INVESTIGATION OF CAUSES OF FOAMING IN INDUSTRIAL WASTE WATER TREATMENT AND EFFECTS OF SUBSTANCES ON INDUSTRIAL WASTE WATER TREATMENT

BY

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree written.

Signed………………………….

Date………………………………

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TERMINOLOGY/ CONCEPT CLARIFICATION

- **BOD -** Biochemical Oxygen Demand
- **COD -** Chemical Oxygen Demand
- **WAS -** Waste Activated Sludge
- **Denitrification-** The anoxic biological conversion of nitrate to nitrogen gas.
- **F/M Ratio-** Food to mass ratio
- **Nitrification** The biological oxidation of ammonia and ammonium sequentially to nitrite and then nitrate.
- **MCRT-** Mean Cell Residence Time: the average time that a given unit of cell mass stays in the activated sludge biological reactor (sludge age).
- **MLSS-** Mixed liquor suspended solids : The total suspended solids concentration in the activated sludge
- **OUR**- Oxygen uptake rate
- **PAC**- Powdered activated carbon

ABSTRACT

The research was aimed to study the causes of excessive foaming in a waste water treatment plant. Although the activated sludge process has been adopted to treat this industrial waste water , lots of problems were experienced by the inhibitory effects of toxic compounds that are found in industrial effluents and the foaming stability that was very high. Industrial waste water treatment using sludge processes was found to be more challenging than the normal municipal waste water treatment although the principle is the same; the foaming tendencies were found to be more in industrial waste water. In this study the composition of influents to the waste water treatment plant and operating parameter's effects on foaming tendencies were examined. The foaming potential in the plant was found to be chemically related due to high contamination of compounds such as phenols, which played a major role in formation of stable foam. It was recommended that there must be pretreatment of the incoming influents to minimize their impact to waste water treatment.

BACKGROUND TO THE STUDY

Despite the fact that a lot of research has been done before regarding the causes of foaming in industry, until now no universally reliable strategy or method has been found to prevent or control foaming. Methods that are effective in some industries are not necessarily effective in other companies. Current strategies that are used to prevent or control foaming include (i) reduction of the foaming potential of the sludge by inhibiting or destroying foam producing bacteria or by changing their surface properties, (ii) or by controlling the actual foam formation and stabilization, (iii) or by limiting foam trapping and accumulation, and lastly by reducing the detrimental consequences to the plant.

The research was conducted in company A (name of company is confidential per agreement with University) which is encountering a problem with foaming. A lot of money is spent on anti-foaming agents but after a few weeks their impact is reduced and the foaming starts all over again. The approach which was taken in this research was to systematically identify and investigate the real causes of foaming in the company over a period of time. The gained insight information is hoped to support or prove wrong some of the hypotheses and therefore lead to the real causes of foaming in the waste water treatment plant.

With regard to the company, the influent into the plant consists of three streams, namely, Stream A, Stream B and Stream C. Stream A water results originally from the combustion of coal with steam and oxygen and is composed mainly of chemical oxygen demand (COD), ammonia and phenols; Stream B is generated by the Synthol Fischer-Tropsch reaction and contains fatty acids and other non-acidic components like alcohols. On the other hand, Stream C water is from the oily and storm sewers from the entire factory operations. It is typically contaminated with oil and dissolved organic material. The above mentioned streams are combined and treated in the activated sludge system (Biological waste water treatment). The organic material of the incoming industrial effluents is broken down by microorganisms. The microorganisms consist of a variety of aerobic digesters which require oxygen to biodegrade the organic compounds in the water. The treated water from the biobasins overflows to sedimentation tanks in order to separate the water from the sludge (micro organisms). The water overflows from the sedimentation tanks as process cooling water make-up and is pumped to the designated process cooling towers. The sludge at the bottom of the sedimentation tanks is split into two streams. One part, RAS (return activated sludge), is pumped back to the biobasins, while the other part, WAS (waste activated sludge), is pumped to the sludge incinerators where it gets dewatered and incinerated.

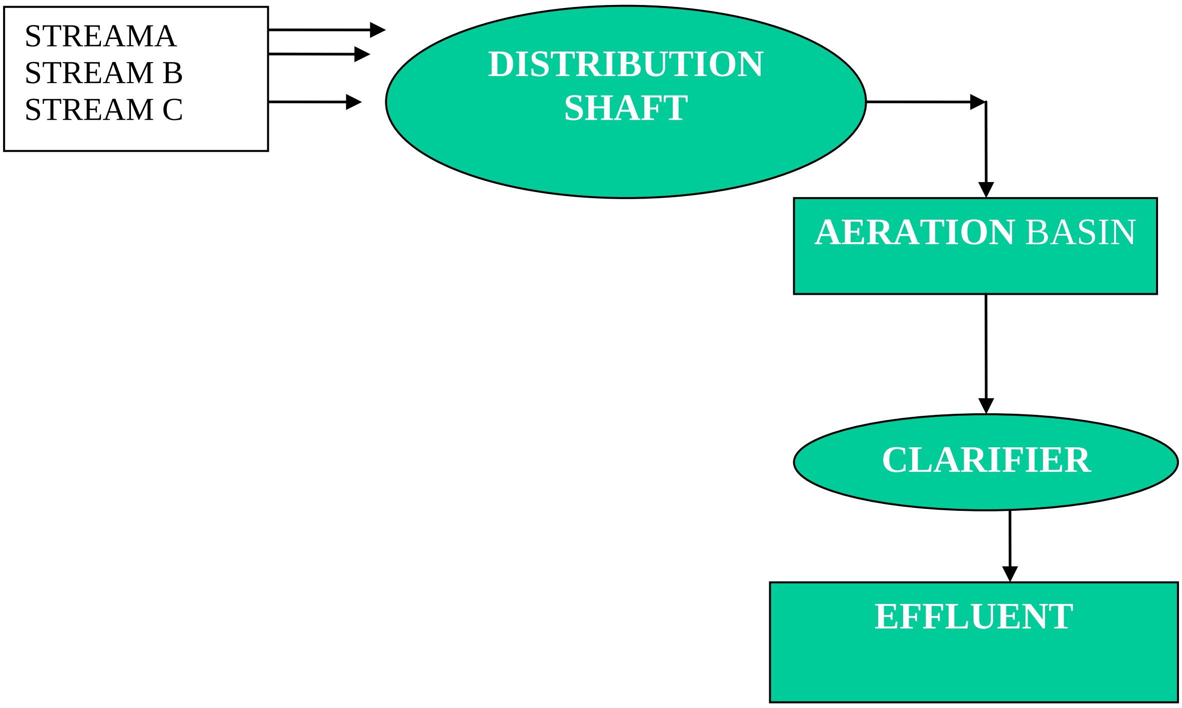

Figure 1: Block flow diagram of the Activated sludge process.

CHAPTER 1

INTRODUCTION

1.1 Background

Foam is a stable dispersion of gas bubbles in a liquid and is considered to be a 2-phase system. In most systems, the presence of surface active agents or surfactants results in foaming. The presence of surfactants enhances both the amount of foam produced by *Nocardia*-containing activated sludge as well as increasing foam stability. For surfactants to exert this effect they must be poorly or slowly biodegradable so that they can persist in the aeration basin (Jenkins, Michael, Richard, Glen & Daigger 2003).

There are five conditions that cause excess foaming in the activated sludge process. Pumice-like foam which is grayish in color is due to solids returning from sludge processing. Slimy foam, which is also grayish but slimy and thick, is caused by nutrient deficiency. Dark brown, thick, scummy foam is usually caused by very old sludge age that promotes the growth of *Nrcardia sp.* or *Microthrix parvicella.* White billowy foam is caused by high surfactants such as detergents, temperature conditions. *M. parvicella* appears at colder temperatures and *Nocardia* occurs at higher temperature conditions (Jenkins *et al.* 1993).

Foaming is reported to occur when microorganisms and molecules with hydrophobic end groups trap air bubbles and prevent them from fully escaping from the stream of water. The microorganisms most commonly responsible for this behavior include two types of filamentous bacteria, namely, *Microthrix parvicella* and *Gordona amarae*-like organisms (GALO, formerly classified as *Nocardia*) Khanal & Paudel (2002). These bacteria are especially active in conditions of high oil and grease concentrations, low F/M (food to microorganism) ratio or long sludge age. *Microthrix parvicella* are long, unbranched filamentous bacteria. Filaments of *M.parvicella* can grow to as long as 400 µm (long). Microbial characteristics of activated sludge foaming is caused by the presence of Actinomycete *b*acteria and *Nocardia amare* Lechevalier (1974). Goddard & Foster (1987) reported that *Nostocoida limicola* and Type 0041 can also cause foaming since both species produce biosurfactants that form foam.

The ability of microorganisms to form flocs is vital for the activated sludge treatment of wastewater. The floc structure enables not only the adsorption of soluble substrates but also the adsorption of the colloidal matter and macro-molecules additionally found in most wastewaters. The adsorptive capacity of flocs therefore facilitates the oxidation of this complex wastewater. However, important also is their ability to settle in a relatively short time under quiescent conditions; otherwise the biomass produced as a result of oxidation of the waste would pass to the receiving watercourse exerting a large pollution load. The main phenomena that lead to a decrease of the quality of the effluent are due to the escape of flocs, and floating sludge attributed to the presence of filamentous organisms that originate foam in the aeration basin (Pujol, Duchene, Schetrite & Canler 1991).

Persistent foaming in the basins causes severe operational problems. The foam tends to accumulate in the basin and overflows covering walkways and thus creating a hazard to operators due to slippery flows and it becomes difficult to operate the plant equipment during winter when the foam freezes. When foam freezes on the secondary clarifier it makes scum removal devices inoperatable and during warm climates it becomes odorous. Halo & Jenkins.

(1988) reported that when foam overflows from the aeration basin it contains 40-50% of activated sludge solids which leads to poor effluent quality since most of the sludge is lost with foam.

Nitrification can create problems in activated sludge operation. Many plants are reported to experience an upset condition with dispersed growth and filamentous bulking every spring when warmer temperatures induce nitrification. Another problem caused by nitrification is de-nitrification. During this process, bacteria common in the activated sludge floc respire using nitrate in place of free oxygen when it is lacking and release nitrogen gas as a by-product. This gas is only slightly soluble in water and small nitrogen gas bubbles form in the activated sludge and cause sludge blanket flotation in the final clarifier (Jenkins *et al.* 2004).

The phenomenon of the sludge rising due to de-nitrification has been reported in literature as early as 1940s Sawyer & Bradney (1945). In plants performing de-nitrification processes, the release of nitrogen microbubbles which occurs, lowers the apparent density of sludge and favors flotation, particularly in the secondary clarifier Richard (2003). Since the critical amount of N_2 gas required to cause sludge rising depends on many factors e.g. denitrifier fraction, biomass concentration, the amount of adsorbed slowly biodegradable organics and nitrate available for endogenous nitrate respiration (ENR), sludge rising problems may occur under different operational conditions.

1.2 AIMS

The overall aim of the study is to:

Identify the causes of excessive foaming at the Biological waste water treatment plant at company A

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1.3 OBJECTIVES

1.3.1 To identify the role which is played by the incoming pollutants from the chemical streams

1.3.2 Reduce the defoamer / antifoam cost accumulated over the past few years.

1.3.3 To establish the origin of foaming in waste water treatment plant from both chemical and microbial point of view.

1.3 PROBLEM STATEMENT

The excessive foaming, especially on the aeration basin has escalated resulting in loss of millions of rands due to the cost of chemicals used as defoamer. The foam blankets on aeration basins are interfering with oxygen uptake by microorganisms causing biological floc to float, producing sludge which does not settle well in the sedimentation tank and which affect the effluent quality. The stable foam production in the aeration basin has become the major concern at the Bioplant.

1.4 RESEARCH QUESTIONS

- According to literature there are different types of foaming: biological, chemical and mechanical foaming. What type of foaming is problematic at the bioplant? And what is its nature?
- What are the effects of pollution of incoming streams on the activated sludge process? (Their biodegrability, Phenols, Ammonia, pH and COD Load etc.)

- Plant operation parameters can lead to foaming; does the plant always operate within its operating parameters? Foaming vs operation parameters?

- Are the chemicals used in the plant ideal for the type of water and also the mode of application?

- According to literature for ideal biological growth sufficient nutrients should be available; any deviations will result in poor treatment and upset conditions. This is especially true if waste water is strong in carbon. What is the case at Bioplant and what will the effect of this be on foaming?

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Metcalf & Eddy (2003) reported that foaming is a major operational problem in wastewater treatment, especially in activated sludge treatment plants. It results in extra maintenance of the plant since it overflows to walkways and the plant’s equipment, and reduction of oxygen transfer. It occurs mostly in aerated units, where oxygen is supplied to the wastewater to support microbial activity. They also noted that in activated sludge treatment facilities, two common mechanisms exist for wastewater aeration. The first mechanism involves bubbling of air or oxygen through the wastewater whilst the second mechanism involves agitation of wastewater at the air/water interface. Tipping (1995) reported that there are three types of foam that can occur in the activated sludge systems, namely biological, chemical and mechanical foam.

2.1.1 Biological foaming

According to Jenkins *et al.* 2003, biological foams appear as sticky, viscous, stable and often chocolate-colored foam on the aeration basin. The occurrence of this foam has been associated with the presence of filamentous organisms in the activated sludge processes. Wanner (1994) reported that foaming is caused by three types of filamentous organisms which are *Microthrix parvicella, Nocardia* and *Nostocoida limicola.* Nocardial foaming appears to be the most common and occurs at approximately 40% of activated sludge plants in the U.S. Pitt & Jenkins (1990) in their USA survey, also showed that 66% of activated sludge plants are experiencing foaming as from 1979.

Nocardial foam occurs as a thick, stable, brown foam or "scum", inches to many feet thick on aeration basins and final clarifier surfaces. This foam consists of activated sludge solids (flocs) containing large amounts of *Nocardia* filaments growing from their surface and is quite stable, compared to most other foams, due to the physical "interlocking" of the *Nocardia* filaments. These foams are easy to diagnose microscopically since they are dominated by branched, Gram positive filaments and are simply identified by Gram stain. In 1998, Wanner reported that the distribution of filamentous organisms in biological foam at waste water treatments plants varies from country to country, from season to season and is changing with time.

Weismann & Dombrowski (2007) reported that biological foam can be caused by grease, septicity, low dissolved oxygen (DO) or just high biological oxygen demand (BOD) and very young sludge age. Sticky, viscous foam occurs when activated sludge is nutrient-limited, probably due to the formation of surface-active extracellular polymeric material by activated sludge micro-organisms (Jenkins *et al.* 1993).

Richard (2003) observed that extracellular polysaccharide is produced by all activated sludge bacteria and is, in part, responsible for floc formation. Overproduction of this polysaccharide can occur due to nutrient deficiency, oxygen deficiency or high F/M which builds up in the sludge and has been found to be poorly degraded and leads to poor sludge settling. Signs of nutrient deficiency include: filamentous bulking; a viscous activated sludge that exhibits significant exopolysaccharide which is referred to as slime when stained with India ink.

The most important design parameters of an activated sludge process are the food to microorganism (F/M) ratio, which balances the influent substrate concentration with the steady state effluent biomass concentration. Activated sludge process performance is a compromise of F/M ratios above or below the optimum value. Too high F/M ratio can lead to low dissolved oxygen concentrations, filamentous bulking and poor BOD removal in the aeration tank. Alternatively, too low F/M ratio promotes foaming by GALO and *Microthrix parvicella*. Again, this control measure in ineffective against surfactant foaming. A typical F/M ratio is 0.4 g substrate/g biomass-day (Metcalf & Eddy, 2003).

Ho & Jenkins (1991) conducted research work to investigate the influence of surfactants on *Nocardia* foaming. They discovered that the foaming of activated sludge was significantly enhanced by the presence of non- ionic surfactants, but surfactants alone could not generate stable foam if the sludge did not contain *Nocardia* cells. The foaming of *Nocardia* -containing activated sludge transported suspended solids and *Nocardia spp*. filaments into the foam and increased their level over those found in the mixed liquor. Also overdosing of polymers in sludge dewatering equipment has been indicated as a possible cause of scum formation Bradley & Kharkar (1996).

2.1.2 Chemical foaming

Chemical foaming is due to the presence of slowly biodegradable surfactants which occur during the treatment of some industrial wastewaters (Jenkins *et.al*, 2003). Large quantities of white frothy foam are often generated on the surface of the aeration tanks and clarifiers during start-up of the plant. This material is probably the accumulation of undergraded surface active organic matter and usually disappears once the sludge mass becomes established (Jenkins *et al.* 1993). This type of foam is usually not so persistent and difficult to remove as biological ones (Jenkins *et al.* 1993).

Rajatanavin (2005) on his study reported that pure liquids do not produce chemical foams, because there is no mechanism for retardation of lamella interfacial destabilization. He reported that addition of surfactants helps to lower surface tension of the system making it easier for foam formation. In his study he further reported that foam stability of surfactants depends on a number of factors, like the chemical structure of surfactants, geometry of surfactants, composition of surfactants and surfactant concentration. Wilson (1996) observed that although a surface active agent is necessary for the formation of foam, it is not sufficient for the production of stable foam. Stable persistent foam is produced when the rupture of lamellae is prevented even after most of the liquid has drained out. The simplest method to determine foam stability is by measuring foam height column as function of time.

Wilson (1996) showed that stability of chemical foam can be enhanced by electrostatic repulsive forces between films, Laplace law relates the pressure, difference between the outside and the inside of gas bubble in foam with their radii and surface Tension (eq 1):

$$\Delta P = 2\gamma / r \text{ …………………….. (Equation 1)}$$

Where ΔP is pressure difference, r is radius, and γ is the surface tension, according to this law, the pressure in the smaller bubble is higher than the pressure in the larger bubble.

According to SCC industries the higher temperatures reduce foam stability, while higher pH results in higher foam stability. SCC industries also reported that other factors that contribute to foam stability are surface area and surface tension which is represented by the formula below.

$$\text{Elasticity} = 2A\,(d\gamma)/(dA) \text{…………………………(Equation 2)}$$

Where

A = surface area of liquid film

γ = surface tension of liquid film.

The above Gibbs-Marangoni effect is however, only applicable within limited concentration range Schramm (2000).

More persistent foams are common in the plants where massive use of even biodegradable detergents and heavy inflow of colloidal organic matter or hydrocarbons occurs. If such an inflow remains occasional the foaming process may affect the plant for a short time only, or it may persist and in the long run cause the development of stable biological foam Pujol *et al.* (1991). Non–ionic synthetic surfactants are used widely in commercial and industrial cleansing applications. They are commonly present in the US wastewaters in concentrations ranging from 1 to 20 mg/l Ho & Jenkins (1991). Because the surfactants have the ability to lower surface tension and thereby stabilize the liquid film between air bubbles it is possible that their presence in the activated sludge containing *Nocardia spp.* could stabilize the foam of *Nocardia* spp. (Jenkins, 19991).

The dispersion of oil in foam is encountered in several applications, and can result in either an increase, or a decrease, in foam stability. The theories concerning the effect of oil on foam stability are not well developed and can be somewhat controversial. The most classical theory is explained in terms of entering and spreading coefficients. Oil droplets, dispersed within the foam film, spread on the air/water surfaces of the foam and, for a variety of reasons, increase the kinetics of film rupture and thus decrease the foam stability (Basheva, Stoyanov, Denkov, Kasuga, Satoh & Tsujii 2001*).* Hadjiiski, Tcholakova, Denkov,Durbut, Broze & Mehreteab

(2001) found that an increase in the entry barrier is a function of surfactant concentration and alkane chain length. Long chain alkanes and other oils with a high entry barrier stabilize the foam by accumulation within the plateau borders, thus inhibiting foam drainage. Oil with a low entry barrier, such as short chain or branched alkanes cause film rupture by dispersing in the surfactant solution immediately spreading along the surface (Rajatanavin 2005).

Among various organic compounds present in coke wastewater, phenol compounds are known to negatively affect nitrifying bacteria. Thus, the effects of various phenol compounds, such as phenol and p-cresol, on nitrification were examined in the activated sludge system. The performance of the activated sludge process is limited by many factors. They are concerned with the biological activity of sludge microorganisms, formation and development of a series of filamentous organisms, organic loading, dissolved oxygen, pH, toxic shock loads, etc. Toxic shocks have been found to be a severe problem in activated sludge operation. In a recent study, toxicity upset was experienced by approximately 10% of 25 Colorado activated sludge plants examined during one year Richard (2003).

Mechanical mixing causes foaming, although this foam is not very stable and collapses on its own very quickly. Examples of mechanical actions are cascading flow parameters, air leakage in pumps, and violent agitation such as those from surface aerators Waste water insight (1998).

2.1.3 Foaming Treatment and Control

Hug (2006) reported that there are four strategies that can be used to prevent or control foaming: (1) to reduce the foaming potential of the sludge by inhibiting or damaging foam-producing bacteria or changing their surface properties, (2) to control the actual foam formation and stabilization, (3) to limit foam trapping and accumulation, or (4) to reduce the detrimental consequences to the plant. Some approaches intend to solve the problem on a long-term basis; others are suitable as emergency measures.

There are three criteria that could govern the selection of waste streams to any Biological treatment system. Only biodegrable organic wastes should be fed to a biological system, all other wastes will reduce process effectiveness which leads to plant upsets such as foaming. Unless required as nutrients, inorganic wastes to the system should be avoided / minimized; as dissolved inorganic solids adversely affect a biological treatment system, especially the sludge settling characteristics. A critical element in maintaining an aerobic system is to supply sufficient oxygen for cell maintenance and sustaining the oxidation process. Sufficient nutrients are required for a biological system. Any supplements added to deficient industrial wastes must balance the need for the biological process because excess nutrient deficiency could result in foaming.

Filamentous foaming is commonly controlled by lowering the mean cell residence time (MCRT) of the affected tank. MCRT or sludge age is a ratio of biomass in the reactor to the rate of biomass leaving the reactor. The mean cell residence time is manipulated by varying the flow rate of wastewater into and out of the biological treatment unit. Typical MCRT values for activated sludge treatment plants are 5 to 15 days for conventional treatment and 20 to 30 days for extended aeration treatment (Metcalf & Eddy 2003).

Richard (2003) highlighted that four filaments, namely, type 0041, type 0675, type 1851 and type 0803 are specifically caused by low F/M conditions, usually below an F/M of 0.15, and a corresponding longer sludge age. These may simply be slow growing and occur only at longer sludge age associated with lower F/M. These may also grow on particulate BOD, which would be used after the more readily degradable soluble BOD is exhausted. It has also been suggested that these filaments compete successfully due to a low endogenous maintenance energy requirement. Control of low F/M bulking can be achieved by reducing the aeration basin MLSS concentration and increasing the F/M. Lowering the MLSS concentration may not be suitable for many plants as this may cause the loss of nitrification and increase waste sludge production.

When the mean cell residence time is reduced, problematic microorganisms like GALO and *M. parvicella* can be washed out of the affected tank, depending on the growth rate of the particular organism. GALO's have a wide range of growth rates, so elimination by washout is difficult (Soddell 1998). GALO is controlled in cold and moderate climates by MCRT reduction to less than 8 days, and by a reduction to less than 3 days in warmer climates (Barber 1995). *M. parvicella* grows slowly, so decreasing sludge age is usually effective in removing the organisms (Soddell 1998). Barber, 1995 reported that *Microthrix parvicella* foaming can be controlled by reducing sludge age although that can be ineffective if the foam is caused by surfactants.

Nitrogen and phosphorus can be growth limiting if not present in sufficient amounts in the influent wastewater, a problem with industrial wastes and not domestic wastes. In general, a BOD5: N: P weight ratio in the wastewater of 100:5:1 is needed for complete BOD removal. Other nutrients such as iron or sulfur have been reported as limiting to activated sludge, but this is not common.

When nitrification is required, properly designed anoxic selectors would be effective in controlling *Nocardia* growth (Jenkins *et al*. (1984); Pitt & Jenkins 1990; Blackall *et al*. 1991). Another solution may be selective foam wasting that uses the increased aeration to strip the foaming organisms from the MLSS into the foam and then selectively wasting the foam (Richards 2003). Lowering SRT is also not successful for all foams caused by actinomycetes*.* They can be suppressed by decreasing the air flow rate, pH value and placing the selector in front of the aeration tank.

Khanal & Paudel (2002) reported that *M. parvicella* and *Gordona amarae*-like organisms are active in conditions of high oil and grease concentration, low F/M ratio or longer sludge age. Tipping (1995) reported that *Nocardia amarae* grows well at 23 -37 ^{0}C with an optimum temperature of 28 ^{0}C. Several researchers have established that *Nocardia amarae* growth is pH sensitive; its optimum growth is at pH of 7.8, foam has been reported when foam dropped from 7.0 to 5.0 with onset of nitrification (Hart 1985). The most successful method of preventing *Nocardia* growth is lowering the SRT since *Nocardia spp*. are slow growing organisms and at the high SRT they have a metabolic advantage in competing for substrate under low F/M conditions. This method however cannot be applied at the nutrient removal plants since it is in contradiction with the requirements of the nitrifiers and they are being washed out from the system.

Chemical foams are not difficult to remove like the biological ones; normally they occur during plant start up Jenkins, *et al.* (1991). Pujol *et al.* (1991) reported that chemical foams may persist and in the long run result in development of biological foam that is difficult to remove.

Non-ionic surfactants commonly used in commercial and industrial cleaning lowers the surface tension and their presence in waste water could stabilize the foam of *Nocardia*, but surfactants alone could not generate stable foam (Ho & Jenkins 1991). Richard, 2003 reported that the thin sludge blanket on the final clarifier as a result of denitrification may cause activated sludge foaming.

Stabilization of the foam by accumulation within the Plateau borders is found to be inhibiting foam drainage. Oils with a low entry barrier, such as short-chain or branched alkanes cause film rupture by dispersing in the surfactant solution and immediately spreading along the surface. Hadjiiski *et al*., (2001) found that an increase in the entry barrier is a function of surfactant concentration and alkane chain length. In 1988, Wasan *et al*. proposed the role of “pseudo-emulsion film”, which is formed between an air/water surface and the surface of the oil drop which is approaching it.

CHAPTER 3
METHODOLOGY

3.1 Materials and Methods

3.1.1 Introduction

In this chapter the experimental methods to investigate the causes of foaming in activated sludge plant are described. The brief approach and methods used are listed.

3.2 Materials and Method

The three incoming streams and aeration basin samples were sampled daily. Samples were analyzed for organic and inorganic compounds. The microscopic analysis on the activated sludge samples was done weekly to identify the filamentous bacteria. The physical inspection on the aeration tanks was done daily. Since influents to an activated sludge system consist of three streams and these streams differ in terms of carbon content and their basicity which kills the bacteria, they were included to establish their impact on the foaming problems in the plant. Variable parameters were done, i.e. COD, phenols, pH, ammonia etc.

The plant operation conditions were monitored as they change with change in defoamer usage. Microorganism's conditions were also analyzed using the oxygen uptake rate test to determine their activity and microscopic analyis.

The method used in compiling this report was as follows:-

- Individual basin defoamer consumptions were recorded and converted to costs, thereby referred to as the operational costs of the basin

- Parameters which are external to the plant were measured, recorded and trended against the operating costs.
- Controllable operating parameters were recorded and trended against the operating costs

The complete sets of experimental conditions investigated in this study are listed below:

Table: 1 Sampling and testing program

	Sampling and testing program		
Sample point	Test	Sample Frequency	Method of collection
Biobasins	MLSS	Daily	24 hours composite sample
	pH	Daily	24 hours composite sample
	Temperature	Daily	24 hours composite sample
	DO	Daily	24 hours composite sample
	Microscopic analysis	Bi- weekly	Once a day
	OUR	Weekly	Once a day
	Knock down tests	Bi- weekly	Once a day
Incoming streams			
Stream A	GC Analysis	Daily	24 hours composite sample
	OA	Weekly	Once a day
	NH_3	Daily	24 hours composite sample
	COD	Daily	24 hours composite sample
Stream B	GC Analysis	Daily	24 hours composite sample
	OA		Once a day
	COD	Daily	24 hours composite sample
Stream C	GC Analysis	Daily	24 hours composite

			sample
	OA	Weekly	Once a day
	SS	Daily	24 hours composite sample
	PO_4	Daily	24 hours composite sample
	COD	Daily	24 hours composite sample

- COD = chemical oxygen demand
- OUR : Oxygen uptake rate
- SS: suspended solids
- DO: dissolved oxygen
- MLSS: Mixed liquor suspended solids

3.3 Experimental Design

The approach adopted in this investigation was broken down in experimental setups listed below:

- Effect of incoming stream's composition on activated sludge foam formation
- Operating conditions
- Effect of foaming on effluent quality
- Foaming control in the plant

3.3.1 Effect of incoming stream's composition on activated sludge foam formation

These experiments were based on studying the effect of incoming streams on microorganisms and their contribution to foaming incidents. Daily composite samples were taken from all three incoming streams per plant, and were analyzed for Organics, chemical oxygen demand (COD), Ammonia, pH, phenols, Non-acidic compounds (NAC) to identify which components have contributed to the activated sludge foaming. The inhibition test of the incoming streams to microorganisms was done bi-weekly for early detection to see if there were any toxic shocks to the plant. STREAM C was analyzed weekly for oil and grease, or immediately when the foam suppression was visually observed in the plant.

3.3.2 Operating conditions

Plant operation's parameters (MLSS, pH, alkanity, microscopic analysis, OUR, Toxicity tests) were monitored on a daily basis for their effects on the efficiency of the treatment and general performance for the activated sludge process Metcalf & Eddy (2003).Composite samples from the plant biobasin were sent to the laboratory daily for analysis on all above mentioned parameters according to the standard methods for the examination of water and waste water.

Plant designs against operating conditions were compared and their effects on microorganisms resulting in foaming incidents were monitored. An online analyzer was installed in basin 3 to monitor the changes in pH, temperature and dissolved oxygen as the foam height changes. According to literature some filamentous organisms that cause foaming can occur as a result of change in operating parameters like pH, temperatures, DO levels (Tipping1995).

Food to mass ratio, sludge age, nutrient content (carbon: phosphorus: nitrogen ratio) on the biobasins were calculated daily as they form part of the plant operating parameters. Activity of the microorganisms was done weekly (OUR test).

Microscopic analysis on the biobasins samples was done weekly or immediately if there was a major upset in the plant. This analysis provides valuable information about conditions of microbial population’s early detection of changes that might have a negative impact on the process performance Metcalf & Eddy (2003).

3.3.3 Effect of foaming incidents on the effluent quality

Defoamer usages were recorded daily and the visual inspection on foam formation in the plant was monitored daily. The correlation between high foaming incidents on the plant effluent quality was monitored daily. The usages were taken by the process controllers from the plant and the effluent samples were sent daily to the laboratory for suspended solids analysis (SS) and chemical oxygen demand (COD).

3.3.4 Foaming control in the plant

During plant operation the defoamer was used to control foam. The effectiveness of controlling foam by using the defoamer is based on the how fast the defoamer can knock down the foam that has already formed and how long with that foam stays down before it can form again. The laboratory knock-down and plant test run were done to determine the effectiveness of the defoamer at different concentrations. Foam control by using defoamer depends also on the method of dosing being used.

3.4 Plant test run

Basin 1 was chosen to evaluate the defoamer development product. A period of six shifts prior to the trial, as well as a period of six shift’s results were evaluated against the three shift trial of a single flow bin (approximately 900kg of product) coupled to the peristaltic pump suction for Basin 1. The foam on the surface of the aeration basin appeared to be dark in colour and dense in texture, the peristaltic pump was left continually running at a high motor speed. The selected basin was the one that had high foam at the time.

3.4.1 Dosing Philosophy

The concentration and pressure at which the defoamer entered the basin emerged to be the two major variables that were of concern, since they could be controlled within the plant. Therefore, the optimisation was with regards to defoamer concentration and pressure. After some laboratory analysis of the functioning of the current defoamer, together with other products, it emerged that a more concentrated product is more efficient.

The current defoamer system consists of:-

- Raw defoamer tanks
- Dosing pumps
- PLC Panel
- Foam level probe
- Primary carrier water (approximately 5m3/hr)
- Secondary carrier water (approximately 5m3/hr)

The level probe senses the level of the foam around it, sends the data to the Data Processor, which is programmed to take an average of ten readings, each received in one millisecond, and transmits a signal to the pump. The pumps then pumps the viscous raw defoamer according to the signal received from the processor. Primary carrier water is then introduced in order to form a solution that is less viscous, therefore easy to pump. Just before the entry point in the biobasin, secondary carrier water is introduced in order to build enough pressure to penetrate the foam.

3.4.2 Alteration to the dosing concentration

The defoamer solution concentration at the entry point varied from 0.1 to 0.6 percent (1000 to 6000 ppm). This is due to the variable speed dosing pumps which deliver defoamer ranging from 10 l/hr to 60 l/hr in 10m^3/hr carrier water. In an attempt to get a defoamer solution that is more concentrated into the basin, the primary carrier water was closed. This halved the carrier water flowrate and effectively doubled the defoamer solution concentration to range from 2 000 -12 000 ppm.

3.4.3 Alterations to the basin dosing point

Emerging from the concerns that there was insufficient pressure at the spray boom header to penetrate the foam, the spray boom header was lowered from approximately 2m to 0.75m above the foam level. A spray system and jet nozzles were attempted in 052 AB 401.

3.4.4 Alterations to the Dosing Program

The pump was initially programmed to start pumping at the minimum when the foam height reached 25% on the foam measuring probe. That was changed to initiate minimum pumping when the foam height reached 35% on the foam measuring probe.

3.5 Description of Analytical Methods

3.5.1 Activated sludge inhibition tests

Incoming streams sample were tested for their inhibitory effect on the activated sludge; samples from biobasins were split into four 100ml samples into different beakers. Each sample from each stream was added in an individual beaker containing the activated sludge from the biobasin according to the concentration/ratio that they enter the plant, and the last beaker with the activated sludge three stream samples were mixed and then added to activate sludge. Samples were then aerated for three minutes before analysis and were analyzed according to the procedure stated in OJL, 133, 1988 for OUR and inhibitory/stimulatory effect.

The oxygen uptake rate is also dependent on the temperature and generally the activity increases with the temperature (Ros 1993; Henze *et.al*., 2002), for these reasons the samples were controlled at 35 ˚C as in the real plant.

3.5.2 Oxygen absorbed by water (OA-value)

The OA-value (oxygen absorbed) is the amount of oxygen needed under specified test conditions to oxidize organic and inorganic matter with potassium permanganate. This value gives an indication of the amount of pollution of the water. High OA-values indicates high pollution that is detrimental to the environment (Reference SABS method 220: 1990 First Revision).The oxygen absorbance values were done on all incoming streams on a weekly basis to determine their effects on microorganisms.

3.5.3 Defoamer Evaluations

3.5.3.1 Laboratory experiment: Knock down test

Samples were taken from the plant in the biobasin where the foaming was the greatest. The samples were evaluated at the process temperatures by recirculation tests method. The foam level in the cylinder was allowed to reach its maximum height and thereafter the defoamer was added. The initial knock down efficiency of the defoamer was recorded in the first 30 seconds. Thereafter the foam height was recorded every minute for 5 minutes in order to determine the effectiveness over a long period (Glenn, Mudaly, Buckman laboratories). This method was used to determine the foam stability Wilson (1996).

3.5.4 Microscopic Analysis

A microscopic analysis of activated sludge and foam samples was carried out immediately after they were sampled. Filamentous organisms were identified according to their morphology as well as Gram and Neisser test following the method by Jenkins *et al. (*2004); Eikelboom (2000).The quantitative composition of the filamentous microorganisms in the samples of activated sludge was estimated using the widespread subjective scoring of filaments abundance proposed by Jenkins *et al*. (2004). Intensity of the foaming problems was expressed by means of a scum index understood as a ratio of organic dry foam and activated sludge.

3.5.5 Determination the chemical oxygen demand (COD)

Chemical oxygen demand depends on the amount of oxygen present to oxidize the contained organic matter. The COD of the incoming streams, biobasins and effluents samples were determined by the procedure stipulated in the standard methods 5220D: closed reflux, colorimetric method (standard methods, 1985).The test procedure involved heating a known sample volume to an elevated temperature of 150 ˚C with excess potassium dichromate in the presence of sulphuric acid for a period of two hours in a sealed glass tube.

3.6 Statistical Analysis

Statistical method used in data analysis for oxygen uptake rate : Linear regression was used to obtain statistically fit straight lines of dissolved oxygen concentration data versus time. R^2 values were also calculated to show goodness of fit for the regression lines.

Anion analysis: Linear regression analysis was used to obtain statistically fit straight lines using nitrate, nitrite and phosphorus standards. R^2 values were also determined for all regressions.

CHAPTER4

PRESENTATION OF RESULTS AND DISCUSSION

4.1 Plant operating parameters conditions

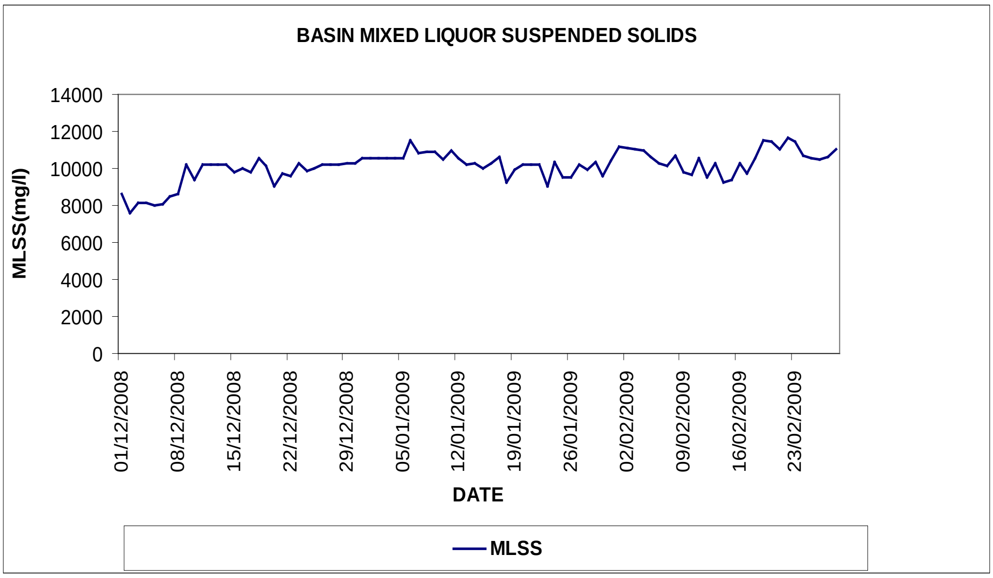

Figure 2: Mixed Liquor suspended solids concentration graph

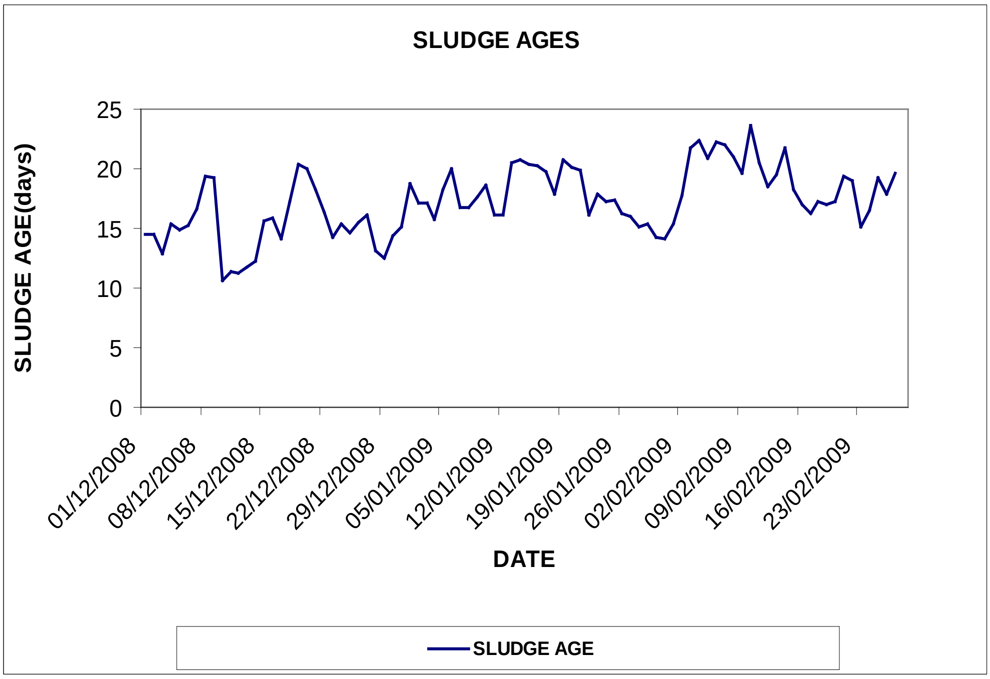

Figure 3: Calculated sludge ages graph

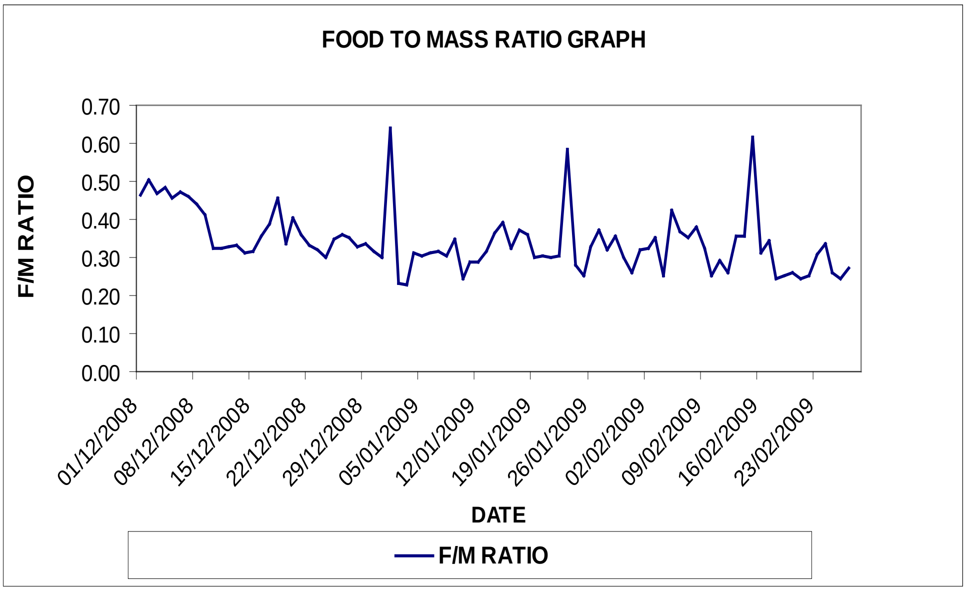

Figure 4: Calculated food to mass ratio's

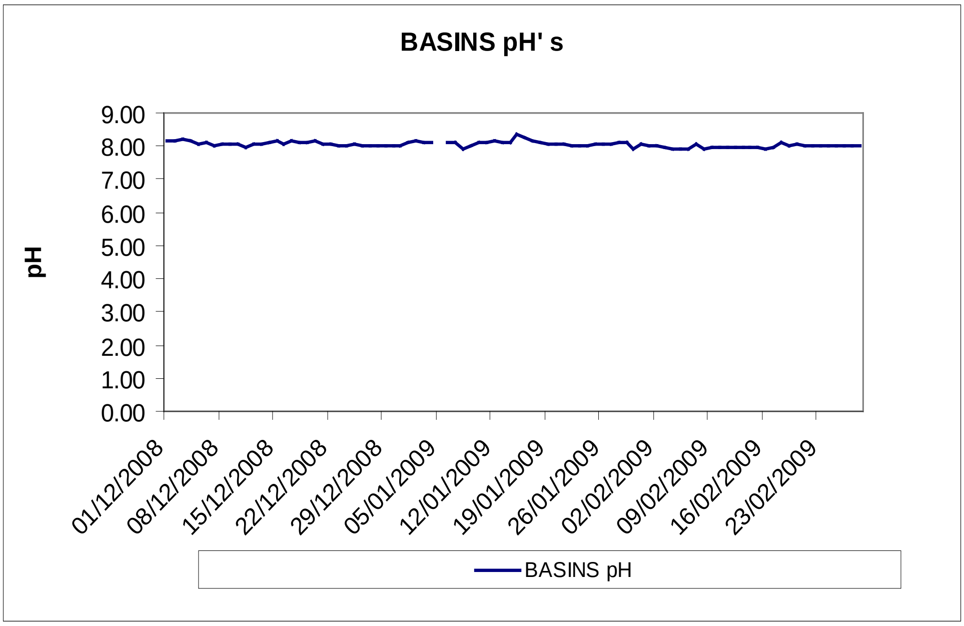

Figure 5: Basin pH graph

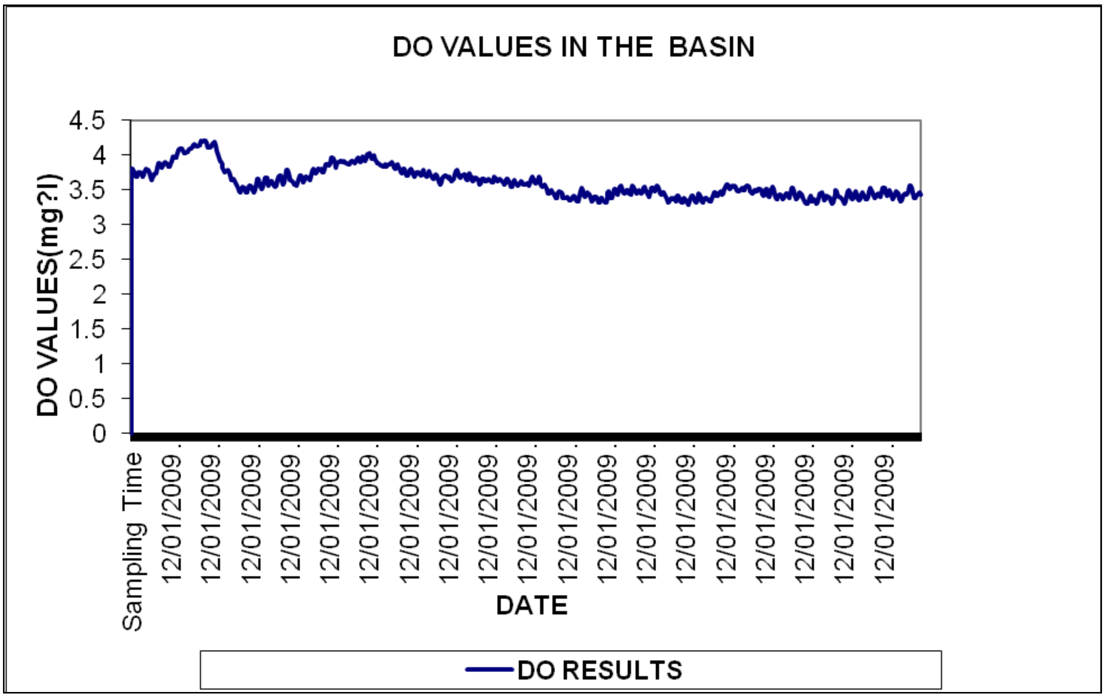

Figure 6: DO levels in the basin

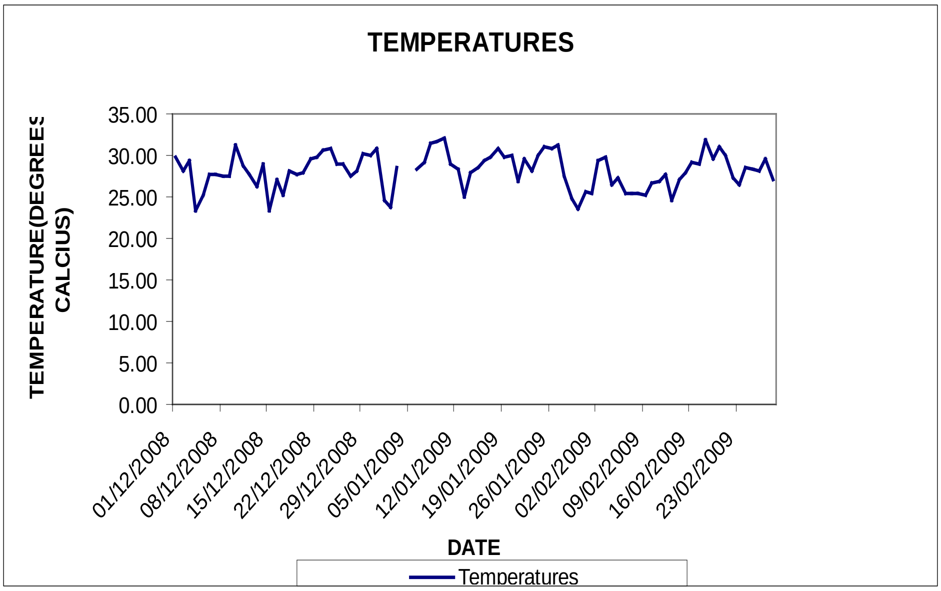

Figure 7: Basin temperatures graph

Figure 8 Image A: Foam/scum layer sample

Figure 9 Image B: Dispersed EPS stain

Figure 10 Image C: EPS stain of foam

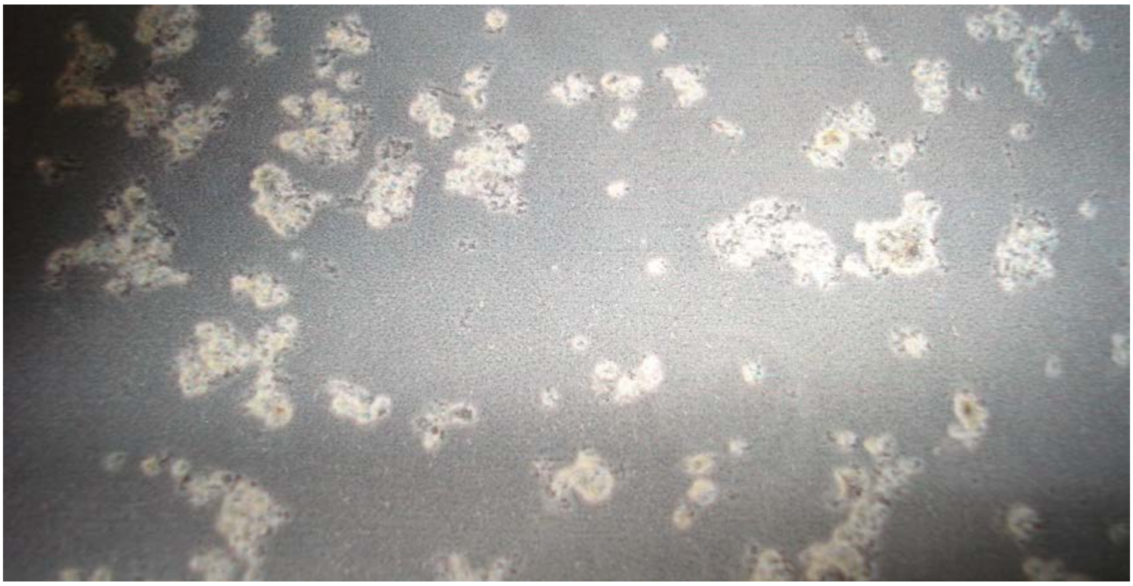

Figure 11 Image D: Small dispersed flocs in the basin

Figure 12 Image E: Unicellular bacteria in bioflocs; tetrads and few filaments of *Microthrix parvicella* and indicator organism of high oils and greases

Figure 13 Image F: Unicellular bacteria, tetrads and protozoa- no filaments evident

4.2 NUTRIENTS TO THE PLANT

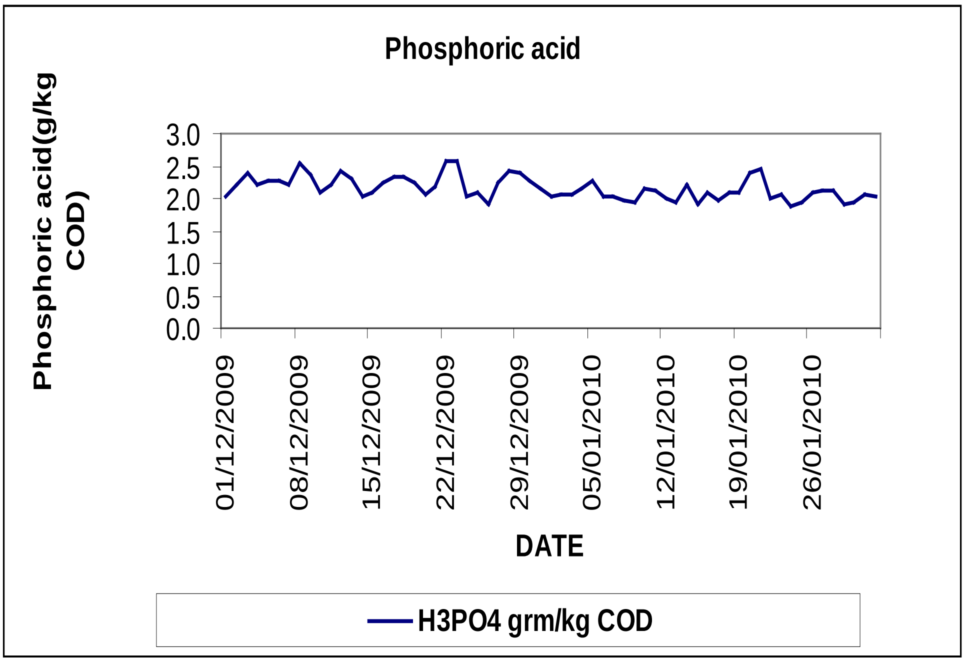

Figure 14: Phosphoric acid concentration graph

4.3 INCOMING STREAMS ANALYSIS

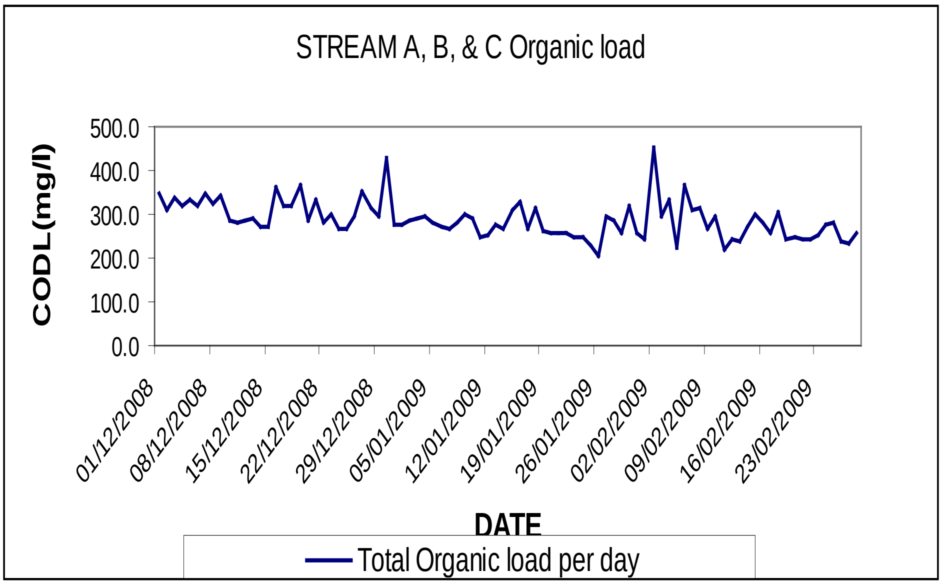

Figure 15: Incoming streams organic loads graph

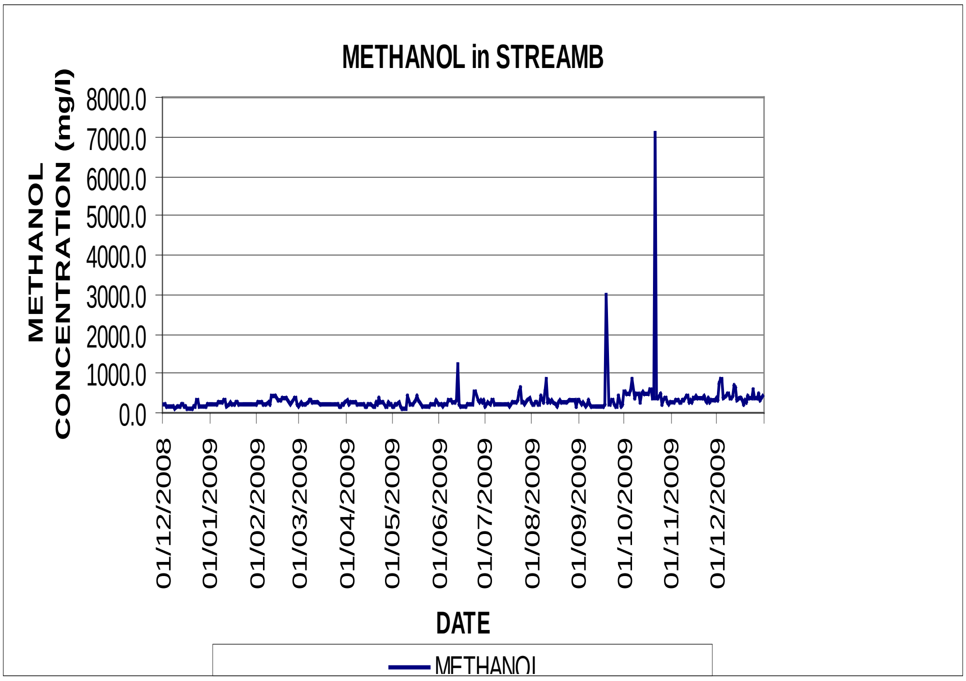

Figure 16: Methanol graph

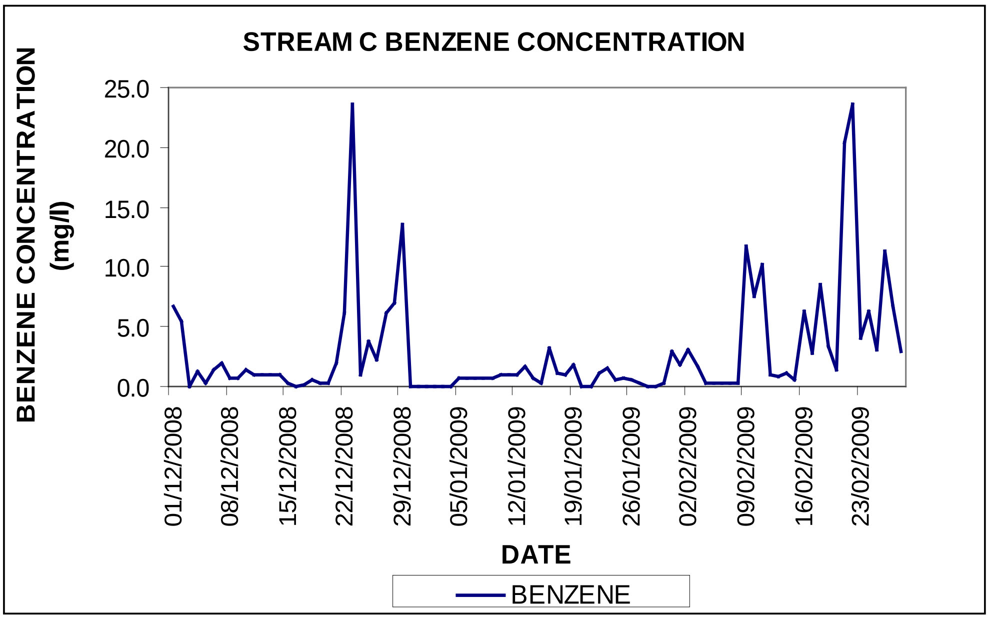

Figure 17: Benzene concentration graph

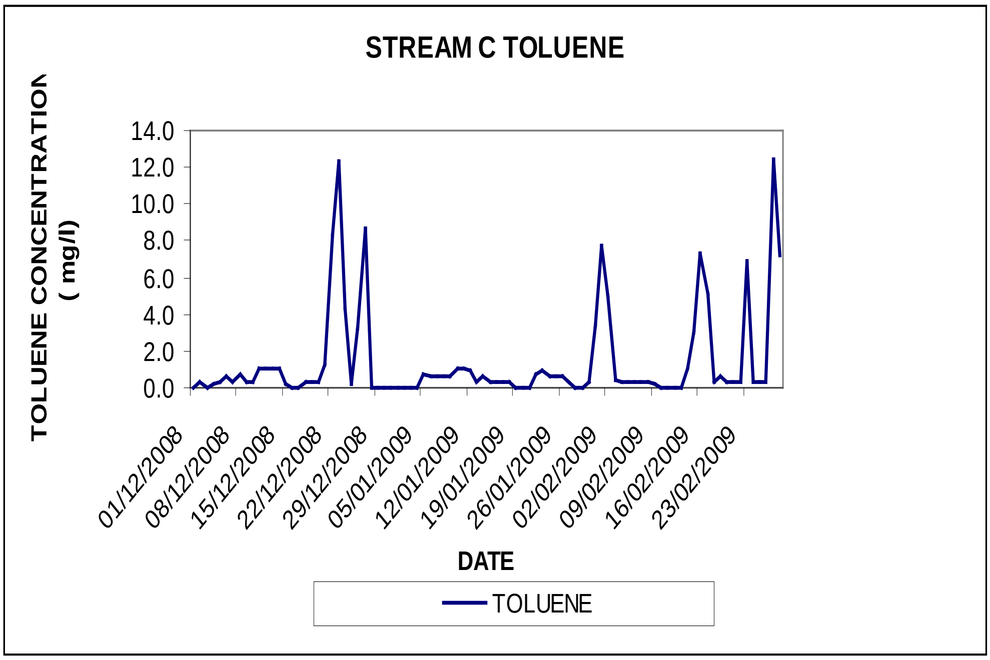

Figure 18: Toluene concentration graph

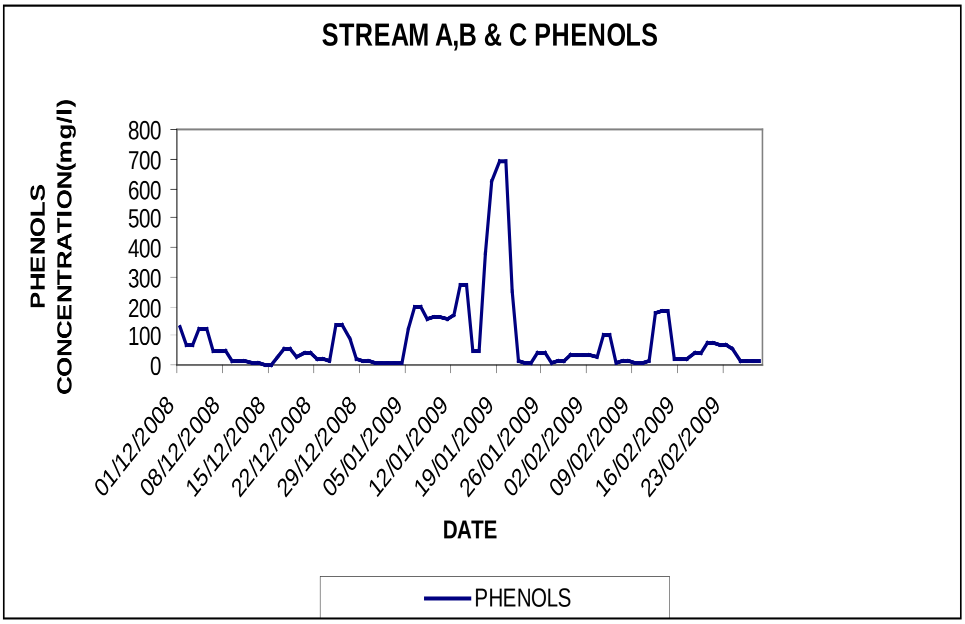

Figure 19: Incoming streams phenol graph

4.4 Defoamer test results and trial run

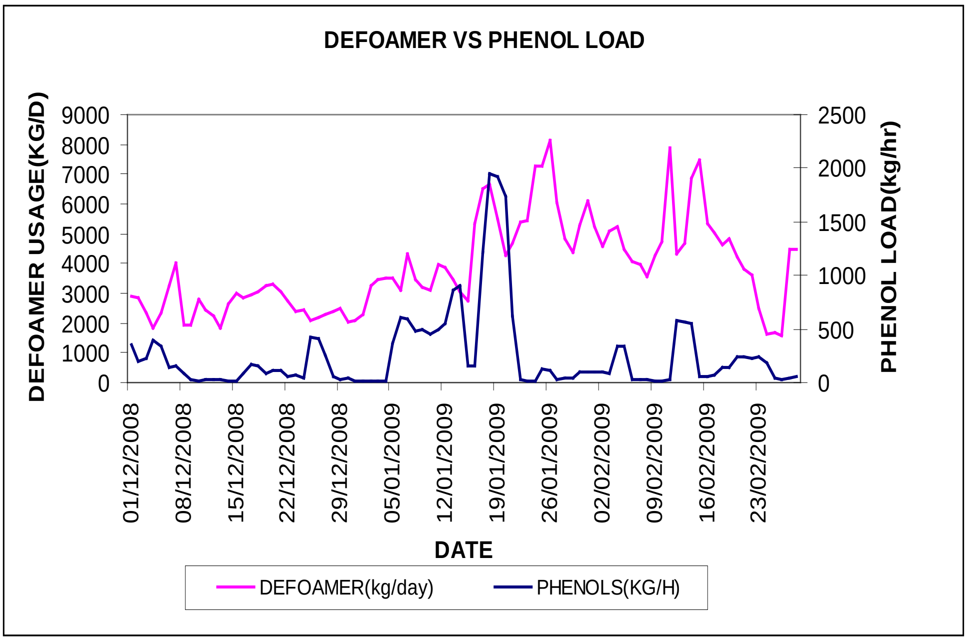

Figure 20: Defoamer/ Antifoam vs. phenol loads graph

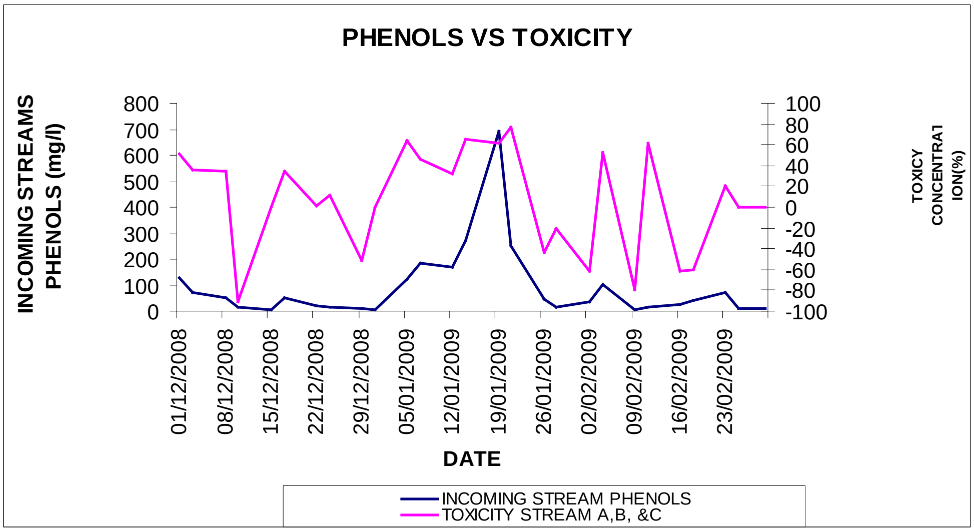

Figure 21: Phenol vs. Toxicity graph

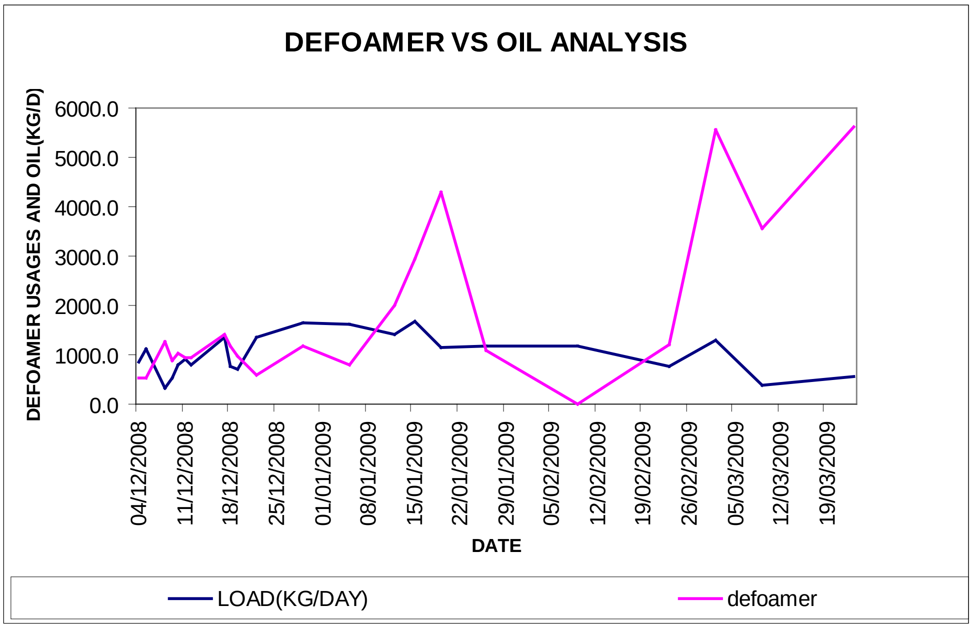

Figure 22: Defoamer vs. oil content graph

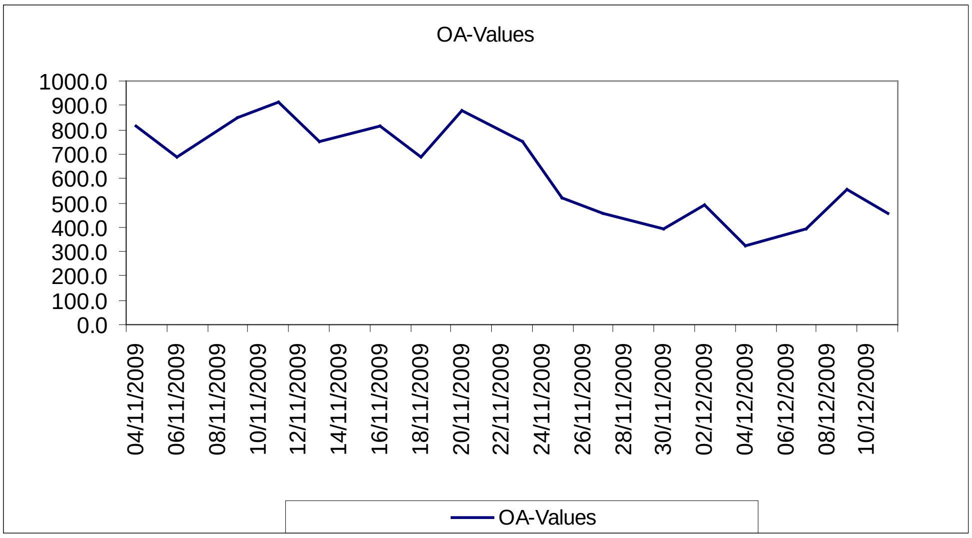

Figure 23: Oxygen absorbance graph

Table2: Statistical analysis (correlation data)

Date	Phenols & Toxicity	Organic L(CODL) & Defoamer usages	STREAM NAC & Defoamer usages	Phenols & Defoamer usages
Dec-08	0.64	-0.08	-0.14	-0.09
Jan-09	0.58	0.13	0.44	0.07
Feb-09	0.40	0.11	-0.47	0.11
Average	0.54	0.05	-0.06	0.03

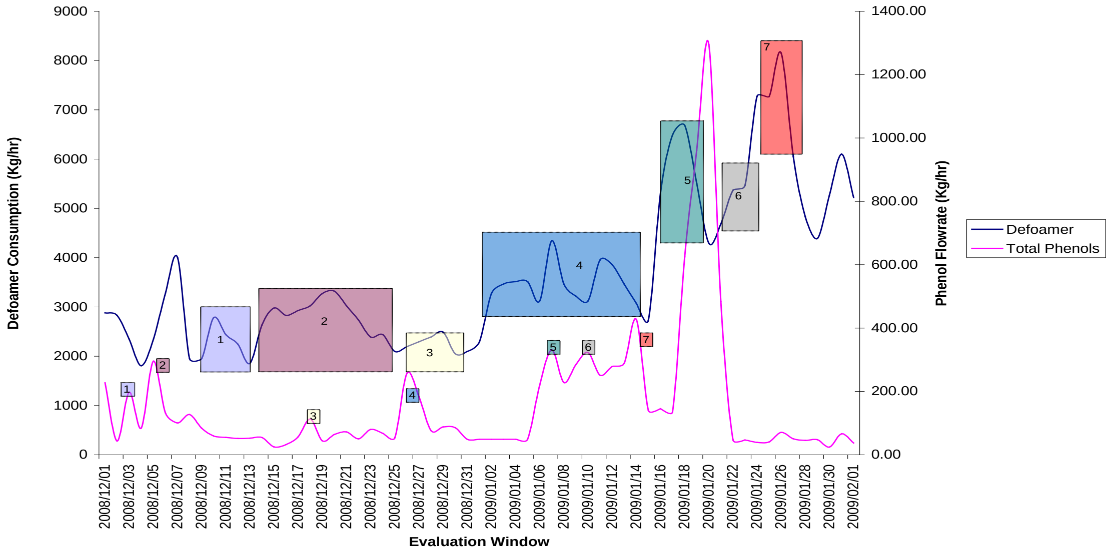

Figure 24: Defoamer vs Phenol graph

Table 3: A demonstration of the Phenol shocks into the plant and the response of the bio-basins.

Phenol Peak Date	Phenol Peak Magnitude (Kg/hr)	Resultant Defoamer Peak (Kg per day)	Kg Defoamer per Kg Phenols (DPI)	System time Delay (days)	Days to work out of system (Days)
03 Dec 2008	197.92	2782	14.06	6	4
05 Dec 2008	295.34	3318	11.23	8	10
08 Dec 2008	127.30	2440	19.16	15	2
18 Dec 2008	112.91	2489	22.04	8	5
26 Dec 2008	257.31	4343	16.88	6	15
07 Jan 2009	330.99	6683	20.19	8	5
10 Jan 2009	323.07	5368	16.61	11	3
14 Jan 2009	426.77	8150	19	12	6
20 Jan 2009	1294.36	-	-	-	-

.

Table 4: Defoamer costs

DATE	R/ KG
01/12/2008	R 71,975
02/12/2008	R 70,750
03/12/2008	R 58,575
04/12/2008	R 45,150
05/12/2008	R 58,550
06/12/2008	R 81,750
07/12/2008	R 100,050
08/12/2008	R 48,800
09/12/2008	R 48,800
10/12/2008	R 69,550
11/12/2008	R 61,000
12/12/2008	R 56,125
13/12/2008	R 46,350
14/12/2008	R 65,875
15/12/2008	R 74,425
16/12/2008	R 70,750
17/12/2008	R 73,200
18/12/2008	R 75,650

19/12/2008	R 81,750
20/12/2008	R 82,950
21/12/2008	R 75,650
22/12/2008	R 68,325
23/12/2008	R 59,775
24/12/2008	R 61,000
25/12/2008	R 52,450
26/12/2008	R 54,900
27/12/2008	R 57,350
28/12/2008	R 59,775
29/12/2008	R 62,225
30/12/2008	R 51,225
31/12/2008	R 52,450
01/01/2009	R 57,350
02/01/2009	R 81,750
03/01/2009	R 86,625
04/01/2009	R 87,825
05/01/2009	R 87,850
06/01/2009	R 78,075
07/01/2009	R 108,575
08/01/2009	R 86,625
09/01/2009	R 80,525
10/01/2009	R 78,075
11/01/2009	R 98,825
12/01/2009	R 96,375
13/01/2009	R 86,625
14/01/2009	R 76,850
15/01/2009	R 68,325
16/01/2009	R 132,975
17/01/2009	R 162,250
18/01/2009	R 167,150
19/01/2009	R 137,850
20/01/2009	R 107,350
21/01/2009	R 117,125
22/01/2009	R 134,200
23/01/2009	R 136,650
24/01/2009	R 181,775
25/01/2009	R 181,775
26/01/2009	R 203,750
27/01/2009	R 151,275
28/01/2009	R 120,775
29/01/2009	R 109,800
30/01/2009	R 131,750
31/01/2009	R 152,500
01/02/2009	R 130,550

02/02/2009	R 114,675
03/02/2009	R 126,875
04/02/2009	R 130,550
05/02/2009	R 112,250
06/02/2009	R 101,250
07/02/2009	R 98,825
08/02/2009	R 89,050
09/02/2009	R 107,350
10/02/2009	R 118,350
11/02/2009	R 197,650
12/02/2009	R 108,575
13/02/2009	R 117,120
14/02/2009	R 172,020
15/02/2009	R 186,660
16/02/2009	R 132,975
17/02/2009	R 125,650
18/02/2009	R 115,900
19/02/2009	R 120,775
20/02/2009	R 104,925
21/02/2009	R 95,150
22/02/2009	R 90,275
23/02/2009	R 62,225
24/02/2009	R 40,260
25/02/2009	R 41,480
26/02/2009	R 39,050
27/02/2009	R 112,250
28/02/2009	R 112,250

FOAMING AND DEFOAMER TESTS RESULTS INCLUDING TRIAL RUNS

Knock down tests

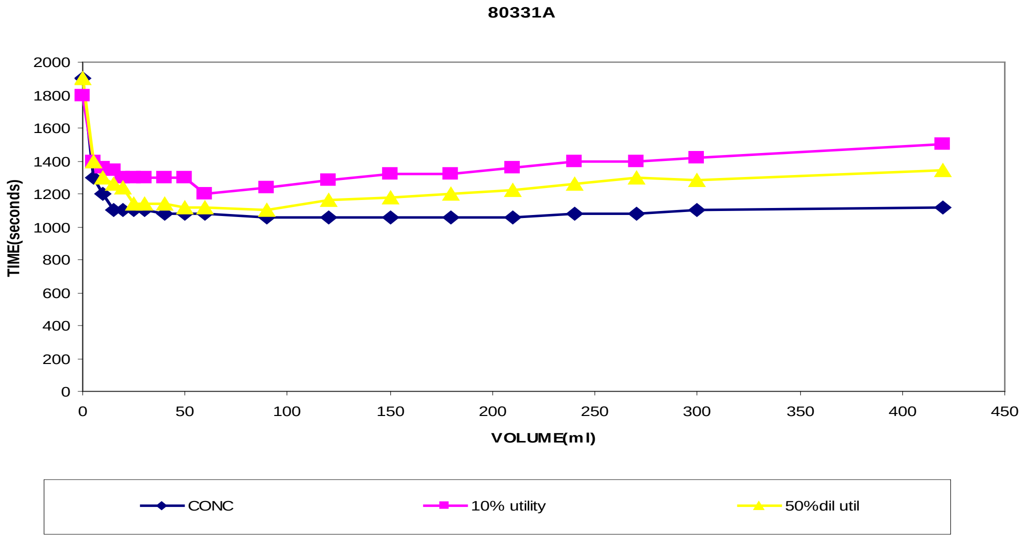

Figure 25: Foam stability graphs

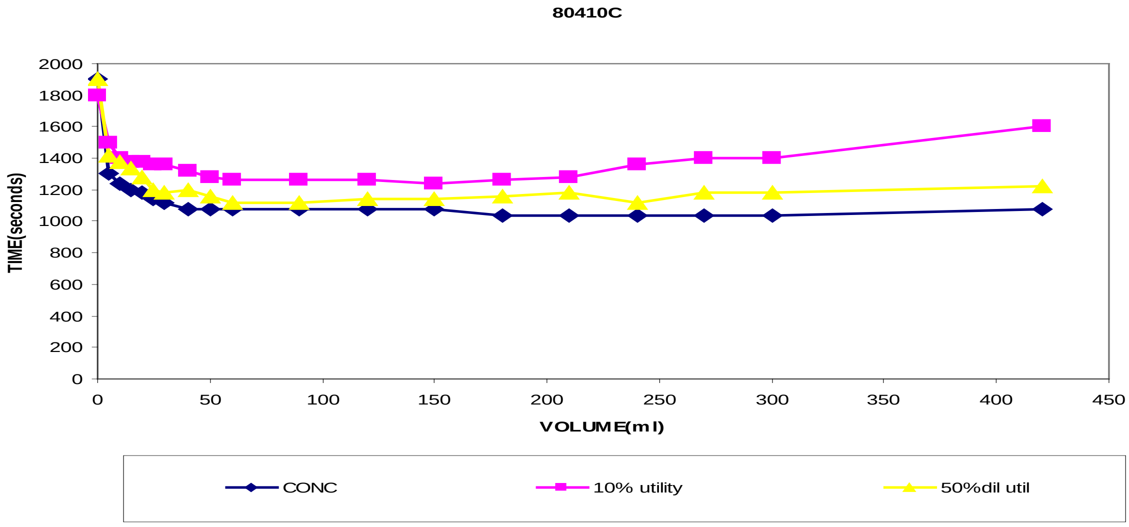

Figure 26: Foam stability graphs

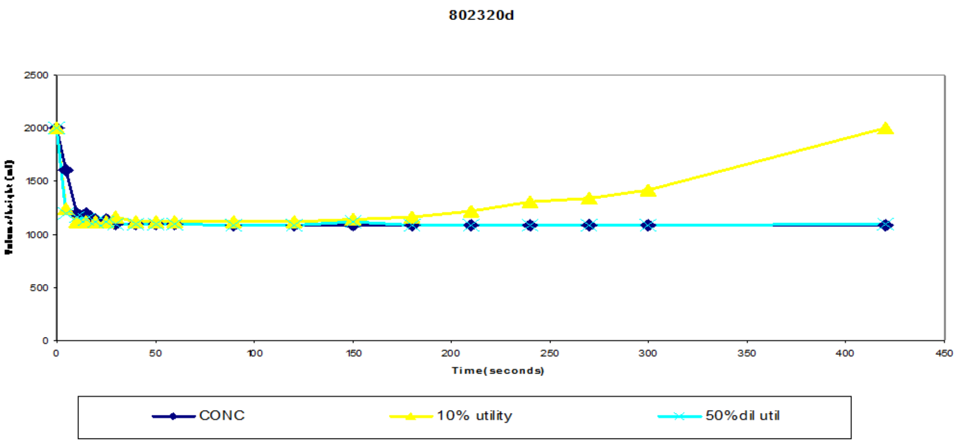

Figure 27: Foam stability graph

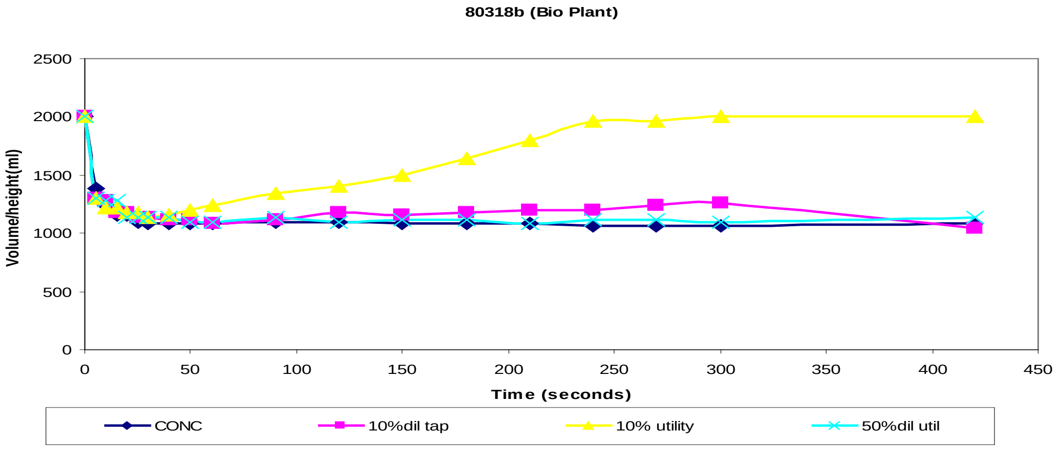

Figure 28: Foam stability graph

Dosing Philosophy trial run

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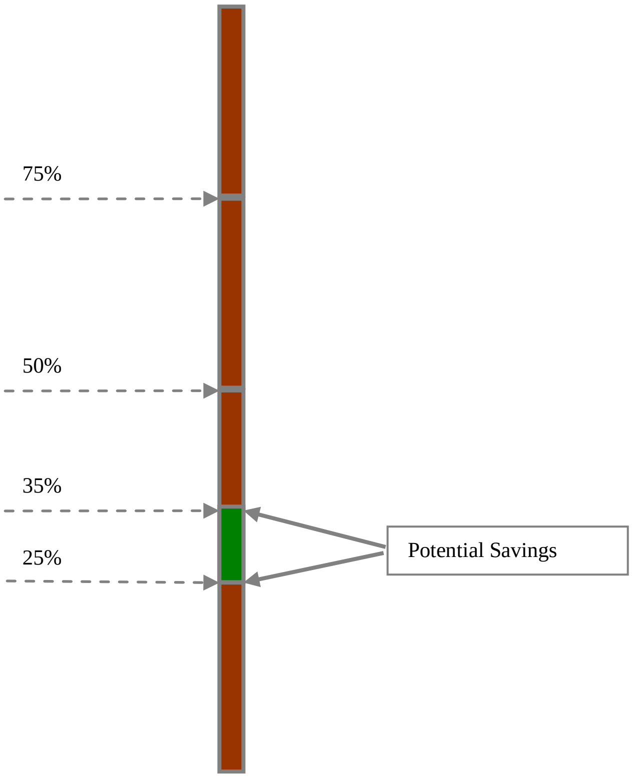

Figure 29: Dosing scale image

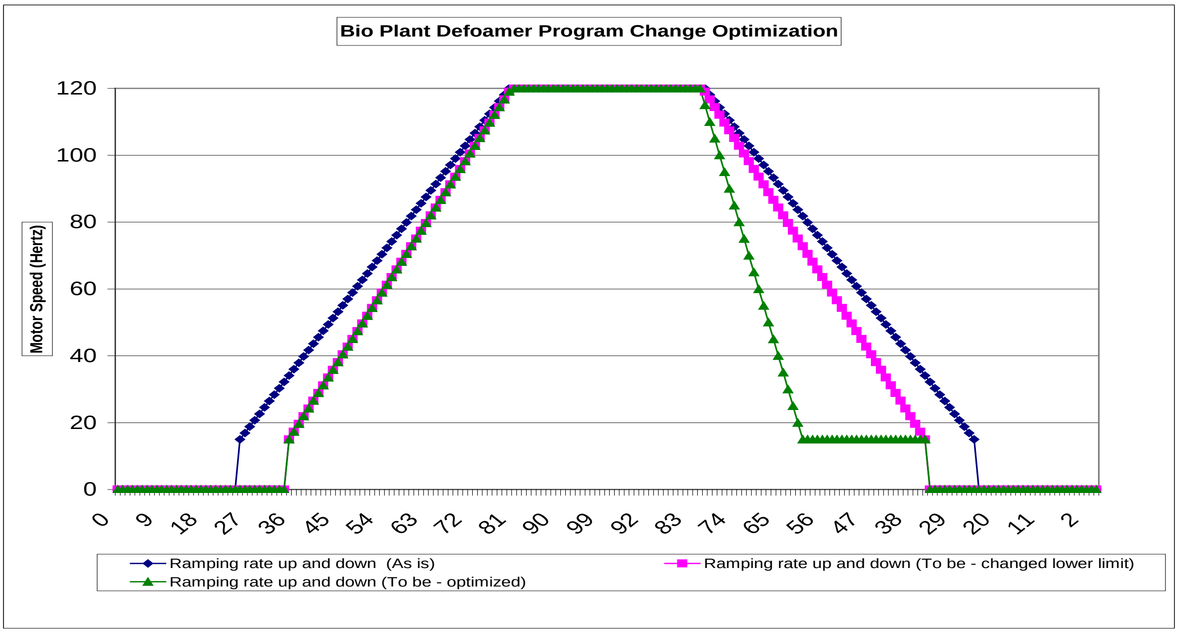

Figure 30: Pump ramps (Potential savings due to doubling the ramp down rate)

Foaming consumption during the trial period

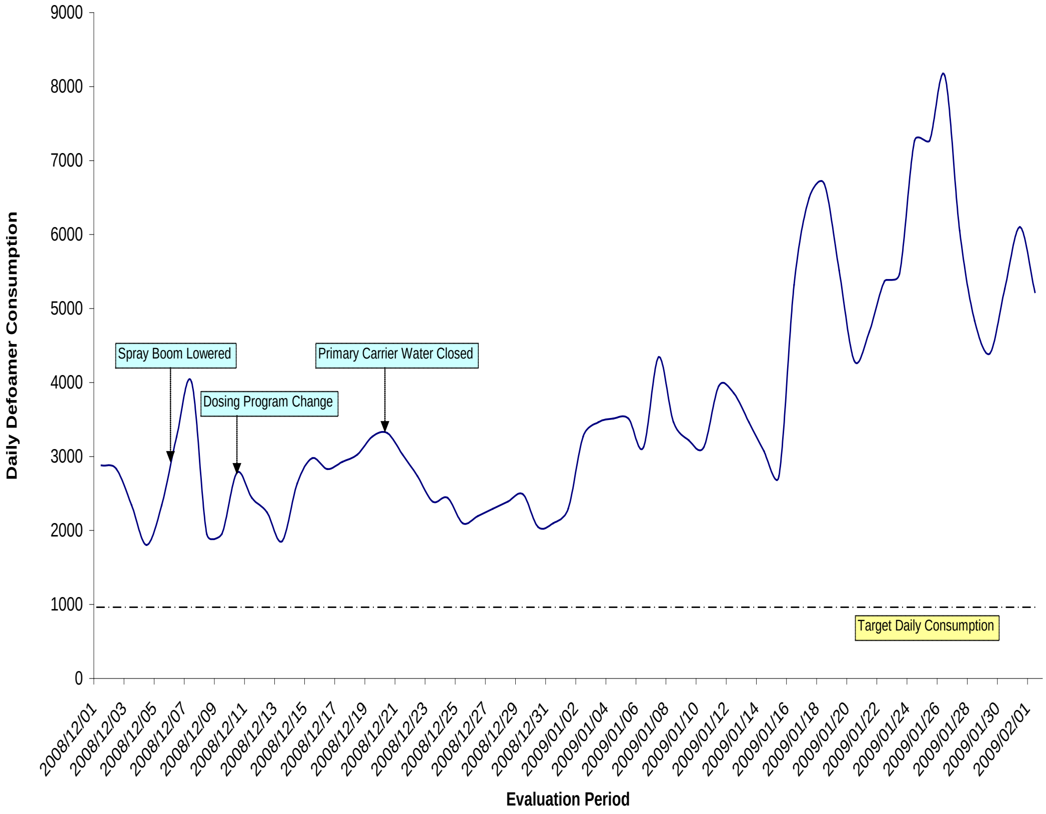

Figure 31: Evaluation of the defoamer consumption graph

4.5 Discussion of results

Operating parameters

According to Tipping (1995) pure culture of foam-causing microorganisms are due to growth rate’s need for specific nutrients and operational factors have been shown to affect the formation of stable foam. During the experimental work there were no issues with operating parameters; MLSS as indicated in Figure 4 were 99.9 % on the time in spec, and foaming potential of activated sludge is increasing with solids (Hug 2006). pH (Figure 5) was 95.7 % on the time in spec, DO was 100 % on the time in spec, F/M (Figure 4) ratio was 99% on the time in spec, sludge age (Figure 3) was 77% on the time in spec, temperature (Figure 17) was 100% on the time in spec, Ammonia was 95% on the time in spec, phosphoric acid

(Figure 14) was 100% on the time in spec, during the study operating parameters were controlled with plant design limits.

The stream A enters the plant at approximately 120 ^{0}C, this temperature is too high and it can affect the microbiological activity and therefore the stream is cooled down prior to entering the basin. The temperature was monitored throughout the whole period and it was found to be below 45 ^{0}C which is the recommended temperature for operating activated sludge systems. Temperatures are an important determination of bacterial growth and the ability of bacteria to grow and degrade chemicals is reduced in cold winter temperatures. Dissolved Oxygen levels/Oxygen saturation levels are also influenced by temperature. During winter seasons the foam was even more difficult to control due to changes in ambient temperature and some bacteria that favors lower temperature conditions grow and contribute to difficult foaming potentials.

Dissolved oxygen is a critical parameter that influences the type and the rate of microorganism activity that occurs in the biobasins. Air is provided by blowers. DO concentrations should be maintained at 1 to 2 mg/l in all parts of the basin in order to achieve efficient COD removal. Currently in the plant there are no DO online meters on the biobasin, but during the study 1 DO meter was installed in one of the basins. This indicated the relationship between DO changes with the pump stop and start that doses defoamer according to the foam level in the basin. It was evident during the study that the more oxygen was supplied to the basin it resulted into increasing foam tendencies (mechanical foaming) and higher defoamer usages.

Microscopic results

Microscopic analysis of the activated sludge is useful in determining the health of the activated sludge system. Fairly fast-setting flocs comprised of unicellular bacteria are indicative of high F/M ratio where the organic matter is rapidly oxidized and assimilated in highly aerated basins. A moderately fast settling rate allows residual suspended solids to settle out along with the flocculated biomass. The sludge age at the plant was typically running between 12 to 18 days as indicated in figure 3.

When the spray boom header was lowered, the defoamer consumption had been on a rise; a day later, however, the consumption came down to two tons. When observing the effects of lowering the spray boom header, it was clear that the defoamer penetrated the foam better, the pressure on line was sufficient to ensure this.

Improvements that were done on the dosing program were implemented on the 10th December 2008, and immediately, a reduction in the defoamer consumption could be seen as the consumption crept back to under two tons. After a week, the consumption was back at three tons.

With the consumption back to three tons, it was seen as an ideal opportunity to implement and evaluate a defoamer solution concentration increase into the basin. This was done by closing off the primary carrier water, hence, effectively doubling the defoamer concentration entering the basin. Physically, a stronger product was observed entering the biobasin, which resulted in better mixing patterns within the biobasin, which seemed to kill the foam much better. This resulted in a gradual decrease in defoamer consumption, which eventually crept back to two tons and stayed there for approximately 10 days, before it started increasing. The only problem with increasing defoamer solution concentration is that the delivery pressure is compromised on. There is some pressure-concentration optimisation to be done there.

Figure8 Image A: Foam/scum layer sample: no protozoa or filaments were identified from the sample, it was just sticky, slimy layers.This may be due to the portion of activated sludge floating which is caused by the excessive production of gases (e.g. Nitrogen) in the basin and by subsequent trapping of bubbles caused by the aeration. The foam appearance was light brown in the basin while sampling and it turned black while allowed to stand for a while. Fogure 9 & 10 Image B & C show the presence of exopolysaccharide (EPS) in the foam/Basin .These normally occur naturally and there will always be EPS formation in the flocs. Excessive amounts of EPS in the flocs could be a concern that can result in settling problems and produce a diffusion barrier against nutrients. However excessive amount of EPS were not observed in the basins.

Figure 11 Image D shows the dispersed flocs in the basin which might be due to the polluted stream that enters the biobasin that acts on the flocs preventing them to aggregate. A lot of dispersed flocs were experienced after the oil break through from stream C although it was evident that the oil suppresses foaming for a couple of days after it enters the system and after a few days the basin foams again and a lot of suspended solids were lost with foam. This gave rise to the settling problems in the biobasin.

There was no type of *Nrcardioform* actinomycetes found in the plant during the whole period of the study, therefore the foam in the plant is not caused by filamentous microorganisms. *Nocardia* filamentous bacteria were not identified during the study. As reported in the literature foam forming bacteria can result because of operating parameters as for instance *Nocardia amarae* growth is pH sensitive and other certain filamentous bacteria are formed during low temperatures Tipping (1991). There were no issues on plant operating parameters that might influence the filamentous bacteria that may result in foaming. The filamentous foaming bacteria were only experienced during the winter season and during high oil breakthrough in the plant (Figure 12 Image E) on some of the biobasins

Carbon to Nitrogen to Phosphorus ratios are important in terms of obtaining good COD breakdown efficiencies. Typically a C: N: P ratio of 100:10:1 is recommended for general waste water treatment plants. Currently at the plant phosphoric acid is added to the biobasins as a source of phosphorus. The acclimated aerobic (oxygen-utilization) microorganisms in the basins utilise this phosphorus, plus the carbon and nitrogen-containing compounds present in the incoming streams to derive energy and multiply. Based on achieved results the foaming is not due to nutrient deficiency, the phosphorus was ranging at 2 kg/COD load according to plant design and ammonia was averaging at about 250 mg/l according to design.

Benzene Toluene, Ethyl-toluene and Xylene are volatile organic compounds that were found present in the incoming waste water streams. Under the right conditions of aeration, pH, and temperature certain bacteria can degrade these compounds as sources of nutrients. High loading of BTEX of greater than 18mg/l has been reported to be toxic to refinery waste water bacterial communities under laboratory conditions and can cause high un-degraded COD levels and foaming Pala (2001) On this experimental work, Total Benzene concentration was found to be very high averaging at concentration 0-10mg/l during the test period. Phenolic compounds are cyclic compounds with hydroxyl groups linked directly to aromatic hydrocarbons. They can be particularly toxic to bacteria. Phenols vary in terms of their relative susceptibilities or inertness to microbiological and chemical degradation. Some are fairly readily oxidised in waste water treatment plants while others remain chemically unchanged for long periods.

Phenols were found to be major inhibitors to the plant (waste water treatment), also when sample had high phenol concentration the toxicity value was very high and the correlation data (table1) when using Pareto analysis showed positive correlation.

Stream B methanol concentration(Figure16) was also found to be present most of the time averaging at 200mg/l, The high concentration of methanol also places an additional toxic burden on the biobasins which would negatively affect the microbial biomass.

On further analysis of the phenol-defoamer comparison (Figure 24), the defoamer-Phenol Index (DPI), which is basically the mass of defoamer used (in kg) per mass of phenols introduced to the plant. Table 2 shows the phenol shocks into plant, the resultant defoamer peaks, the DPI and the system’s response to the shocks.

The STREAM B water was always above plant design limit regarding its phenol concentration, when the phenols concentration was high, the samples were found to be inhibitory at very 20mg/l phenols concentration; STREAM B was the highest contributor of phenols. There was also a correlation between changes in phenol loads to the plant versus defoamer usages. There was no correlation found on the organic loads to the plant and defoamer usages; during oil break through incidents, the basins became flat as the oil enters the plant and after some time the plant starts to foam very badly with brown thick foam as a result of oil from the STREAM C and STREAM B. During winter months high foaming incidents occurred as a result of drop in ambient temperature. While phenols were high STREAM B oxygen absorbances were high which also confirms that phenols are very toxic to the microorganisms which contribute to foaming tendencies.

Dosage and dilution

As indicated in figure 25, 26, 27 and 28 the knock down test has proved that antifoam dilutions has an effect on effectiveness of the chemical in breaking down the foam. Defoamer agents have to be used undiluted for maximum efficiency. Experimental plant trial is the best way to determine the optimal dosage of the appropriate defoamer; however a preliminary test in the lab often indicates suitable products. Generally optimal defoamer dosage is between 10 and 1000 ppm according to the application and to the stability of the foam.

Defoamers can be diluted in water to obtain a better dispensability in the foaming medium, but efficiency of the antifoam will be affected. In case of dilution, in the literature it is recommended not to exceed a dilution ratio of 1:10. The diluted product must be used immediately. (Glenn, 2005)

Alteration to the dosing concentration

The defoamer solution concentration at the entry point varied from 0.1 to 0.6 percent (1000 to 6000 ppm). This is due to the variable speed dosing pumps which deliver defoamer ranging from 10 l/hr to 60 l/hr in 10m^3/hr carrier water. In an attempt to get a defoamer solution that is more concentrated into the basin, the primary carrier water was closed. This halved the carrier water flow rate and effectively doubled the defoamer solution concentration to range from 2 000-12 000 ppm. Figure 34 indicates the alterations that were done on the system.

Alterations to the basin dosing point

Emerging from the concerns that there was insufficient pressure at the spray boom header to penetrate the foam, the spray boom header was lowered from approximately 2m to 0.75m above the foam level. A spray system and jet nozzles were attempted in 052 AB 401(Figure 29).

Alterations to the Dosing Program

The pump was initially programmed to start pumping at the minimum when the foam height reached 25% on the foam measuring probe. That was changed to initiate minimum pumping when the foam height reached 35% on the foam measuring probe (figure 30).

Effects of the alterations on the overall defoamer consumption

Visual observations

Visually, the most effective alteration was the alteration to the dosing concentration. This was observed by monitoring the system, which showed:-

- Lower pump revolutions
- More vigorous mixing patterns
- Better foam control

Lowering the spray boom header slightly improved the defoamer solution penetration. The addition of spray nozzles and jet nozzles did not add value as they got blocked and one of the jet nozzles fell into the basin after pressure build-up, resulting from a blockage.

Potential benefits due to the program change

Delaying the initial pumping points had big benefits when the foam level in the basin was low. This can be seen by observing Figure 29, which shows the foam level probe. This change is not very beneficial when the foam level rises vigorously, as the defoamer saved in the lower levels will be consumed when the level goes over 75%. Overall, the change is beneficial because it is not common for the foam level to rigorously climb.

From the above results it was evident that concentration of antifoam has an effect on the knock down time. It can be seen that the more concentrated the solution the better is the results. Results were also looking better when using tap water but tap water, which is much cleaner than the current carrier water

The optimum concentration of the antifoam solution was determined and tested on the plant in the trial run. More savings could be realized due to doubling the dosing pump's ramp down rate. This change implies that the pump will frequently be in the lower ranges, hence pump less; Figure 30 demonstrates the potential savings due to change.

The results of this research are partitioned into three sections. The first section focuses on the operating parameters, Secondly the incoming streams properties and thirdly foaming control.

CHAPTER5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From outcomes of the study, the following conclusions were made:-

- Industrial waste water treatment using activated sludge process is more challenging than the normal municipal waste water treatment although the principle is the same, Industrial waste water has high levels of pollution from the incoming streams.

- One of the most difficult problems that were experienced during the study was the discharge of very polluted streams to the plant that slowly accumulates in biomass, the lab results showed that this pollution inhibits the ability of biomass to treat feed and eventually causing an effluent excursion or unexpected changes in properties of biomass.

- There were no filamentous microorganisms found in any of the basins, and it is therefore concluded that foam is not due to filamentous bulking or microbiologically related, it is rather caused by non-filamentous bulking. Non-filamentous bulking is a result of overproduction of extracellular slime resident microorganisms in activated sludge. The foaming is chemically related to the streams that are very polluted coming into the plant. There were a few incidents where foaming was formed because of filamentous microorganisms (Figure 12 Image E) in some of biobasins and in most of the incidents the foaming was due to chemistry changes of incoming streams.

- Based on results it can be concluded that the effectiveness of defoamer is also reduced by dilution factors; this was evident during the knockdown test and the field test when the carrier water had reduced the knockdown time and stay down time was improved. The cost can be reduced by using a correct concentration when dosing, the is evident in the knock down time graphs, the higher concentrated antifoam solution stay down time is longer.

- Plant operating parameters play a major role in stable foam formation; the plant must always be operated within its design condition.

5.2 Recommendations

From the conclusions above, the following recommendations are made:-

- Pretreatment of streams to minimize impact of toxicity on the activated sludge process.
- Identify the source of ammonia to the plant by using chemicals such as UAN rather than depending on incoming stream ammonia content, there are a lot of variations on compositions of incoming streams which might result in nutrient deficiency if not enough Ammonia is present and that will have impact on foaming potential.
- Investigation must be done on possibilities of using emulsion breaker on stream C and oil skimming must be reinstated before this stream enters the plant because this stream has a high content of oil which increases the foaming potential in the plant.
- Phenols were found to be the highest contributor to foaming to the plant; future work must be done on phenol recovery from stream A.
- More research work must be done to investigate the possibility of using Powdered Activated Carbon in biobasins which can help in treating non-biodegrable organics.
- When dosing the antifoam, it must be distributed evenly and optimum concentration must be used to prevent over-dilution resulting in waste of product without achieving results, which was evident during the study.
- Ensuring that less contaminants stream into the waste water treatment plant and correct antifoam concentration will reduce the cost.

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