Interpretation

The Life Cycle Interpretation is a resultant from the Life Cycle Inventory Analysis evaluated for the competing blower technologies. The energy consumed by the blowers are represented in yearly basis and expressed in giga joules.

6.3.1 Interpretation for the Hibon multi- stage centrifugal blowers

As per the data collected from the Stuarts Draft WWTP facilities, the report for the year 2008 was comprised from August to December. The Hibon blowers consumed an average of 327.65 giga joules of energy from their monthly electricity bill. The energy consumed per month varied from a minimum of 306.72 giga joules to a maximum of 358.56 giga joules with a total sum of 2,621.16 giga joules of energy consumed from the months of August till December.

For the calendar year of 2009, the Hibon bowers consumed an average of 316.62 giga joules of energy each month. The energy consumption pattern varied from a minimum of 290.52 giga joules of energy to maximum consumption of 352.08 giga joules of energy. The total annual sum of energy consumed for the year 2009 was 3,799.44 giga joules of energy.

The Hibon blowers were last seen in full operation in the year 2010. When comparing the energy consumption pattern with the previous years, the energy consumption remained roughly the same. The Hibon blowers consumed an average of 336.80 giga joules of energy per month with the minimum and maximum energy consumed per month ranging from 297 giga joules to 393.12 giga joules respectively. The total energy consumed for the year 2010 when the blowers were active (Jan-Jul) was 2,357.64 giga joules. Thus, from the energy analysis we arrive at a conclusion that the Hibon blowers consumed an average of 337.62 giga joules of energy per month. The minimum and maximum energy consumption was 290.52 giga joules and 393.12 giga joules of energy per month respectively in the period of 27 months when the Hibon blowers were completely active.

6.3.2 Interpretation for the Neuros high-speed turbo blowers

The report for the year 2010 consisted of data from August until December after the Neuros high speed turbo blowers were installed. They consumed an average of 346.03 giga joules of energy per month with the minimum energy consumption being 300.24 giga joules and maximum being

388.80 giga joules of energy. The total energy consumption totaled 1730.16 giga joules of energy for the months August till December.

In the year 201Q21, the Neuros blowers were completely active. The average energy consumption totaled 309.06 giga joules of energy per month. The minimum energy consumption ranged from 279.72 giga joules with a maximum limit up to 342.36 giga joules of energy per month. The total annual energy consumed for the year 2011 was 3708.72 giga joules.

The energy report for the current year is available until July where the Neuros blowers were in full operation. But the Hibon blowers were active for a period of only l5 days for a performance test. The purpose of this shift was to conduct a comparative performance test between these two technologies. There weren't any issues or repair problems with the Neuros blowers. The average energy consumed per month was 308.88 giga joules of energy and minimum and maximum energy consumption per month ranged from 282.96 giga joules to 358.56 giga joules of energy respectively. The total annual energy consumption until July totaled 2162.16 giga joules of energy. Thus, from the energy analysis, we arrive at a conclusion that the Neuros blowers consumed an average of 330.49 giga joules of energy per month. Minimum and maximum energy consumption ranged from 279.72 giga joules to 388.80 giga joules of energy per month respectively in the period of 24 months when the Neuros blowers were active.

	Hibon	Neuros
* Avg. Energy per month	337.62	330.49
*Minimum energy per month	290.52	279.72
*Maximum energy per month	393.12	388.80
*Max. sum of energy per year	3799.44	3708.72

*All expressions are expressed in terms of giga joules

Table 6.9 Comparison of Energy consumption between the blower technologies

The above table provides a better picture of the energy comparison between the two blowers used at the treatment plant. The column represents the energy consumed by the two blower technologies.

6.4 Impact analysis

In this section, the potential energy impacts on these two blower technologies are discussed. This phase encompasses the energy differences between the blower technologies and their impacts on the energy consumption pattern.

Average Energy consumed per month in giga joules

Figure 6.5 Average Energy consumption per month chart

After calculating the average energy consumed by both of the blower technologies, the annual average energy consumed rate was brought to a conclusion. The energy consumed by the Hibon blowers were calculated for a period of 27 months and the Neuros were calculated for a period of 24 months. There were some irregularities in energy consumptions found in the whole cycle. As discussed earlier in the energy analysis section of this chapter, the winter seasons showed more irregularities by consuming more energy than the normal time of the year. Another irregularity when comparing these two blowers energy consumption is that, after the installation of Neuros in July 2010, the following months of September, October, November, and December showed an unusual pattern of high energy consumption which varied from 70 to 90 giga joules when compared to the previous year's data consumption by the Hibon technology.

Minimum energy consumed per month in giga joules

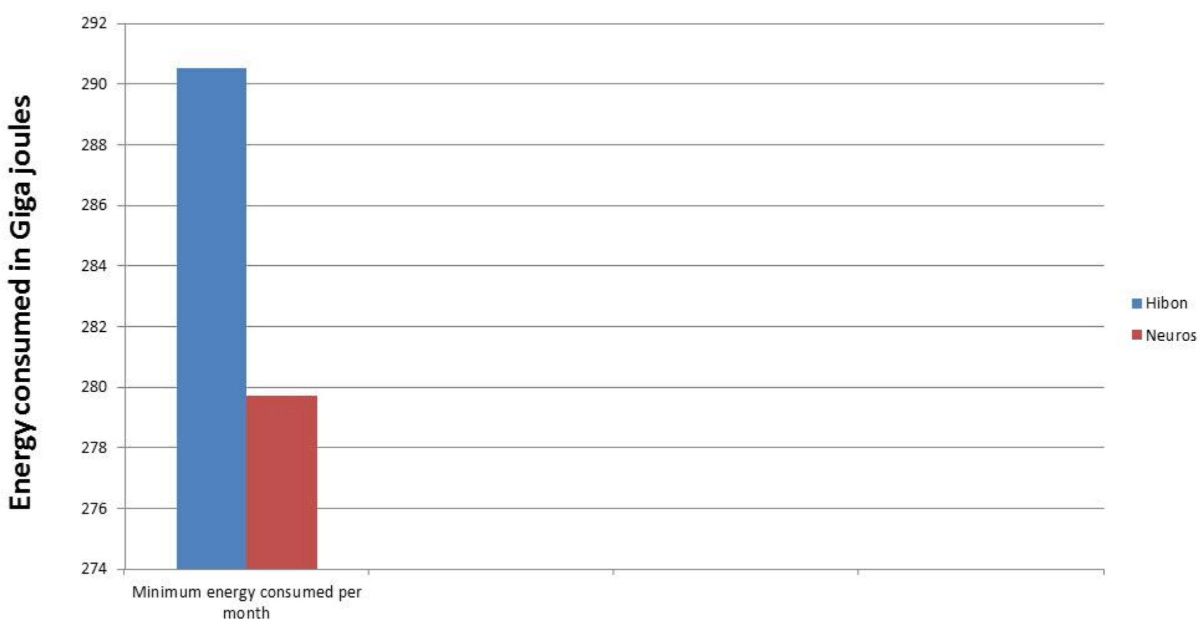


Figure 6.6 Minimum energy consumption chart

The above chart is the representation of minimum energy consumed per month in the last five years. The energy consumption has never been constant except for a few exceptions. From the above bar chart representation we can conclude that the Hibon blowers need more than 20 giga joules of energy than the Neuros blowers.

Maximum energy consumed per month in giga joules

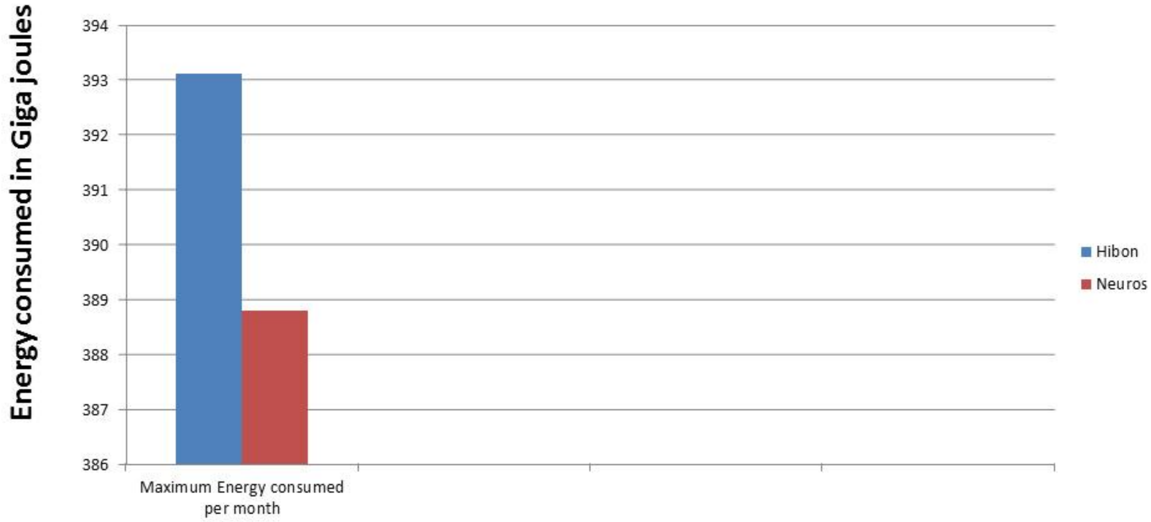


Figure 6.7 Maximum energy consumed per month in giga joules

The maximum energy consumption chart shows a similar trend as Figure 6.6. The Hibon blowers require more than 20 giga joules of energy than the Neuros.

Maximum total annual sum of energy consumed in giga joules

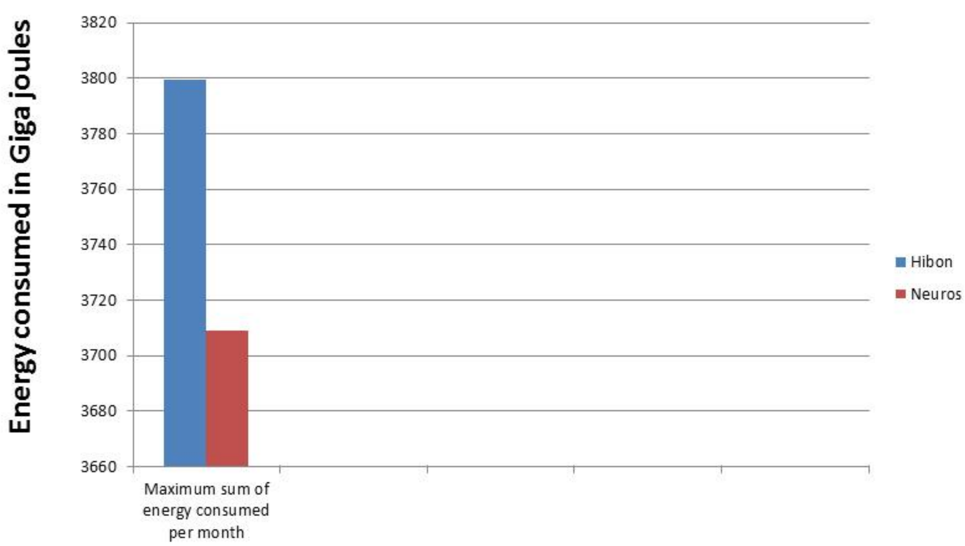


Figure 6.8 Annual maximum energy consumption chart

This bar chart gives a clear idea of the amount of energy consumed annually. With more than 400 giga joules of energy consumption shown by the Hibon blowers, the Neuros are clearly a more efficient technology on a longer time scale.

6.4.1 CDM Design memorandum report

Table 6.1 explains the estimated summary provided by the Stuarts Draft WWTP blower comparison rate. The cost and performance comparisons between the multistage centrifugal and high-speed turbo blowers were revised to reflect the expanded blower system operating at current plant demands and updated vendor pricing. The cost involved in buying two Neuros NX-150 turbo blowers was greater than two Hibon 60.90 blowers. But from the turbo blower report provided by CDM Design states that CDM’s multi- phase improvement program instantaneously recognized the WWTP’s activated sludge aeration system as having major potential for energy reduction. The aeration system is responsible for 36% of the plant’s electrical consumption. The system suffered from operational issues, despite several improvement attempts. In effort to implement a permanent, reliable solution and prompted by impressive manufacturer claims, CDM made arrangements to demonstrate a new, highly efficient turbo blower at this treatment plant. The performance of the turbo bower was better than anticipated, consuming 38% less power than the existing blowers. Further design modification and optimization of the system could result in an electrical consumption decrease of more than 50%. In addition, when compared to the existing blowers, the turbo blowers are significantly quieter, require much less space, do not require oil, perform without any noticeable vibration, and demand little maintenance [60]. Thus, the authorities of the Stuarts Draft WWTP installed the Neuros turbo blowers.

6.4.2 Life Cycle Cost involved in Hibon high speed blowers

	Hibon high speed
Equipment Cost	$ 213,500
Annual Cost of Borrowed Money	$ 14,384
Minimum energy consumed per month	290.52 Giga joules
Maximum energy consumed per month	393.12 Giga joules

Total sum of energy consumed	*8778.24 Giga joules
Avg. energy consumed per month	337.625 Giga joules
Avg. sum of energy consumed per year	4389.12 Giga joules
Repair and Maintenance	$ 1360
Decommission cost	$ 7752
Cost of electricity per month	$ 703
Cost of electricity per year	$ 84406
Estimated Annual total cost (Electricity + Maintenance)	$ 85766

Table 6.10 Life Cycle Cost of Hibon high speed blowers

* Total sum denotes the sum of energy consumed from Aug 2008 to Jul 2010.

The cost involved in buying two new Hibon multi speed centrifugal blowers is $213,500. The Hibon blowers have a comparable performance of consuming a minimum of 290.52 giga joules of energy per month to a maximum of 393.12 giga joules of energy per month on an average scale. In the operation of the last 27 months, the blowers consumed a total of 8778.24 giga joules of energy with an average sum of 337.625 giga joules of energy per month. They consumed an annual average sum of 4389.12 giga joules of energy. When calculating the cost of electricity with $0.075 per kWh, the electric consumption cost accounted for $7,033.84 per month with an annual cost of $84,406.15. The only repair and maintenance cost is the cost of change of oil for the blades every two months in these aeration blowers. So considering for a Life Cycle of ten years, these machines are subjected to cost $ 857,661.50.

6.4.3 Life Cycle Cost involved in Neuros high speed blowers

	Neuros high speed
Equipment Cost	$ 235,270
Annual Cost of Borrowed Money	$ 14,260
Minimum energy consumed	279.72 Giga joules
Maximum energy consumed	388.80 Giga joules
Total sum of energy consumed	*7601.04 Giga joules

Avg. sum of energy consumed per month	330.49 Giga joules
Avg. sum of energy consumed per year	3965.94 Giga joules
Repair and Maintenance	$ 6300
Decommission cost	$ 1591
Cost of electricity per month	$ 6885
Cost of electricity per year	$ 82620
Estimated total cost (Electricity + Maintenance)	$ 88,920

Table 6.11 Life Cycle Cost of Neuros turbo blowers.

*Total sum denotes the sum of energy consumed from Aug 2010 to Jul 2012.

The cost involved in buying two new Neuros high speed turbo blowers is $235,270. The Neuros blowers have a higher comparative performance than the Hibon blowers. Neuros blowers consume a minimum of 279.72 giga joules of energy per month to a maximum of 388.80 giga joules of energy per month on an average scale. In the operation of the last 24 months the blowers consumed a total of 7601.04 giga joules of energy with an average sum of 330.49 giga joules of energy per month. They consumed an annual average sum of 3965.94 giga joules of energy. When calculating the cost of electricity with $0.075 per kWh, the electric consumption cost accounted for $6,885 per month with an annual cost of $82,620. The only repair and maintenance cost is the cost of changing the harmonic filters every two months. So considering for a Life Cycle period of ten years, these machines are subjected to cost $ 889,200

6.4.4 Performance test on the blower technologies

A weekly parallel performance test was conducted between the Neuros high-speed turbo blowers and the Hibon multistage centrifugal blowers. The data was recorded from the 20^{th} of July to the 30^{th} of July. During the period, the Neuros blowers were active from the 20^{th} to the 25^{th} of July and the Hibon were active from the 26^{th} to the 30^{th} of July. The data was divided and analyzed and labeled as “Neuros Days 1 to 5” when the Neuros turbo blowers were active and “Hibon Days 1 to 5” when the Hibon centrifugal blowers were active.

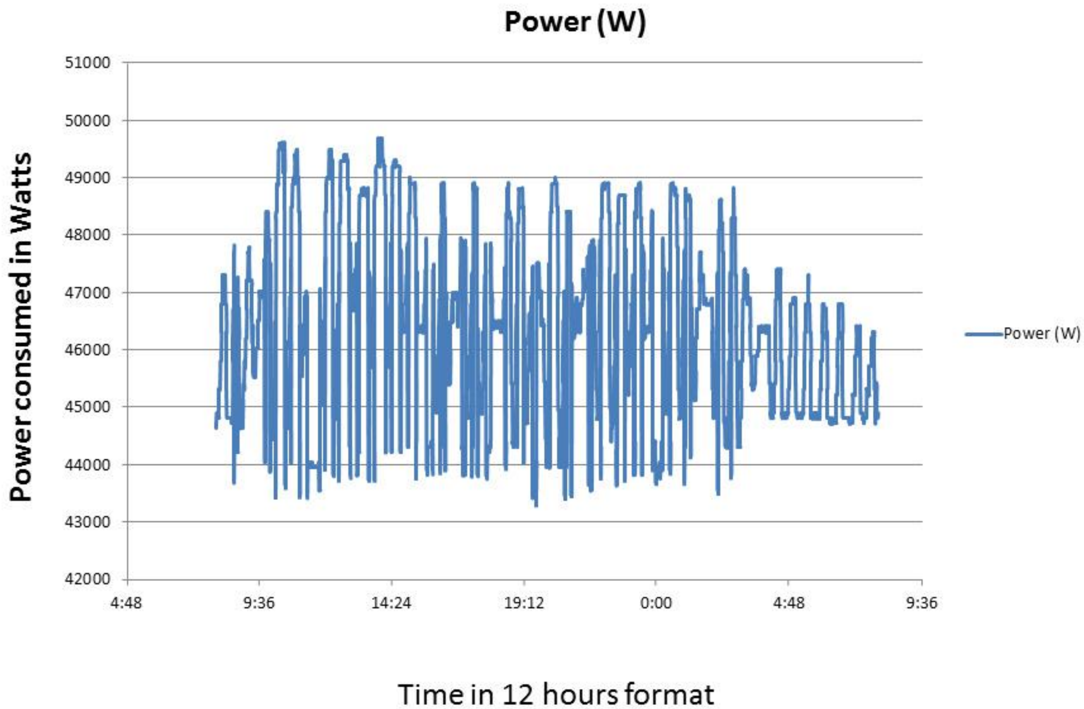
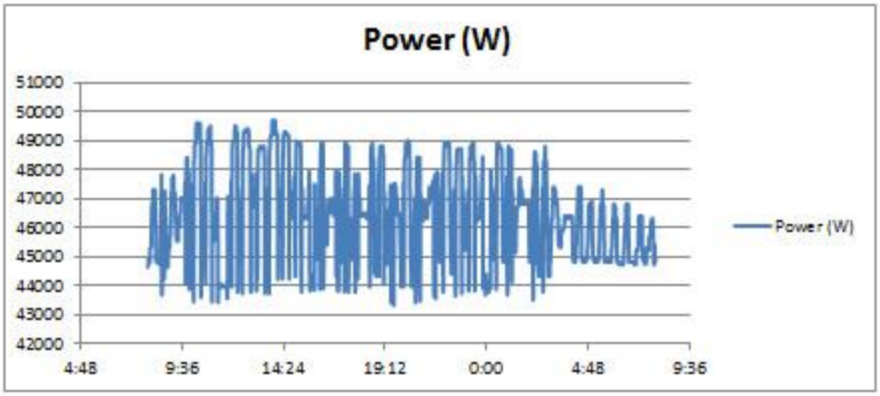


Figure 6.9 Power consumption per hour: Neuros Day 1

The above chart shows the power consumption pattern in a day on an hourly basis. The x-axis represents the time in a 12 hour format, and the y-axis represents the power consumed. A similar pattern was seen in almost all the days when the Neuros blowers were active.

Neuros day 1



Neuros day 2

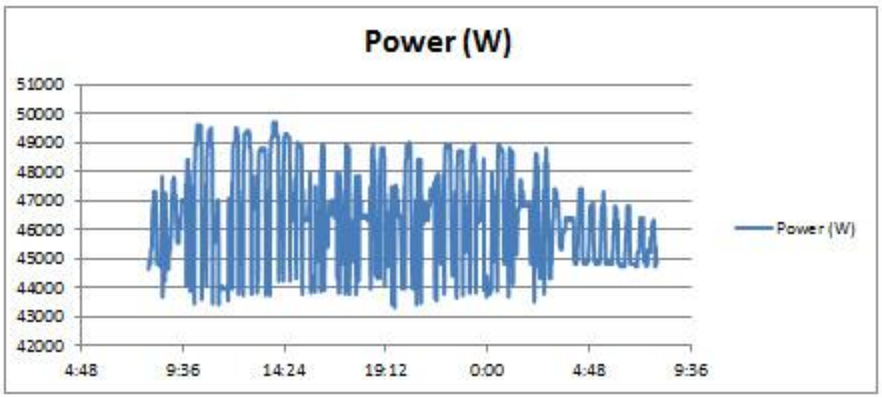


Figure 6.10 Power consumption per hour: Neuros Day 1 and 2.

The power consumption showed a common pattern by consuming more energy at the daytime when there are more activities in the city and the consumption dropped during the night. But on the day of transfer from Neuros to Hibon there was an unusual pattern of energy consumption. The Hibon day 1 had the most energy consumed day of all the ten days, because the normal specifications and functions applicable to the Neuros are not applicable to the Hibon. The load and specification did not match; thus two Hibon blowers were active throughout the day to keep the routine work going. Except for the day 1 of Hibon activity, the other days showed a similar pattern as the Neuros.

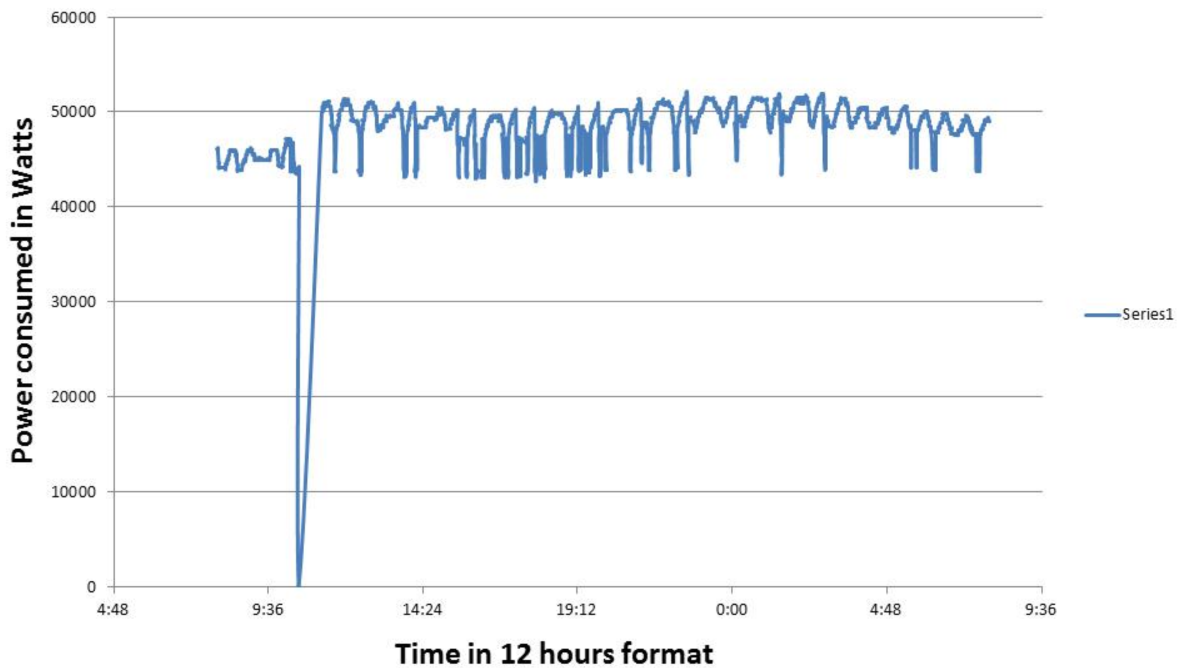


Figure 6.11 Power consumption per hour: Hibon day 1

Day	**current consumed (amp)**	**voltage consumed (V)**	**Total power consumed (W)**
N1	93	497	46438
N2	92	497	45781
N3	91	496	45678
N4	92	496	45906
N5	93	497	46324
H1	98	493	48553
H2	94	493	46650
H3	94	493	46723

H4	92	493	45853
H5	93	493	45985

Table 6.12 Power consumed between Hibon and Neuros

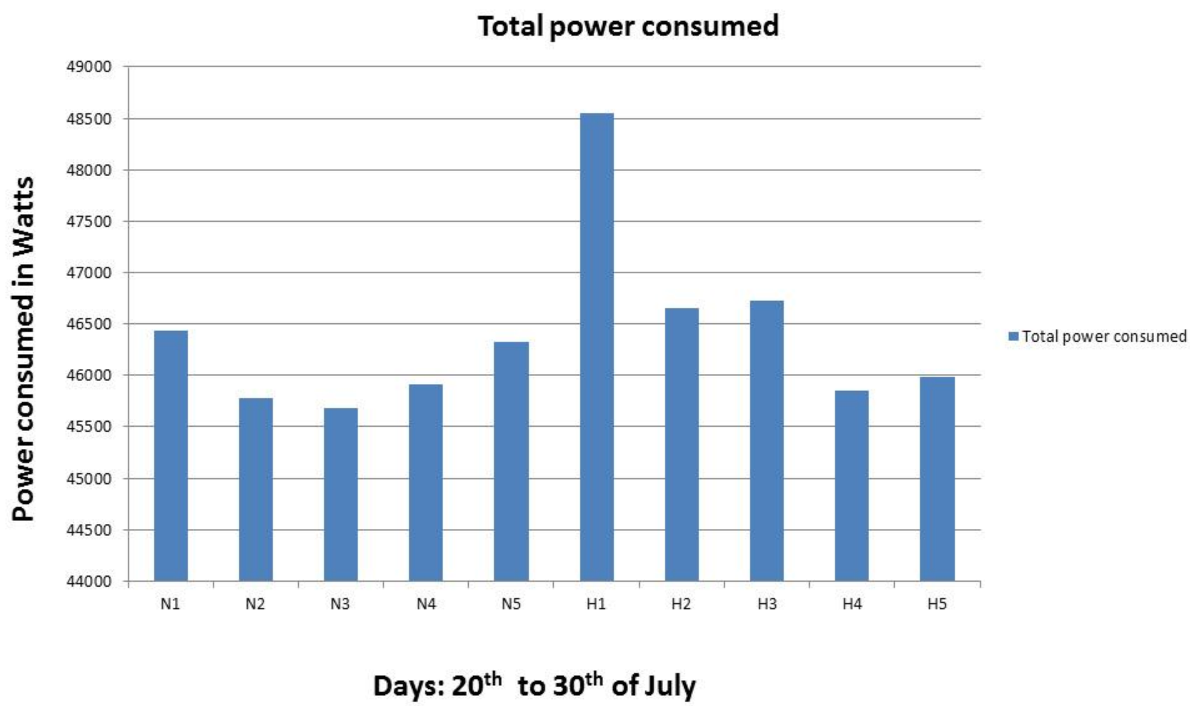


Figure 6.12 Power consumption by Hibon and Neuros.

Table 6.12 and Figure 6.12 explain the power consumed by the Hibon and the Neuros blowers on the days when they were active. The minimum and maximum consumption ranged from 45,678W to 48,553W respectively. Figure 6.12 represents the power consumed for the Hibon and Neuros days when they were active. The x-axis represents the days in which the blowers were active, and the y-axis represents the power consumed in Watts on each day. From the chart it is clear that except for the day 1 of Hibon activity other days does not show a huge difference in activity compared to the Neuros. But, if worked into details, a little margin of more consumption is recorded for the Hibon than the Neuros which are very likely to resemble the yearly data analysis done before.

Chapter 7

Results and Conclusion

After analyzing a range of documents starting from the CDM design memorandum scripted in 2009, to the monthly electricity bills until July 2012, they showed that there is only small energy savings. As stated in Chapter 6, Section 6.4.1 the turbo blowers are predicted to save nearly 50% of cost and energy consumption from the previous technology. But there isn't any such witness of a major reduction in energy or cost at the Stuarts Draft WWTP after shifting to the Neuros high-speed turbo blowers.

	Hibon multi-speed centrifugal blowers	Neuros high-speed turbo blowers
Equipment Cost	$ 213,500	$ 235,270
Annual Cost of Borrowed Money	$ 14,384	$ 14,260
Minimum energy consumed per month	290.52 Giga joules	279.72 Giga joules
Maximum energy consumed per month	393.12 Giga joules	388.80 Giga joules
Avg. energy consumed per month	337.625 Giga joules	330.49 Giga joules
Avg. sum of energy consumed per year	4389.12 Giga joules	3965.94 Giga joules
Repair and Maintenance	$ 1360	$ 6300
Decommission cost	$ 7752	$ 1591
Cost of electricity per month	$ 7034	$ 6885
Cost of electricity per year	$ 84406	$ 82620
Estimated total cost (Elec + Maintainence)	$ 85766	$ 88,920

Table 7.1 Life Cycle Cost of Hibon multi-speed centrifugal blowers and Neuros high-speed turbo blowers.

After comparing the monthly bills and the performance test taken in July, Stuarts Draft WWTP report states that after the installation of Neuros there was a significant savings of $150 per month. This saving is proven by the energy analysis report conducted in the previous chapter.

The energy analysis report proves that the Neuros blowers are saving approximately $150 to $175 per month at the RAS end of the plant. The authorities and the plant supervisor from the Stuarts Draft WWTP agreed on that value and their interpretation of the first 12 months after installing Neuros were the same. The energy observations and evaluations prove that 423.18 giga joules of energy are being saved every year after the installation of the Neuros turbo blowers. With more than 400 giga joules of energy conservation, Stuarts Draft WWTP can save up to $2,000 per year. As stated by the EPA, even an annual energy savings of just 10 percent in this sector could collectively save about $400 million every year. The total expenditure on the Hibon multi stage blowers include an annual cost of borrowed money, repair and maintenance cost, year expenditure on electricity and decommission. The Hibon and the Neuros blowers installed at the site have a ten year warranty period including free service and decommission if the system completely fails. But considering a worst case scenario and the system's long life, the cost of repair and decommission is included. The Hibon blowers would spend an amount of $85766 per year with a $7752 decommission cost. With taking the above consideration and assumption, we arrive at $88,920 per year for the Neuros blowers with a decommission cost of $159. At current conditions and plant capacities, both the Neuros and the Hibon blowers are capable of functioning effectively. But if the plant expands in the future, Hibon blowers would not be the best choice to be used alternatively or parallel to the Neuros blowers. It is proven from the specifications and by the performance test that the Hibon blowers are not capable of taking in heavy load and cannot run at 100% current peak. If there is a situation of 100% current peak, the Hibon blowers need two active aeration units to run the operation because it doesn't have the required specification to satisfy the conditions with one blower unit. This incident was proven on the first day of Hibon activity during the performance test in July. Thus, even though Hibon are economically cheaper than the Neuros, the Neuros blowers are suitable for the future requirements and worst case in-load conditions.

After, conflicting with some control system problem during the performance test phase in July, the control system for these blowers was articulated and the corresponding solution was found. Thus, in conclusion the control systems operation can be overridden manually; this function would help us save energy by switching to the high efficient blower which will be the best for that situation. From the total annual estimated cost it is surprising that Hibon blowers conserve more economically than Neuros, but taking the decommission cost, future developments of the plant into consideration and the requirement of air flow at present and also for the future. Thus, after considering the economy, functionalities and performances of both these blowers, the Neuros high-speed turbo blowers hold an upper hand. In conclusion, I would recommend the Stuarts Draft WWTP to continue with the Neuros high-speed turbo blower to conserve more energy and cost.

7.1 Recommended Case study

Efficient Aeration System Boosts Energy Savings

By Cheri D. Cohen

To reduce the vast consumption of energy by the aerator systems, a new effective aeration system was installed in Ontario, Canada which saved the waste water treatment plant a whopping $47,000 annually in energy costs. In addition to giving this waste water facility a financial boost, the new improved aeration system achieved an additional equipment cost savings by saving aeration horsepower by more than half of the plant usage. This environmental awareness city is located in the Oregon/ Idaho border area and it is meeting all of its waste water discharge permits [61].

The waste water treatment facility located in the city of Ontario operates a five-cell lagoon system with a total volume of approximately 305 million gallons. The treatment plant has a total influent of 2.174 mgd covering a 600 acre land site. The site is also certified for irrigation during crop growing season. The waste water treatment facilities in the U.S. must meet stringent effluent standards to stay in compliance with government regulations. Dependable aeration equipment is a precarious module of an effective treatment facility.

The Ontario facilities were employed with float-mounted aspirator aerators, and the plant's discharge was adaptable to compliance standards. The facility staff from the treatment plant were satisfied with the aeration system's treatment performance and maintenance record over the year and had also recommended the equipment to other treatment facilities in the state.

7.1.1 Upgrades considered

In 2002, the treatment plant staff and authorities decided to upgrade their system to a new energy-saving aerator/mixer which was introduced by the same aeration system manufacturer.

A preliminary sizing and energy analysis was conducted and the results showed that the upgrade of the new aerator/mixer system would result in significant cost benefit and energy savings, attributable to system's oxygen dispersion and mixing capabilities. After the results, the project upgrade was approved.

In effect of the approval, the new systems were installed in 2004. The previous aspirator aeration system consumed a total of 435 hp, which comprised of a combination of 15hp and 25hp aspirator aeration systems. The equipment ran continuously for 24 hours a day, 365 days a year, consuming 2,842,700 kWh per year.

The new aeration system used 13-15hp Aire-O2 Triton process aerator/mixer for a total of 195 hp, which also runs 24/7, 365 days a year. But this system uses less than half of the energy required, thus consuming a total of 1,274,317 kWh per year.

"We cut our horsepower in half at the plant," said Ken Rossen, Oregon waste water treatment superintendent [61].

7.1.2 Electrical savings calculation

The new system had more effective treatment removal rates and energy efficient air compressed motors which resulted in large electrical savings. The operational cost of these electrical savings can be calculated by the following formula:

Kw x $/Kwh x hours of operation = Operating Costs

For example, the city of Ontario waste water treatment facility cut its horsepower from 435 to 195. For an average wastewater treatment facility, a 240hp savings in operational equipment means:

(.746) {Hp to Kw} x (0.07) {average cost of electricity in Oregon} x 24 {hours in a day} x 365 {for one year}.

The above electrical savings resulted in an astounding $109,787 savings in a year with the newly installed aerator/mixer system or $548,935 savings over five years.

Ken Rossen, Oregon wastewater treatment superintendent, also reported that with the power rate of $0.03, a substantial savings of $47,050 per year or $235,260 in five years can be achieved. The average cost of national electricity is $0.10.

The new system provides accurate and sufficient oxygen and mixing to provide the biological performance efficiencies to attain the permitted requirements. The plants' influent BOD is 158 mg/L, TSS 139 mg/L and NH3-N 12. The effluent treatment levels are BOD 17 mg/L, TSS 18 mg/L and NH3-N 1.24 mg/L.

The process aerator/mixer system's unique features and capabilities matched the plant's design requirements and still the horsepower requirements were considerably reduced.

The Aire-O2 triton process includes a regenerative blower with an electric motor and a propeller-type floating aerator. The aerator provides a flow-linkage mixing under the surface of water by inducing flow of air using multiple unit arrangements. The Triton can be used both as a mixer or an aerator. Triton is a combination of aeration efficiency and optimal hydraulics [61].

Bubble size, hang time and complete mixing of basin to prevent dead spots and short circuiting are the factors that affect aeration oxygen transfer. The new aeration triton system has the ability to disperse oxygen throughout an entire waste water treatment basin which increases its performance efficiency and transfer rates.

7.1.3 Mixing efficiency put to the test

The mixing tests were performed to check the new Triton aerator/mixer. The results showed substantial results with the new aerator can achieve down a lagoon depth of 24 feet and it has a maximum allowable distance of approximately 60 feet. The above results were conducted and published by Redmon Engineering Co. consulting engineers.

Thus, this type of aeration mixer is very useful for induced flow rates that have greater pumping rates. This aerator/mixer can also control the direct air by monitoring the regenerative blowers, which helps in saving more energy. When the desired oxygen levels are reached, the blowers automatically turns off independently and later turns on at various intervals during the time when needed. The average national electrical running rate is about 40.83 per kWh. There are no sleepless nights in Ontario with the savings they relish.

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Appendix

Section 1- Definitions

Saprotrophic bacteria -Saprotrophic bacteria attack and decompose organic matter. This characteristic has posed a problem to mankind as food such as stored grains, meat, fish, vegetable and fruits are attacked by saprotrophic bacteria and spoiled. Similarly milk and products are easily contaminated by bacteria and spoiled.

Sphaerotilus natans -Sphaerotilus natans is a filamentous bacterium that is covered in a tubular sheath and can be found in flowing water and in sewage and wastewater treatment plants.

F:M Ratio - One of the process parameters used to control activated sludge solids inventory is known as the Food-to-Microorganism ratio or F:M ratio. It is a baseline established to determine how much food a single pound of organisms will eat every day. A pound of bugs will eat between 0.05-0.6 pounds of food per day depending on the process.

MLSS/MLVSS - The biomass of critters that is responsible for removing the BOD make up a large portion of the solids that are contained in the process. They are the "active" part of activated sludge. The solids under aeration are referred to as the Mixed Liquor Suspended Solids or MLSS. The portion of the MLSS that is actually eating the incoming food is referred to as the Mixed Liquor Volatile Suspended Solids or MLVSS. The inventory of the biomass is calculated as pounds of microorganisms based on the volume of the tanks and the concentration of the MLVSS.

RAS/WAS - As the mixed liquor moves to the secondary clarifier, the activated sludge settles to the bottom of the tank and is removed. This sludge is not a thick as primary sludge. The solids concentrations will normally be between 0.5-0.8% or 5,000-8,000 mg/L. One of two things will happen to the settled sludge. Most of it will be returned to the aeration basins to keep enough activated solids in the tanks to handle the incoming BOD. This is known as the Return Activated Sludge or RAS. A small portion of the sludge will be removed from the system as the MLSS inventory grows. It is referred to as Waste Activated Sludge or WAS.

Detention time - Detention time, or the length of time the MLSS are under aeration, differs with each type of activated sludge process. RAS flows can be used to manipulate the detention time in the aeration tanks. Increasing the RAS flow at night will help maintain the proper detention times as influent flows drop.

MCRT/Sludge Age - Another control parameter is the length of time the bugs stay in the process. If a system wastes 5% of the solids in the system every day, then MLSS would only remain in the system an average of about 20 days (100% / 5% per day = 20 days). This is known as the Mean Cell Residence Time or MCRT. Some operators also refer to this number as Sludge Age.

SVI - The sludge volume index or SVI is a measurement of how well the activated sludge settles in the clarifier. Sludge settleability in a large part depends on the condition of the organisms. Good settling sludge will have an SVI between 80 and 120. As the sludge becomes lighter and the settled volume increases the SVI will also increase.

Putrefaction is one of seven stages in the decomposition of the body of a living organism. It can be viewed, in broad terms, as the decomposition of proteins in a process that results in the eventual breakdown of cohesion between tissues and the liquefaction of most organs.

Pseudomonas is a genus of gammaproteobacteria, belonging to the family Pseudomonadaceae containing 191 validly described species. The members of the genus demonstrate a great deal of metabolic diversity, and consequently are able to colonise a wide range of niches.

Section 2: Aeration Blower Calculations

Aeration and Post Aeration Peak Air Requirements
CENTRIFUGAL BLOWERS

TTN 4/10/2009

CLIENT/JOB ACSA Stuarts Draft
DATE 4/10/09
ENGINEER Tung Nguyen, Al Saikkonnen

Requires User Input; defaults given where appropriate
Output
BASED ON SANITAIRE MEMBRANE DIFFUSERS

INPUT	
6,711	Total Peak Air Requirements scfm
2,336	Enter Additional Air Required, scfm
13.98	Ambient pressure psia corrected for El. 1371.0
0.30	Inlet Losses, psig; assumed, need to verify with manufactuer
8.64	Pressure at top of diffuser dropleg, psig; assumed (0.8+static), need to verify with Sanitaire
0.50	Piping losses, psig;
0.40	Allowance for dirty diffusers, psig; assumed
1.70	Sum Discharge side losses, psig
18.11	Diffuser submergence, ft; verify with Sanitaire
0.283	"n"
0.405	n/blower efficiency (assume 70% eff for multistage centrifugal)
110	Maximum Inlet Temperature, °F
0	Minimum Inlet Temperature, °F
0.85	Relative Humidity; assumed 85%
0.70	Blower efficiency; assumed confirm with Manufacturer
0.3390	Saturated vapor pressure of water at standard temperature, psia
1.2748	Saturated vapor pressure of water at ambient temp (max 110°F), psia (see table)

Design Conditions	
2,336	Max air flow rate-scfm
13.68	**Blower Inlet pressure, psia**
7.84	Static pressure, psig
23.52	**Blower discharge pressure, psia**
0.0646	Density of air at blower inlet, lb/ cu ft
528	Standard Temperature °R
0.36	Standard RH
14.7	Standard Pressure, psia
570	Maximum Inlet Temperature, °R
460	Minimum Inlet Temperature, °R
53.5	R - Gas constant for air, ft-lb/lb

Actual Air flow rates	
570	Ambient Temperature, °R
2913	**Max airflow rate, acfm**

Blower BHP	
9.84	**pressure rise during compression, psia**
3.136	weight flow of air, lb/sec
151	Brake HP @ max temp
1.24	Temp Adjust for cold weather
[illegible]	BHP @ min temp

Calculate Friction Losses:

Commentary

Reference: Wastewater Engineering 3rd Edition (Metcalf & Eddy page 566-569)

Step One- Enter Process Parameters

Enter Pipe Dia:	24	8	in	Enter pipe run for worst reach of piping for length/size/flow
Area:	[illegible]	[illegible]	ft^2	pipe bore area
Enter Pipe Length:	310	197	ft	Enter pipe run for worst reach of piping for length/size/flow
Ambient Pressure (P_1):	13.78	13.78	psia	corrected for elevation
Assume operating pressure:	11.00	11.00	psia	assumed blower operating pressure for friction loss estimate
Discharge Pressure (P_2):	24.78	24.78	psia	sum operating and ambient pressure
Ambient Temperature (T_a):	110	110	F	design temperature for worst case
Air Flow Rate:	6700	2325	scfm	design air flow requirements
blower efficiency:	0.7	0.7		assumed blower efficiencies
n:	0.283	0.283	constant for air	adiabatic constant for air
R:	52.3	52.3	(ft*lb)/(lb air*°R)	gas constant for air
Adiabatic Temperature Rise (ΔT):	147.11	147.11	F	calculated compressed temperature rise
Discharge Temperature (T_d):	257.1[illegible]	257.11	F	sum ambient and compressed temperature rise
μ:	0.0233	0.0233	centipoise	calculated viscosity
N_R:	[illegible]	[illegible]		calculated Reynolds Number
Volumetric Flowrate (V_2):	[illegible]	[illegible]	ft^3/min	calculated volumetric flow rate
Pipe Velocity (v):	1,492.04	4,659.83	ft/sec	calculated pipe velocity

Step Two- Enter Moody Diagram and Friction Loss Parzemters

e:	0.00015	0.00015		roughess coefficient from Table I-2
e/D:	0.00007	0.0002		Roughness factor from Table I-2
f:	0.013	0.0154		Use e/D and N_R to find friction factor from Moody Table I-1
specific weight air (γ_a):	0.0951	0.0951	lb/ft^3	air density corrected for temperature and pressure
velocity head (h_v):	0.1763	[illegible]	in of water	velocity head in inches of water
headloss (h_L):	0.3553	7.8271	in of water	headloss in inches of water

Total Pipe Friction Loss:	8.1826	in
	0.6820	ft
	0.2956	psi

Section 3: Aeration Demand Tables

Table 5-3 Mass Balance Concentrations
(17 deg C) Annual Average Day

Key	Elements	Flow [mgd]	COD [mg/L]	cBOD [mg/L]	TSS [mgTSS/L]	VSS [mgVSS/L]	TN [mgN/L]	TKN [mgN/L]	NH4-N [mgN/L]	NO3-N [mgN/L]	TP [mgP/L]
A	Influent	4.00	489	215	230	207	32.0	32.0	15.4	0.0	5.4
B	Infl + Recycle	4.31	472	201	229	202	32.6	30.6	14.3	2.0	5.7
C	Infl + Recycle + RAS	5.95	3637	705	3158	2319	192.9	190.5	10.5	2.5	100.2
D	Infl to 3	2.23	3637	705	3158	2319	192.9	190.5	10.5	2.5	100.2
E	NRCY3	5.00	3468	591	3116	2274	181.3	177.6	0.3	3.7	100.2
F	Infl to 1 & 2, each	1.86	3637	705	3158	2319	192.9	190.5	10.5	2.5	100.2
G	NRCY1	5.00	3450	581	3104	2262	180.1	176.5	0.5	3.4	100.2
H	NRCY2	5.00	3450	581	3104	2262	180.1	176.5	0.5	3.4	100.2
I	Abasin Effluent Blend	5.95	3456	584	3109	2266	180.5	176.9	0.4	3.5	100.2
J	Clar Alum	300 gpd	0	0	0	0	0.0	0.0	0.0	0.0	0.0
K	Clarifier Effluent Blend	4.25	45	4	17	13	6.5	2.8	0.4	3.5	0.6
L	Filter Bypass	0.00									
M	Methanol	20 gpd	1188000	839113	0	0	0.0	0.0	0.0	0.0	0.0
N	Denite Filter Filtrate	3.99	26	1	0	0	3.1	2.0	0.9	0.9	0.0
O	Effluent to UV	3.99	26	1	0	0	3.1	2.0	0.9	0.9	0.0
P	Nonpotable/Beltwash	0.0003	26	1	0	0	3.1	2.0	0.9	0.9	0.0
Q	Denite Filter Backwash	0.25	57	14	12	8	3.0	3.0	1.5	0.0	3.6
R	RAS Mix (incl WAS)	1.70	11984	2035	10866	7900	615.7	612.1	0.4	3.5	349.4
S	WAS Split	0.06	11984	2035	10866	7900	615.7	612.1	0.4	3.5	349.4
T	Alkalinity (Caustic)	0 gpd	0	0	0	0	0.0	0.0	0.0	0.0	0.0
U	Aerobic Digesters	0.06	9698	429	9257	6304	600.7	454.3	0.1	146.4	348.3
V	Thickener/Belt Press Filtrate	0.06	1054	46	985	671	195.9	49.5	0.1	146.4	37.1
W	Thickened WAS	0.004	145121	6434	138857	94553	6943.6	6797.2	0.1	146.4	5224.0
X	Backwash Pond Solids	0.00	20569	614	19071	13352	953.7	953.7	1.5	0.0	489.7
Y	Recycle (Solids Processing)	0.31	249	20	204	136	40.2	12.0	1.2	28.2	10.1
Z	RAS Return	1.64	11984	2035	10866	7900	615.7	612.1	0.4	3.5	349.4

Table 5-4 Mass Balance Loadings (17 deg C) Annual Average Day

Key	Elements	COD [lb/d]	cBOD [lb/d]	TSS [lb/d]	VSS [lb/d]	TN [lb/d]	TKN [lb/d]	NH3-N [lb/d]	NO3-N [lb/d]	TP [lb/d]
A	Influent	16324	7178	7679	6910	1068	1068	513	0	180
B	Infl + Recycle	16973	7231	8227	7265	1173	1099	516	74	206
C	Infl + Recycle + RAS	180562	35007	156767	115104	9578	9454	521	121	4975
D	Infl to 3	67711	13128	58788	43164	3592	3545	196	46	1866
E	NRCY3	144691	24647	130037	94887	7567	7409	13	154	4182
F	Infl to 1 & 2, each	56426	10940	48990	35970	2993	2955	163	38	1555
G	NRCY1	143948	24232	129530	94377	7514	7366	19	141	4182
H	NRCY2	143948	24232	129530	94377	7514	7366	19	141	4182
I	Abasin Effluent Blend	171574	29012	154316	112500	8962	8782	20	174	4975
J	Clar Alum	0	0	0	0	0	0	0	0	0
K	Clarifier Effluent Blend	1597	150	619	450	229	101	14	124	20
L	Filter Bypass	0	0	0	0	0	0	0	0	0
M	Methanol	198	140	0	0	0	0	0	0	0
N	Denite Filter Filtrate	851	24	0	0	102	66	30	31	0
O	Effluent to UV	851	24	0	0	102	66	30	31	0
P	Nonpotable/Beltwash	0.06	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Q	Denite Filter Backwash	668	63	572	403	37	34	2	2	20
R	RAS Mix (incl WAS)	169977	28862	154120	112050	8733	8681	6	50	4955
S	WAS Split	6388	1085	5792	4211	328	326	0	2	186
T	Alkalinity (Caustic)	0	0	0	0	0	0	0	0	0
U	Aerobic Digesters	5186	230	4950	3371	321	243	0	78	186
V	Thickener/Belt Press Filtrate	530	23	495	337	98	25	0	74	19
W	Thickened WAS	4656	206	4455	3033	223	218	0	5	168
X	Backwash Pond Solids	515	15	477	334	24	24	0	0	12
Y	Recycle (Solids Processing)	649	53	533	355	105	31	3	74	26
Z	RAS Return	163589	27777	148328	107839	8405	8355	6	48	4769

Table 5-5 Mass Balance Concentrations
Winter (10.5 deg C) Average Day Maximum Month

Key	Elements	Flow [mgd]	COD [mg/L]	cBOD [mg/L]	TSS [mgTSS/L]	VSS [mgVSS/L]	TN [mgN/L]	TKN [mgN/L]	NH4-N [mgN/L]	NO3-N [mgN/L]	TP [mgP/L]
A	Influent	5.40	500	220	235	212	32.0	32.0	15.4	0.0	5.6
B	Infl + Recycle	5.81	487	208	236	208	33.4	31.0	14.7	2.4	5.8
C	Infl + Recycle + RAS	8.03	4535	995	3950	2923	247.0	242.9	11.1	4.0	115.0
D	Infl to 3	3.01	4535	995	3950	2923	247.0	242.9	11.1	4.0	115.0
E	NRCY3	1.50	4366	880	3912	2882	238.3	231.0	1.3	6.8	115.0
F	Infl to 1 & 2, each	2.51	4535	995	3950	2923	247.0	242.9	11.1	4.0	115.0
G	NRCY1	0.00	4357	874	3908	2877	245.5	230.2	0.7	15.1	115.0
H	NRCY2	5.00	4356	875	3904	2874	235.4	232.2	3.5	2.6	115.0
I	Abasin Effluent Blend	8.03	4360	877	3908	2878	239.6	231.1	1.8	8.1	115.0
J	Clar Alum	522 gpd	0	0	0	0	0.0	0.0	0.0	0.0	0.0
K	Clarifier Effluent Blend	5.74	50	6	22	16	12.9	4.4	1.8	8.1	0.7
L	Filter Bypass	0.00									
M	Methanol	150 gpd	1188000	839113	0	0	0.0	0.0	0.0	0.0	0.0
N	Denite Filter Filtrate	5.39	28	2	0	0	3.1	2.8	1.8	0.3	0.0
O	Effluent to UV	5.39	28	2	0	0	3.1	2.8	1.8	0.3	0.0
P	Nonpotable/Beltwash	0.07	28	2	0	0	3.1	2.8	1.8	0.3	0.0
Q	Denite Filter Backwash	0.34	110	49	17	13	8.6	8.6	6.4	0.0	1.7
R	RAS Mix (incl WAS)	2.29	15133	3053	13662	10032	806.3	797.7	1.8	8.1	400.7
S	WAS Split	0.07	15133	3053	13662	10032	806.3	797.7	1.8	8.1	400.7
T	Alkalinity (Caustic)	500 gpd	0	0	0	0	0.0	0.0	0.0	0.0	0.0
U	Aerobic Digesters	0.08	11925	832	11392	7791	777.1	575.6	0.2	201.5	398.0
V	Thickener/Belt Press Filtrate	0.07	1305	90	1225	838	264.6	63.1	0.2	201.5	42.8
W	Thickened WAS	0.005	153009	10691	146462	100174	7585.7	7384.2	0.2	201.5	5117.2
X	Backwash Pond Solids	0.00	42663	6283	38450	28193	2228.1	2228.1	6.4	0.0	1045.4
Y	Recycle (Solids Processing)	0.41	314	56	226	154	52.3	17.9	5.3	34.4	8.7
Z	RAS Return	2.22	15133	3053	13662	10032	806.3	797.7	1.8	8.1	400.7

Table 5-6 Mass Balance Loadings
Winter (10.5 deg C) Average Day Maximum Month

Key	Elements	COD [lb/d]	cBOD [lb/d]	TSS [lb/d]	VSS [lb/d]	TN [lb/d]	TKN [lb/d]	NH4-N [lb/d]	NO3-N [lb/d]	TP [lb/d]
A	Influent	22554	9916	10592	9554	1442	1442	692	0	252
B	Infl + Recycle	23632	10108	11423	10082	1622	1504	710	118	282
C	Infl + Recycle + RAS	303985	66675	264771	195937	16558	16282	744	268	7705
D	Infl to 3	113994	25003	99289	73476	6209	6106	279	101	2889
E	NRCY3	54651	11018	48970	36075	2982	2892	16	86	1439
F	Infl to 1 & 2, each	94995	20836	82741	61230	5174	5088	232	84	2408
G	NRCY1	0	0	0	0	0	0	0	0	0
H	NRCY2	181775	36512	162907	119934	9823	9687	146	110	4797
I	Abasin Effluent Blend	292244	58753	261960	192908	16061	15490	121	544	7705
J	Clar Alum	0	0	0	0	0	0	0	0	0
K	Clarifier Effluent Blend	2416	274	1051	772	620	212	86	388	31
L	Filter Bypass	0	0	0	0	0	0	0	0	0
M	Methanol	1487	1050	0	0	0	0	0	0	0
N	Denite Filter Filtrate	1242	74	1	0	139	125	79	11	0
O	Effluent to UV	1242	74	1	1	139	125	79	11	0
P	Nonpotable/Beltwash	0.06	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Q	Denite Filter Backwash	1491	348	1226	946	88	87	5	1	31
R	RAS Mix (incl WAS)	289828	58479	261645	192136	15441	15278	35	155	7674
S	WAS Split	9475	1912	8554	6282	505	499	1	5	251
T	Alkalinity (Caustic)	0	0	0	0	0	0	0	0	0
U	Aerobic Digesters	7516	524	7180	4911	490	363	0	127	251
V	Thickener/Belt Press Filtrate	765	53	718	491	155	37	0	118	25
W	Thickened WAS	6751	472	6462	4420	335	326	0	9	226
X	Backwash Pond Solids	1068	157	963	706	56	56	0	0	26
Y	Recycle (Solids Processing)	1078	192	776	528	180	62	18	118	30
Z	RAS Return	280353	56568	253091	185855	14936	14779	33	150	7423

Table 5.7

Aeration Demands for Stuart's Draft WWTP Expansion								
Warm Weather								
Scenario		**AA**	**MM**	**MM**	**Peak**	**Peak**	**Partial Peak**	**Partial Peak**
Infl flow, mgd		4	5.4	5.4	12	12	9.4	9.4
WW Temp, C		28	28	20	20	23	23	28
Anoxic Vol		Normal	Normal	Normal	Normal	Normal	Normal	Normal
NRCY, MGD		5/5/5	5/5/5	5/5/5	5/5/5	5/5/5	5/5/5	5/5/5
RAS, %		40	40	40	40	40	40	40
Aerobic SRT, d		9	9	9	5.5	5.5	7.5	7.75
DO, mg/L		2	2	2	2	1	1	1
MLSS, mg/L		3100	3900	4000	4000	3900	3950	3950
Aeration Grid	**Volume, MG**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**
1a (center)	0.379	0	0	0	0	0	0	0
1b	0.168	63.85	90.14	78.59	126.59	129.15	107.44	116.8
1c	0.168	34.05	46.49	44.1	62.61	64.19	54.54	57.89
1d	0.168	23.86	32.15	36.42	55.19	55.38	45.12	42.58
1e	0.168	19.49	26.66	29.69	49.35	48.16	37.49	34.71
Deox 1	0.04	0	0	0	0	0	0	0
Basin 1 Total	1.091	141.25	195.44	188.8	293.74	296.88	244.59	251.98
2a (center)	0.379	0	0	0	0	0	0	0
2b	0.168	63.85	90.14	78.59	126.59	129.15	107.44	116.8
2c	0.168	34.05	46.49	44.1	62.61	64.19	54.54	57.89
2d	0.168	23.86	32.15	36.42	55.19	55.38	45.12	42.58
2e	0.168	19.49	26.66	29.69	49.35	48.16	37.49	34.71
Deox 2	0.04	0	0	0	0	0	0	0
Basin 2 Total	1.091	141.25	195.44	188.8	293.74	296.88	244.59	251.98
3a (center)	0.123	0	0	0	0	0	0	0
3b (swing)	0.130	0	0	0	0	0	0	0
3c	0.295	77.82	109.38	95.46	155.27	159.65	133.9	146.31
3d	0.295	46.7	63.1	66.82	100.32	101.22	83.15	81.52
3e	0.295	35.59	48.53	51	82.99	81.24	64.05	61.58
Deox 3	0.03	0	0	0	0	0	0	0
Basin 3 Total	1.168	160.11	221.01	213.28	338.58	342.11	281.1	289.41
Total	3.35	442.61	611.89	590.88	926.06	935.87	770.28	793.37

Table 5.8

Aeration Demands for Stuart's Draft WWTP Expansion					
Cold Weather					
Scenario		**AA**	**AA**	**MM**	**Peak**
Infl flow, mgd		4	5.4	5.4	12
WW Temp, C		10.5	10.5	10.5	10.5
Anoxic Vol		Normal	Minimum	Minimum	Minimum
NRCY, MGD		5/5/5	0/5/1.5	0/5/1.5	0/5/5
RAS, %		40	40	40	40
Aerobic SRT, d		11.5	14	10.25	6.5
DO, mg/L		2	2	2	2
MLSS, mg/L		4000	4000	4000	4000
Aeration Grid	**Volume, MG**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**	**OTR [lb/hr]**
1a (center)	0.379	0	80.28	98.35	115.94
1b	0.168	53.25	27.14	34.68	40.76
1c	0.168	28.85	21.39	29.74	37.87
1d	0.168	26.07	17.3	24.94	35.16
1e	0.168	24.5	15.15	21.18	32.49
Deox 1	0.04	0	0	0	0
Basin 1 Total	1.091	132.67	161.26	208.89	262.22
2a (center)	0.379	0	0	0	0
2b	0.168	53.25	49.57	66.42	117.73
2c	0.168	28.85	28.24	35.18	43.75
2d	0.168	26.07	25.75	32.11	37.81
2e	0.168	24.5	24.26	30.52	36.06
Deox 2	0.04	0	0	0	0
Basin 2 Total	1.091	132.67	127.82	164.23	235.35
3a (center)	0.123	0	0	0	0
3b (swing)	0.130	0	29.11	39.55	74.94
3c	0.295	61.89	52.31	64.08	73.92
3d	0.295	47.51	44.12	56.41	66.84
3e	0.295	42.41	35.56	48.53	62.8
Deox 3	0.03	0	0	0	0
Basin 3 Total	1.168	151.81	161.1	208.57	278.5
Total	3.35	417.15	450.18	581.69	776.07

Section 4: Diffused Aeration System Calculation

Air Requirements

Total Process Air Requirements:

Process	Design Condition	Use	Temperature (°C)	Flow (MGD)	AOR (lb/hr)	SOR[4,5] (lb/hr)	Air Required (SCFM)
Aeration	Peak Day[1]	Blower Size	23	12.00	936	1806	6,200
Post Aeration	Post Aeration[2]		23	8.4	30	-	511
							6,711
Aeration	Annual Average (Warm)[1]	Diffuser Qty	28	4.00	443	1010	2,932
							2,932
Aeration	Annual Average (Cold)[1]	Turn down	10.5	4.00	418	906	2,685
Aeration	Minimum Mixing Air[3]		-	-	-	-	1,192
						Minimum:	1,192

Assumptions:

1. Based on AOR output from BioWIN model for Aeration
2. Based on SCFM output from BioWIN model for Post -Aeration
3. Based on ASG recommended minimum air for two existing tanks in service: (0.12 sfcm/ft^2)
4. α=0.65 β=0.95 Θ=1.024 El=1371.0'
5. Min D.O.: Peak Day= 1.0 mg/l, Annual Average Day= 2.0 mg/l

Aeration Tank No.3 Design:

Aeration Tank Diffuser Design Summary				
Section of Tank	Number of Diffusers	A_t/A_d	Number of Holders	A_t/A_h
3b	193	27	232	22
3c	469	11	563	9
3d	264	20	317	16
3e	231	22	277	19
Total	1157		1389	

Check for Mixing:

Raw Tapered Diffuser Count

	PD (10.5°C)	AA (28°C)	AA (28°C)	AA (28°C)
Section	[redacted]			
Diffusers	193	469	281	214
Spares	39	94	56	43
Holders	232	563	338	257

Diffuser Counts Adjusted for Mixing

PD (10.5°C)	AA (28°C)	AA (28°C)	AA (28°C)
3b	**3c**	**3d**	**3e**
193	469	264	231
39	94	53	46
232	563	317	277

Check Aeration Basin No.3 c,d,e for Minimum Airflow:

Enter Anonic Zone Outer Diameter:	35.67	ft
Enter Oxic Zone Inside Diameter	102.5	ft
Gross Oxic Zone Area:	7,252	ft^2

Enter Final Oxic Zone Angle:	105	degrees	
Minimum Air flow per SF:	0.12	SCFM/ft^2	Per ASG v2
Oxic Tank Area:	2,115	ft^2	
Minimum Diffusers Required:	230.8		

Check Aeration Basin No.3b for Minimum Airflow:

Enter Anonic Zone Outer Diameter:	35.67	ft
Enter Oxic Zone Inside Diameter	102.5	ft
Gross Oxic Zone Area:	7,252	ft^2

Enter Final Oxic Zone Angle:	45	degrees	
Minimum Air flow per SF:	0.12	SCFM/ft^2	Per ASG v2
Oxic Tank Area:	907	ft^2	
Minimum Diffusers Required:	98.9		

Check Existing Aeration No.1 and 2 for Mixing

Existing Basin Actual Diffuser Layout

Section	**1b**	**1c**	**1d**	**1e**	**2b**	**2c**	**2d**	**2e**
Diffusers	393	325	255	197	393	325	255	197
Spares	39	47	41	99	39	47	41	99
Holders	432	372	296	296	432	372	296	296

Check Existing Basin No. 1 and 2 Minimum Airflow (Actual Layout)

Enter Anonic Zone Outer Diameter:	60.67	ft
Enter Oxic Zone inside Diameter	100	ft
Gross Oxic Ozone Area:	4,963	ft^2

Enter Final Oxic Zone Angle:	90	degrees	
Minimum Air flow per SF:	0.12	SCFM/ft^2	Per ASG v2
Oxic Tank Area:	1,241	ft^2	
Minimum Diffusers Required:	135.4		

AIR REQUIREMENTS - Design

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09
CLIENT/JOB ACSA Stuarts Draft WWTP
DATE 4/8/09
ENGINEER Tung Nguyen, Al Saikkonnen

This spreadsheet converts oxygen requirements to scfm.
The scfm is used to size the diffuser system (including taper) and as input into the blower design.

[redacted]

[redacted]

[redacted]

Depth Correction for Diffuser Submergence

$C_{sc} = ([P_a + (c \times d)]/P_a) \times C_s$

C_{sc}	depth corrected saturation factor
P_a	atmospheric pressure, ft of water
c	depth correction factor (use 25% of diffuser submergence)
d	diffuser submergence in ft

β 0.7 - 0.98; 0.95 is normal

α 0.40-0.45 for non-nitrifying systems; 0.55-0.65 for nitrifying systems

Temperature Corrections

$\theta^{(T-20)}$ corrects alpha for temperature

T	in °C
θ	1.024

$$\tau = \frac{C_{ST}}{C_{S20}}$$

See attached saturation table

C_{ST}	Solubility at process temperature - °C
C_{S20}	Solubility at 20°C

Pressure Correction

corrects for plant altitude

$$\Omega = \frac{P_{ambient}}{P_{standard}}$$

$P_{ambient}$	atmospheric pressure at plant
$P_{standard}$	14.7 psi (atmospheric pressure at sea level)

Driving Force Correction

$$Driving \;\; force \;\; corection = \frac{C*_{SC} - C}{C_{SC}}$$

C^*_{SC}	DO saturation corrected for pressure, temperature & wastewater, mg/l
C_{SC}	DO saturation corrected for depth of submergence, mg/l
C	min DO under operating conditions

Summary Equation

$$OTE_{field} = SOTE \quad \frac{\beta \tau \; \Omega \; C_{SC} - C}{C_{SC}} \alpha \; \theta^{(T-20)}$$

AIR REQUIREMENTS - Design Max AOR (23°C and Peak Day Flows)

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09
CLIENT/JOB ACSA Stuarts Draft WWTP
DATE 4/8/09
ENGINEER Tung Nguyen, Al Saikkonnen

Requires user input; defaults given where appropriate
Output

INPUT		
22,461	Average Oxygen requirements	For Peak Day: 12.0 MGD
1	Peak Factor (Max:Avg)	
18.91	Depth of aeration Tanks, ft	
0.80	Height of diffuser off tank floor, ft	Assumed from Sanitaire
0.95	β	0.95 for WW (ASG V2)
0.65	α	Chose 0.55-0.65 (ASG V2)
23	Process temp, °C	Peak Flow Design Temp
0.33	c (depth correction factor for submergence)	1/3 of submergence (ASG V2)
2.0	Min Operating DO, mg/l	Per 10 States Standards
32.35	atmospheric pressure, ft of water	corrected for El. 1371.0
1.024	θ	
8.58	C_{ST}	temperature of 23°C and 0 mg/L
9.09	C_{S20}	
13.98	Ambient pressure, psi	corrected for El. 1371.0
14.7	Standard pressure, psi	
1.05	Allowance for diffuser fouling	Assume limited fouling
1.80	SOTE, % per ft of diffuser submergence	is obtained

Design Conditions	
18.11	Depth of diffuser submergence - ft
32.60	SOTE-%
10.78	C_{SC}
0.94	τ
0.95	Ω
1.074	$\theta^{(T-20)}$

Output	
15.2	OTE_{FIELD}
0.47	$OTE_{FIELD}/SOTE$
6,200	Average air, scfm
n/a	Max Day air, scfm

Basin No.1 and 2 subscript are for outer ring quadrants, Basin No.3 has on Swing Zone

	check	1b	1c	1d	1e	2b	2c	2d	2e	3c	3d	3e
		31.25%				31.25%				37.50%		
Average Oxygen requirements	22,461	3,100	1,541	1,329	1,156	3,100	1,541	1,329	1,156	3,832	2,429	1,950
Peak Factor (Max:Avg)		1	1	1	1	1	1	1	1	1	1	1
Depth of aeration Tanks, ft		18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91
Height of diffuser off tank floor, ft		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
β		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
α		0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Process temp, °C		23	23	23	23	23	23	23	23	23	23	23
c		0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Min Operating DO, mg/l		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
atmospheric pressure, ft of water		32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35
θ		1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024
C_{ST}		8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58
C_{S20}		9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09
Ambient pressure, psi		13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98
Standard pressure, psi		14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Allowance for diffuser fouling		1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
SOTE, % per ft of diffuser submergence		1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Depth of diffuser submergence - ft		18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11
SOTE-%		32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60
C_{SC}		10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77
τ		0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Ω		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
$\theta^{(T-20)}$		1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074	1.074
OTE_{FIELD}		15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
$OTE_{FIELD}/SOTE$	check	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Average air, scfm	6,202	856	425	367	319	856	425	367	319	1,058	671	538
Max Day air, scfm		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Enter Desired Diffuser Flowrate: 2.5 scfm/diffuser; check with Sanitaire

Basin Section:	1b	1c	1d	1e	2b	2c	2d	2e	3c	3d	3e
Diffuser Counts	342	170	147	128	342	170	147	128	423	268	215
Number of Blanks:	68	34	29	26	68	34	29	26	85	54	43
Number of Holders:	411	204	176	153	411	204	176	153	508	322	258

AIR REQUIREMENTS - Design Average AOR (28°C and Annual Average Flows)

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09

CLIENT/JOB ACSA Stuarts Draft WWTP
DATE 4/8/09
ENGINEER Tung Nguyen, Al Saikkonnen

Requires user input; defaults given where appropriate
Output

INPUT		
10,623	Average Oxygen requirements	For Annual Average: 4.0 MGD
1	Peak Factor (Max:Avg)	
18.91	Depth of aeration Tanks, ft	
0.80	Height of diffuser off tank floor, ft	Assumed from Sanitaire
0.95	β	0.95 for WW (ASG V2)
0.65	α	Chose 0.55-0.65 for nitrifying systems (ASG V2)
28	Process temp, °C	Summer Design Temp
0.33	c (depth correction factor for submergence)	1/3 of submergence (ASG V2)
2.0	Min Operating DO, mg/l	Per 10 States Standards
32.35	atmospheric pressure, ft of water	corrected for El. 1371.0
1.024	θ	
7.83	C_{ST}	and 0 mg/L salinity.
9.09	C_{S20}	
13.98	Ambient pressure, psi	corrected for El. 1371.0
14.7	Standard pressure, psi	
1.05	Allowance for diffuser fouling	Assume limited fouling
1.80	SOTE, % per ft of diffuser submergence	used 1.8% per foot until info from Sanitaire is obtained

Design Conditions	
18.11	Depth of diffuser submergence - ft
32.60	SOTE-%
10.78	C_{SC}
0.86	τ
0.95	Ω
1.209	$\theta^{(T-20)}$

Output	
15.2	OTE_{FIELD}
0.47	$OTE_{FIELD}/SOTE$
2,932	Average air, scfm
n/a	Max Day air, scfm

Basin No.1 and 2 subscript are for outer ring quadrants, Basin No.3 has on Swing Zone

		1b	1c	1d	1e	2b	2c	2d	2e	3c	3d	3e
	check	31.25%				31.25%				37.50%		
Average Oxygen requirements	10,623	1,532	817	573	468	1,532	817	573	468	1,868	1,121	854
Peak Factor (Max:Avg)		1	1	1	1	1	1	1	1	1	1	1
Depth of aeration Tanks, ft		18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91
Height of diffuser off tank floor, ft		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
β		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
α		0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Process temp, °C		28	28	28	28	28	28	28	28	28	28	28
c		0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Min Operating DO, mg/l		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
atmospheric pressure, ft of water		32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35
θ		1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024
C_{ST}		7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83
C_{S20}		9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09
Ambient pressure, psi		13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98
Standard pressure, psi		14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Allowance for diffuser fouling		1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
SOTE, % per ft of diffuser submergence		1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Depth of diffuser submergence - ft		18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11
SOTE-%		32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60
C_{SC}		10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77
τ		0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Ω		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
$\theta^{(T-20)}$		1.209	1.209	1.209	1.209	1.209	1.209	1.209	1.209	1.209	1.209	1.209
OTE_{FIELD}		15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
$OTE_{FIELD}/SOTE$	check	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Average air, scfm	2,933	423	226	158	129	423	226	158	129	516	309	236
Max Day air, scfm		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Enter Desired Diffuser Flowrate: 1.1 scfm/diffuser; check with Sanitaire

Basin Section:	[redacted]										
Diffuser Counts	386	205	144	117	385	205	144	117	469	281	214
Number of Blanks	77	41	29	23	77	41	29	23	94	56	43
Number of Holders	462	246	172	141	462	246	172	141	563	338	257

AIR REQUIREMENTS - Design Minimum AOR (10.5°C and Annual Average Flows)

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09
CLIENT/JOB ACSA Stuarts Draft WWTP
DATE 4/8/09
ENGINEER Tung Nguyen, Al Seikkonnen

Requires user input; defaults given where appropriate
Output

INPUT			check	3b
1,799	lb/day Oxygen requirements	For Annual Average; 4.0 MGD	1,799	1,799
1	Peak Factor (Max:Avg)			1
18.91	Depth of aeration Tanks, ft			18.91
0.80	Height of diffuser off tank floor, ft	Assumed from Sanitaire		0.80
0.95	β	0.95 for WW (ASG V2)		0.95
0.65	α	Chose 0.55-0.65 for nitrifying systems (ASG V2)		0.65
10.5	Process temp, °C	Winter Design Temp		10.5
0.33	c (depth correction factor for submergence)	1/3 of submergence (ASG V2)		0.33
2.0	Min Operating DO, mg/l	Per 10 States Standards		2.0
32.35	atmospheric pressure, ft of water	corrected for El. 1371.0		32.35
1.024	θ			1.024
11.16	C_{st}	and 0 mg/L salinity.		11.16
9.09	C_{s20}			9.09
13.98	Ambient pressure, psi	corrected for El. 1371.0		13.98
14.7	Standard pressure, psi			14.7
1.05	Allowance for diffuser fouling	Assume limited fouling		1.05
1.80	SOTE, % per ft of diffuser submergence	used 1.8% per foot until info from Sanitaire is obtained		1.80

Design Conditions		
18.11	Depth of diffuser submergence - ft	[redacted]
32.60	SOTE-%	
10.78	C_{sc}	
1.23	τ	
0.96	Ω	
0.798	$\theta^{(T-20)}$	

Output			
[redacted]	OTE_{FIELD}		[redacted]
	OTE_{FIELD}/SOTE	check	
	Average air, scfm	483	
	Max Day air, scfm		

Enter Desired Diffuser Flowrate:	2.5
Basin Section:	[redacted]
Diffuser Counts	193
Number of Blanks:	39
Number of Holders:	232

AIR REQUIREMENTS - Design Minimum AOR (10.5ºC and Annual Average Flows)

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09

CLIENT/JOB ACSA Stuarts Draft WWTP

DATE 4/8/09

ENGINEER Tung Nguyen, Al Sukkonnen

Requires user input; defaults given where appropriate

Output

INPUT		
10,012	lb/day Oxygen requirements	For Annual Average: 4.0 MGD
1	Peak Factor (Max:Avg)	
18.91	Depth of aeration Tanks, ft	
0.80	Height of diffuser off tank floor, ft	Assumed from Sanitaire
0.95	β	0.95 for WW (ASG V2)
0.65	α	Chose 0.55-0.65 for nitrifying systems (ASG V2)
10.5	Process temp, °C	Winter Design Temp
0.33	c (depth correction factor for submergence)	1/3 of submergence (ASG V2)
2.0	Min Operating DO, mg/l	Per 10 States Standards
32.35	atmospheric pressure, ft of water	corrected for EL 1371.0
1.024	θ	
11.16	C_{ST}	and 0 mg/L salinity.
9.09	C_{surf}	
13.98	Ambient pressure, psi	corrected for EL 1371.0
14.7	Standard pressure, psi	
1.05	Allowance for diffuser fouling	Assume limited fouling
1.80	SOTE, % per ft of diffuser submergence	used 1.8% per foot until info from Sanitaire is obtained

Basin No.1 and 2 subscript are for outer ring quadrants, Basin No.3 has on Swing Zone

check	1b	1c	1d	1e	2b	2c	2d	2e	3c	3d	3e
	31.25%				31.25%				37.50%		
10,012	1,278	692	626	588	1,278	692	626	588	1,465	1,140	1,018
	1	1	1	1	1	1	1	1	1	1	1
	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91	18.91
	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35	32.35
	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024
	11.16	11.16	11.16	11.16	11.16	11.16	11.16	11.16	11.16	11.16	11.16
	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09
	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98	13.98
	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80

Design Conditions	
18.11	Depth of diffuser submergence - ft
32.60	SOTE-%
10.78	C_{SC}
1.23	τ
0.95	Ω
0.798	$\theta^{(T-20)}$

18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11
32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60	32.60
10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77	10.77
1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798

Output	
15.6	OTE_{FIELD}
0.48	OTE_{FIELD}/SOTE
2,685	Average air, scfm
n/a	Max Day air, scfm

check											
	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
check	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
2,686	343	186	168	158	343	186	168	158	398	306	273
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Enter Desired Diffuser Flowrate: 1.1 scfm/diffuser; check with Sanitaire

Basin Section:											
Diffuser Counts	312	169	153	143	312	169	153	143	362	278	248
Number of Blanks:	62	34	31	29	62	34	31	29	72	56	50
Number of Holders:	374	203	183	172	374	203	183	172	435	334	298

Section 5: Site Plan of the Stuarts Draft WWTP

The following diagram shows the vertical view of the Site plan of the Stuarts Draft WWTP

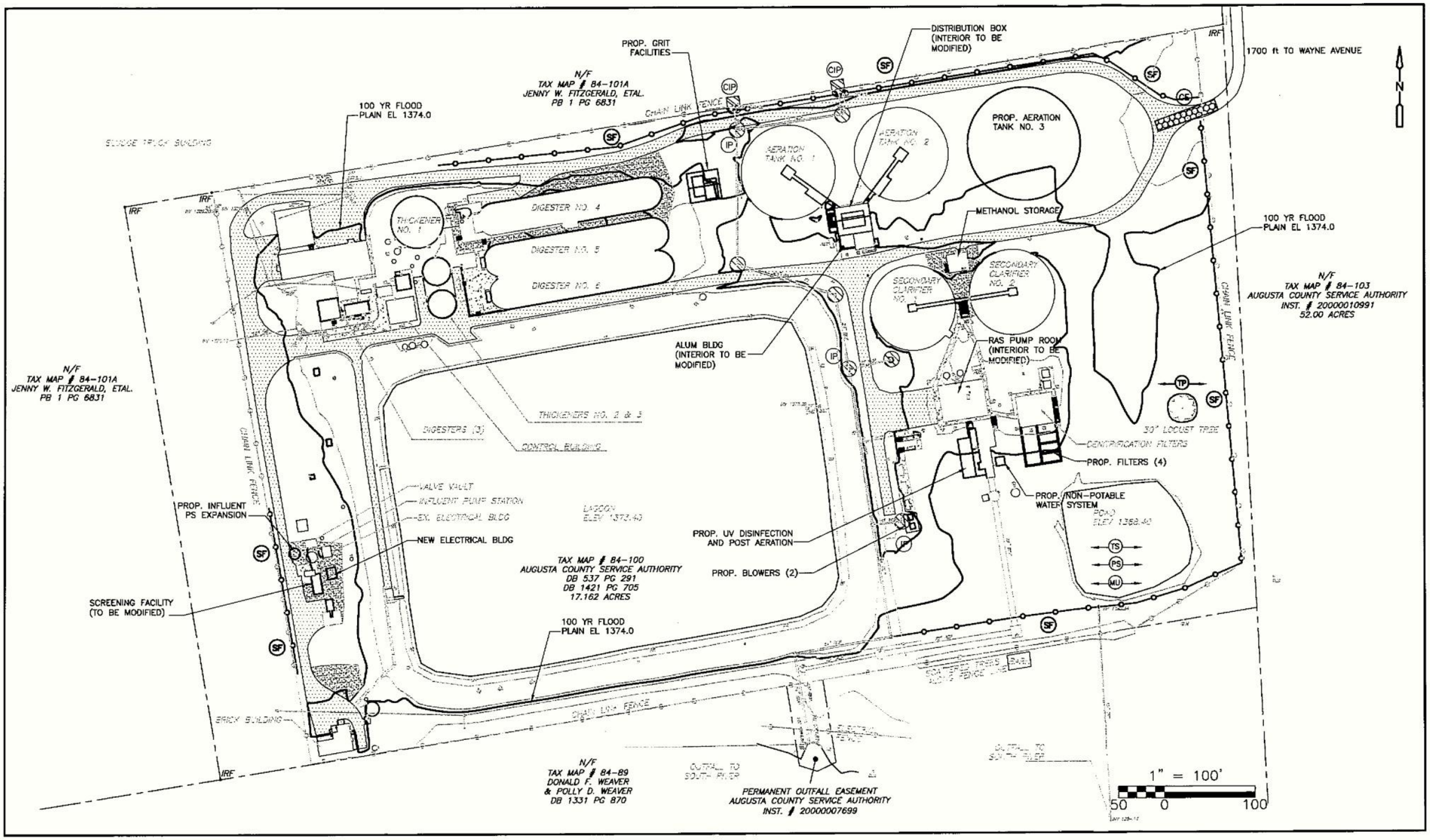

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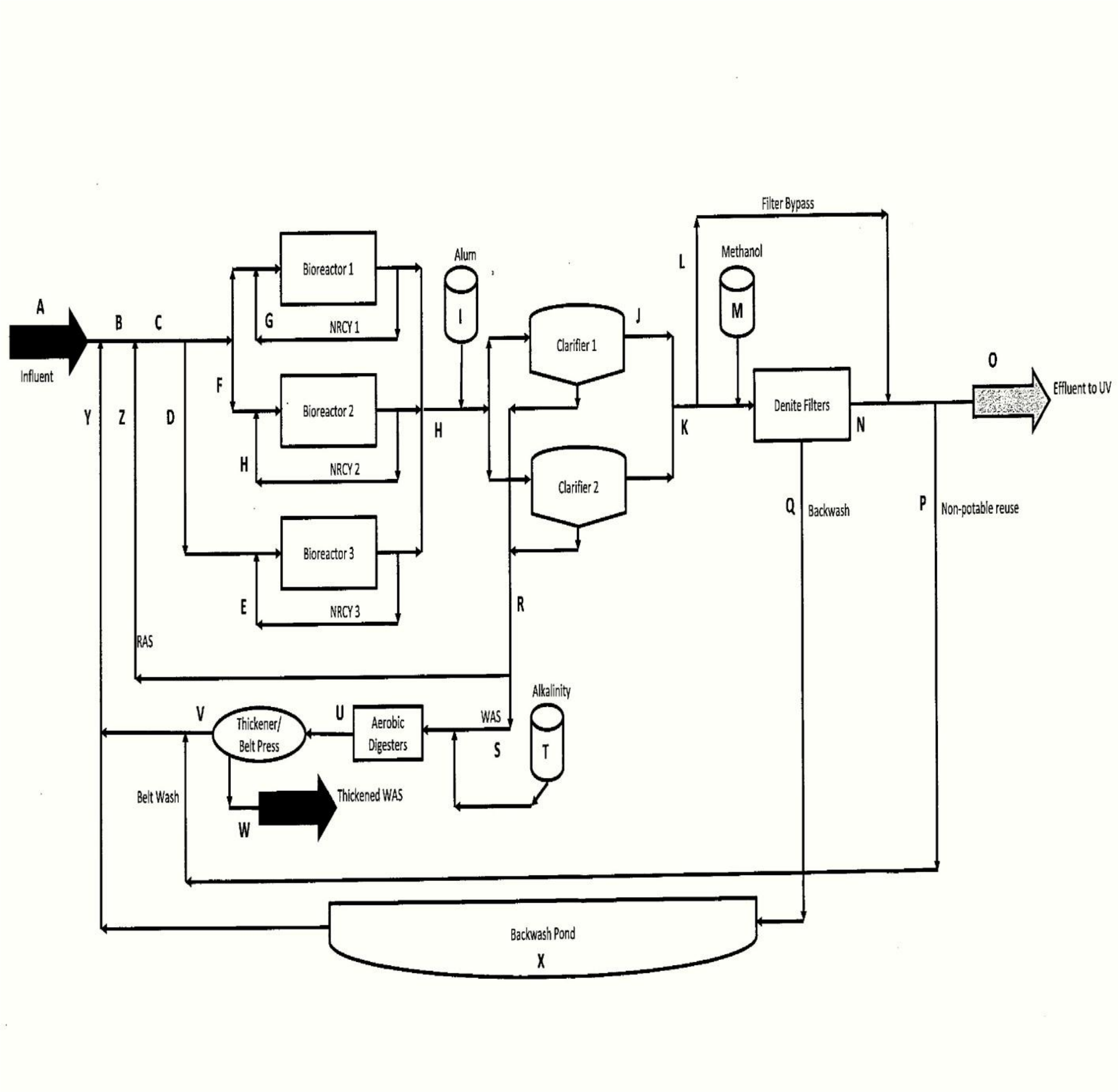
Figure No. 2-1
EXPANSION AND ENR UPGRADE
SITE PLAN
ASCA-STUARTS DRAFT

Section 6: Process Flow Diagram of the Stuarts Draft WWTP



Section 7: CDM Design Memorandum Calculation

AIR REQUIREMENTS - Design Average AOR (28ºC and Annual Average F

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09

CLIENT/JOB ACSA Stuarts Draft WWTP

DATE 4/8/09

ENGINEER Tung Nguyen, Al Saikkonnen

Requires user input; defaults given where appropriate

Output

INPUT		
7,625	Average Oxygen requirements	For Annual Average: 4.0 MGD
1	Peak Factor (Max:Avg)	
18.91	Depth of aeration Tanks, ft	
0.80	Height of diffuser off tank floor, ft	Assumed from Sanitaire
0.95	β	0.95 for WW (ASG V2)
0.65	α	Chose 0.55-0.65 for nitrifying systems (ASG V2)
28	Process temp, ^{0}C	Summer Design Temp
0.33	c (depth correction factor for submergence)	1/3 of submergence (ASG V2)
2.0	Min Operating DO, mg/l	Per 10 States Standards
32.35	atmospheric pressure, ft of water	corrected for El. 1371.0
1.024	θ	
7.83	C_{ST}	0 mg/L salinity
9.09	C_{S20}	
13.98	Ambient pressure, psi	corrected for El. 1371.0
14.7	Standard pressure, psi	
1.05	Allowance for diffuser fouling	Assume limited fouling
1.80	SOTE, % per ft of diffuser submergence	used 1.8% per foot until info from Sanitaire is obtained

Design Conditions	
18.11	Depth of diffuser submergence - ft
32.60	SOTE-%
10.78	C_{SC}
0.86	τ
0.95	Ω
1.209	$\theta^{(T-20)}$

Output	
15.2	OTE_{FIELD}
0.47	OTE_{FIELD}/SOTE
2,104	Average air, scfm
n/a	Max Day air, scfm

AIR REQUIREMENTS - Design Average AOR (28ºC and Annual Average F

Fine Bubble-Full Floor Diffuser Coverage

TTN 4/8/09
CLIENT/JOB ACSA Stuarts Draft WWTP
DATE 4/8/09
ENGINEER Tung Nguyen, Al Saikkonnen

Requires user input; defaults given where appropriate
Output

INPUT		
2,733	Average Oxygen requirements	For Annual Average: 4.0 MGD
1	Peak Factor (Max:Avg)	
18.91	Depth of aeration Tanks, ft	
0.80	Height of diffuser off tank floor, ft	Assumed from Sanitaire
0.95	β	0.95 for WW (ASG V2)
0.65	α	Chose 0.55-0.65 for nitrifying systems (ASG V2)
28	Process temp, ^{0}C	Summer Design Temp
0.33	c (depth correction factor for submergence)	1/3 of submergence (ASG V2)
2.0	Min Operating DO, mg/l	Per 10 States Standards
32.35	atmospheric pressure, ft of water	corrected for El. 1371.0
1.024	θ	
7.83	C_{ST}	0 mg/L salinity.
9.09	C_{S20}	
13.98	Ambient pressure, psi	corrected for El. 1371.0
14.7	Standard pressure, psi	
1.05	Allowance for diffuser fouling	Assume limited fouling
1.80	SOTE, % per ft of diffuser submergence	used 1.8% per foot until info from Sanitaire is obtained

Design Conditions	
18.11	Depth of diffuser submergence - ft
32.60	SOTE-%
10.78	C_{SC}
0.86	τ
0.95	Ω
1.209	$\theta^{(T-20)}$

Output	
15.2	OTE_{FIELD}
0.47	OTE_{FIELD}/SOTE
754	Average air, scfm
n/a	Max Day air, scfm

Table 1-1. Stuarts Draft Influent Loads and Peaking Factors

Parameter	2003	2004	2005	2006	2007	Design
BOD						
Annual Average, lbs/day	1,912	2,296	1,789	2,256	1,493	
Flow Weighted Avg. Conc., mg/L	137	242	217	240	194	
Maximum Month, lbs/day	2,705	3,098	2,360	2,947	2,352	
Peak Day, lbs/day	7,152	7,629	4,798	4,956	4,375	
MM/AA Peak Factor	1.41	1.35	1.31	1.31	1.57	1.38
PD/MM Peaking Factor	2.64	2.46	2.03	1.68	1.86	1.7[a]
TSS						
Average, lbs/day	2,096	2,574	1,987	3,025	2008	
Flow Weighted Avg. Conc., mg/L	150	272	241	322	261	
Maximum Month, lbs/day	2,383	3,482	2,798	4,428	3,182	
Peak Day, lbs/day	6,715	7,519	6,216	9,082	6,104	
MM/AA Peak Factor	1.14	1.35	1.41	1.46	1.58	1.38
PD/MM Peaking Factor	2.82	2.16	2.22	2.05	1.92	2.0
Ammonia						
Average, lbs/day	135	121	120	131	131	
Flow Weighted Avg. Conc., mg/L	10	13	14.6	14	17.1	
Maximum Month, lbs/day	180	145	153	151	155	
Peak Day, lbs/day	343	163	176	209	199	
MM/AA Peak Factor	1.33	1.2	1.27	1.15	1.18	1.23
PD/MM Peaking Factor	1.90	1.12	1.15	1.39	1.29	1.37
Oxygen Demand						
Maximum Month, lbs/day	3,694	4,423	3,451	4,355	3,624	
Peak Day, lbs/day	5,729	7,625	3,990	6,874	6,217	
MM/AA Peak Factor	1.30	1.42	1.36	1.46	1.59	1.43
PD/MM Peaking Factor	1.55	1.72	1.15	1.58	1.72	1.7[a]
TKN						
Average, lbs/day	251	290	229	309	207	
Flow Weighted Avg. Conc., mg/L	18.0	30.6	27.7	32.9	26.9	
Maximum Month, lbs/day	357	486	346	444	293	
Peak Day, lbs/day	571	1,392	488	630	426	
MM/AA Peak Factor	1.4	1.68	1.5	1.44	1.42	1.49[b]
PD/MM Peaking Factor	1.6	2.63	1.4	1.42	1.45	1.7[a]
TP						
Average, lbs/day	48	49	39	56	45	
Flow Weighted Avg. Conc., mg/L	3.4	5.1	4.8	6.0	5.9	
Maximum Month, lbs/day	67	64	58	38	57	
Peak Day, lbs/day	94	99	88	159	84	
MM/AA Peak Factor	1.4	1.3	1.47	1.56	1.25	1.40
PD/MM Peaking Factor	1.4	1.5	1.52	1.81	1.49	1.55
Flow						
Average, mgd	1.67	1.135	0.990	1.13	0.92	
Maximum Month, mgd	2.00	1.46	1.32	1.95	1.42	
Peak Day, mgd	6.13	4.23	3.59	4.28	3.42	
MM/AA Peak Factor	1.20	1.29	1.33	1.74	1.54	1.35
Maximum Month, lbs/day	3.67	3.73	3.63	3.80	3.71	3.0

X= 3909

Notes:

(a) "Oxygen demand" was calculated from BOD and ammonia data to examine the coincident peaking factors that should be applied to the aeration design. A peak day to maximum month factor of 1.7 was thus applied to both the BOD and TKN loads used for design.

(b) Nitrogen peaking factors were developed considering a combination of ammonia and TKN data. A net MM/AA factor of 1.35 was applied to TKN for the actual design.

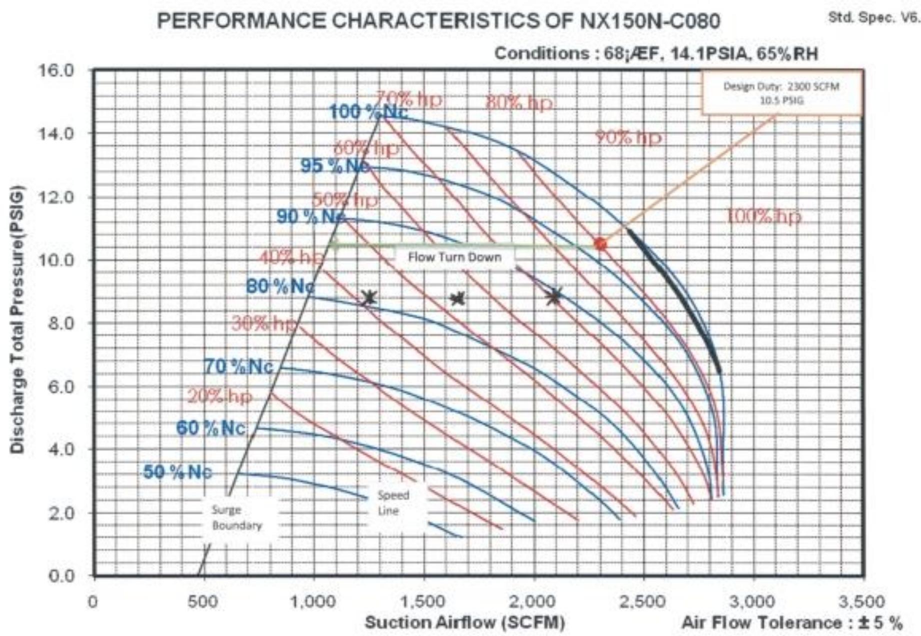
Table 1-1. Stuarts Draft Influent Loads and Peaking Factors

Parameter	2003	2004	2005	2006	2007	Design
BOD						
Annual Average, lbs/day	1,912	2,296	1,789	2,256	1,493	
Flow Weighted Avg. Conc., mg/L	137	242	217	240	194	
Maximum Month, lbs/day	2,705	3,098	2,360	2,947	2,352	
Peak Day, lbs/day	7,152	7,629	4,798	4,956	4,375	
MM/AA Peak Factor	1.41	1.35	1.31	1.31	1.57	1.38
PD/MM Peaking Factor	2.64	2.46	2.03	1.68	1.86	1.7[a]
TSS						
Average, lbs/day	2,096	2,574	1,987	3,025	2008	
Flow Weighted Avg. Conc., mg/L	150	272	241	322	261	
Maximum Month, lbs/day	2,383	3,482	2,798	4,428	3,182	
Peak Day, lbs/day	6,715	7,519	6,216	9,082	6,104	
MM/AA Peak Factor	1.14	1.35	1.41	1.46	1.58	1.38
PD/MM Peaking Factor	2.82	2.16	2.22	2.05	1.92	2.0
Ammonia						
Average, lbs/day	135	121	120	131	131	
Flow Weighted Avg. Conc., mg/L	10	13	14.6	14	17.1	
Maximum Month, lbs/day	180	145	153	151	155	
Peak Day, lbs/day	343	163	176	209	199	
MM/AA Peak Factor	1.33	1.2	1.27	1.15	1.18	1.23
PD/MM Peaking Factor	1.90	1.12	1.15	1.39	1.29	1.37
Oxygen Demand						
Maximum Month, lbs/day	3,694	4,423	3,451	4,355	3,624	X= 3909
Peak Day, lbs/day	5,729	7,625	3,990	6,874	6,217	
MM/AA Peak Factor	1.30	1.42	1.36	1.46	1.59	1.43
PD/MM Peaking Factor	1.55	1.72	1.15	1.58	1.72	1.7[a]
TKN						
Average, lbs/day	251	290	229	309	207	
Flow Weighted Avg. Conc., mg/L	18.0	30.6	27.7	32.9	26.9	
Maximum Month, lbs/day	357	486	346	444	293	
Peak Day, lbs/day	571	1,392	488	630	426	
MM/AA Peak Factor	1.4	1.68	1.5	1.44	1.42	1.49[b]
PD/MM Peaking Factor	1.6	2.63	1.4	1.42	1.45	1.7[a]
TP						
Average, lbs/day	48	49	39	56	45	
Flow Weighted Avg. Conc., mg/L	3.4	5.1	4.8	6.0	5.9	
Maximum Month, lbs/day	67	64	58	38	57	
Peak Day, lbs/day	94	99	88	159	84	
MM/AA Peak Factor	1.4	1.3	1.47	1.56	1.26	1.40
PD/MM Peaking Factor	1.4	1.5	1.52	1.81	1.49	1.55
Flow						
Average, mgd	1.67	1.135	0.990	1.13	0.92	
Maximum Month, mgd	2.00	1.46	1.32	1.95	1.42	
Peak Day, mgd	6.13	4.23	3.59	4.28	3.42	
MM/AA Peak Factor	1.20	1.29	1.33	1.74	1.54	1.35
Maximum Month, lbs/day	3.67	3.73	3.63	3.80	3.71	3.0

Notes:

(a) "Oxygen demand" was calculated from BOD and ammonia data to examine the coincident peaking factors that should be applied to the aeration design. A peak day to maximum month factor of 1.7 was thus applied to both the BOD and TKN loads used for design.

(b) Nitrogen peaking factors were developed considering a combination of ammonia and TKN data. A net MM/AA factor of 1.35 was applied to TKN for the actual design.



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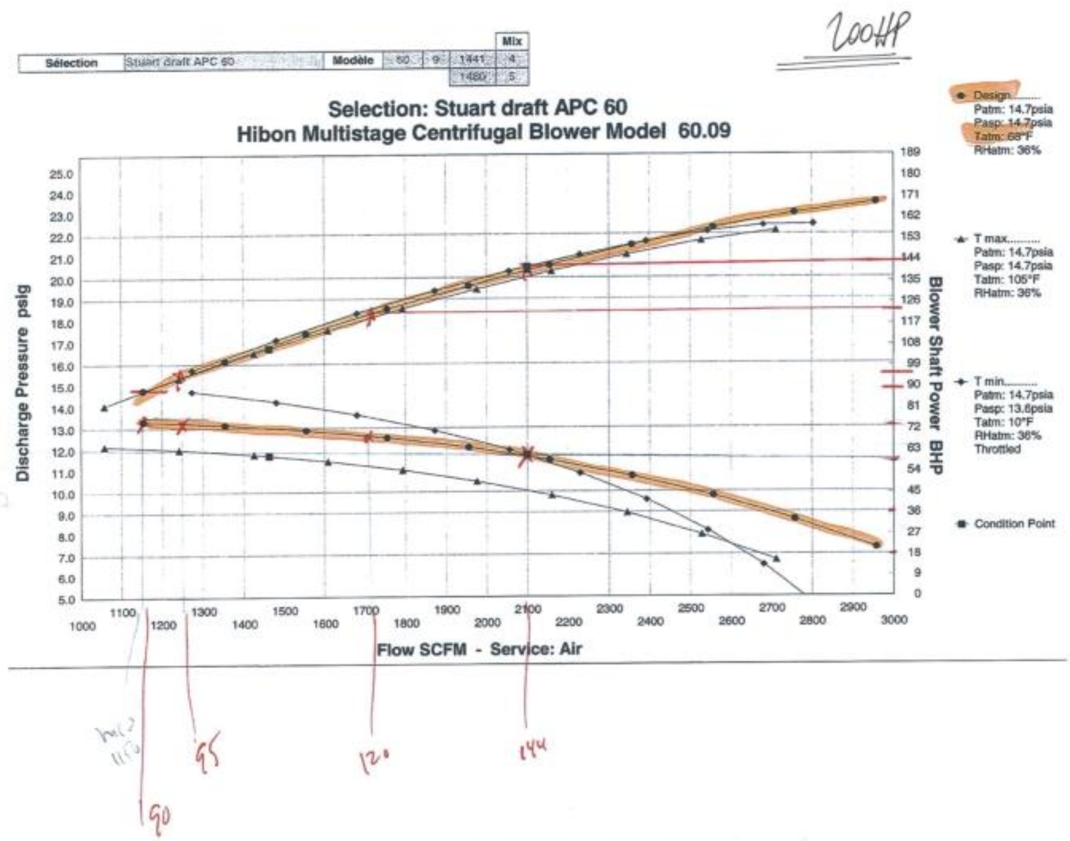
200HP
Sélection
Stuart draft APC 60
Modèle
60
9
1441
1480
Mix
4
5
Selection: Stuart draft APC 60
Hibon Multistage Centrifugal Blower Model 60.09
Discharge Pressure psig
Blower Shaft Power BHP
Flow SCFM - Service: Air
Design
Patm: 14.7psia
Pasp: 14.7psia
Tatm: 68°F
RHatm: 36%
T max
Patm: 14.7psia
Pasp: 14.7psia
Tatm: 105°F
RHatm: 36%
T min
Patm: 14.7psia
Pasp: 13.6psia
Tatm: 10°F
RHatm: 36%
Throttled
Condition Point
90
95
120
144

-End-