The startup process for moving bed bio-reactors (MBBR) in freshwater recirculating aquaculture systems (RAS) within the Norwegian aquaculture industry.

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Preface

This 30 credit master thesis has been written in the final semester of a two year long MSc course in Aquaculture at the Norwegian University of Life Sciences. The idea to go ahead with this thesis has been motivated by the university itself and Krüger Kaldnes and has therefore been located both at a Marine Harvest owned hatchery-smolt farm along the coast of Dalsfjord in Sunnmøre, Norway and in the fish laboratory at the university.

I would like to offer gratitude to a number of people who have shown great support and guidance throughout this thesis: first and foremost to my main and second supervisors Assoc Prof Odd Ivar Lekang and Sr Engr Bjørn Frode Eriksen. Moreover, to Marius Hægh and Engr Andreas Brunstad from Krüger Kaldnes, Engr Bjørn Reidar Hansen and Engr Jon Asper from the IMT department, Prof Jon Fredrik Hanssen from the IKBM department, Prof Tore Krogstad from the IPM department and at the Norwegian University of Life Sciences and finally to the manager, Moritz, technicians and employees at Marine Harvest Norway AS Avd Dalsfjord.

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Abstract

Recirculating aquaculture system (RAS) technology is becoming increasingly popular in today's growing aquaculture industry, as it provides further expansion on already limiting good freshwater resources in a controllable and environmentally friendly manner. There are several different biofiltration technologies existing in RAS, of which moving bed-bio reactors (MBBR) are the most prevalent. Research has shown that MBBRs have, amongst other benefits, a small footprint and a low maintenance. The startup process of such systems are, however, rather time consuming and complicated, as they cultivate and grow live nitrifying bacteria, and therefore need further looking into and understanding.

Two experiments where performed in this thesis, taking a deeper look at the startup process in detail, with regard to startup time, bacterial growth and toxic product peaks. The experiments included registering and documenting the startup process of a large scale industrial MBBR delivered by Krüger Kaldnes to the Norwegian aquaculture industry and taking a deeper look at different startup additives and conditions through a small scale experiment.

Results showed a startup time of 34 days for the large scale experiment to approximately 64 days for the small scale experiment, in addition to ways of improving future startup processes.

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1 Introduction

The Norwegian aquaculture industry is gradually expanding with salmon playing the lead role as it makes up for approximately 90% of annual sales. Towards the end of 2010, Norway reached a staggering annual production of 1000 tons of salmon and rainbow trout, while only half that amount was produced during the year 2000 (SSB 2011). However, further expansion is becoming limited, mostly due to the lack of good fresh water resources. Companies therefore, are becoming more and more interested in upscaling production at already existing locations by utilizing the principle of water recirculation (Lekang Personal Communication). This can result in using 90 – 99% less water than a conventional aquaculture system (Ebeling & Timmons 2012).

"In order for the world aquaculture community to supply the world per capita needs for aquatic species over the coming decades in an environmentally friendly manner, recirculating aquaculture systems (RAS) must become a key technology" (Ebeling & Timmons 2012).

RAS can consist of basic unit operations such as oxygenation, aeration, carbon dioxide removal, nitrogenous waste management, solid waste removal, disinfection etc. and many different designs and setups exist (Gebauer et al. 1992; Ødegaard 1992; Timmons & Ebeling 2007a). However, the most central unit of operation is nitrogenous waste management as it is the main prerequisite for recirculating water in aquaculture systems.

It is well known and documented (Eding et al. 2006; Fivelstad et al. 1993; Jensen 2003; Pinto et al. 2007) that nitrogenous waste products such as unionised ammonia and nitrite, are extremely harmful for rearing species in aquaculture systems. It is therefore necessary to achieve removal rates equal to or greater than production rates.

Nitrogenous waste can be either physically/chemically or biologically removed. The most widely used method is undoubtedly biological removal, more commonly known as biofiltration. The main principle in this method is that one utilises a substrate with a high specific surface area (large surface area per unit volume, m^2/m^3) on which nitrifying bacteria can attach and grow.

There are several different biofiltration methods and technologies existing in RAS, such as trickling filters, rotating biological contractors etc. However, this thesis shall only focus on moving bed bio-reactor (MBBR) systems. The MBBR system is one of the most prevalent nitrogenous waste removal methods used in RAS (Rusten et al. 2006).

What separates MBBR's from the other methods mentioned above is that they utilise a plastic medium, with equal density to water, as substrate. These are kept in a continuous state of movement by the help of an aeration system and/or water pump/submerged mixer. Compared to other biofiltration methods, MBBR's have a small footprint and low maintenance i.e. they can operate continuously with no need for back flushing, they have a low head loss and an even waste distribution over the biofilm surface area. MBBR's can also be operated under aerobic or anoxic conditions for nitrification or denitrification purposes respectively, however, the first mentioned is the favoured purpose in aquaculture applications (Rusten et al. 2006; Timmons & Ebeling 2007b).

The startup process of completely new large scale industrial MBBR's is a very time consuming (Rusten et al. 2006) and slightly complicated process that needs further understanding and looking into. Complicated in the sense that one is cultivating sensitive and slow growing live organisms, so care and caution is needed in such areas as foreign contaminants, species specification, growth and environmental factors etc. A deeper understanding leading to greater control and a faster startup process will lead to more effective production for today's intensive aquaculture systems and a competitive advantage in an increasingly growing market. It is therefore essential to research, investigate and develop different more efficient startup methods.

The purpose and goal of this thesis is to register and document the startup process of a large scale industrial MBBR delivered by Krüger Kaldnes, in relation to time, bacterial growth and nitrite peak occurrence, in addition to investigating ways to provoke these factors through a small scale experiment.

Nomenclature	
AMO	Ammonia-monooxygenase
AOB	Ammonia-oxidizing bacteria
B*x*	Bucket number, where *x*=1,2,3,4,5,6,7,8
COD	Chemical oxygen demand
DO	Dissolved oxygen (mg L^{-1})
HAO	Hydroxylamine-oxidoreductase
MBBR	Moving bed bio-reactor
NH_4^+–N	Ammonium-nitrogen (mg L^{-1})
NO_2^-–N	Nitrite-nitrogen (mg L^{-1})
NO_3^-–N	Nitrate-nitrogen (mg L^{-1})
NOB	Nitrite-oxidizing bacteria
PO_4^{3-}–P	Orthophosphate-phosphorus
TP	Total phosphorus
RAS	Recirculating aquaculture system
SS	Suspended solid (mg L^{-1})
TAN	Total ammonia nitrogen (mg L^{-1})
TN	Total nitrogen (mg L^{-1})
NXR	Nitrite oxidoreductase
Gp*x*	Water quality parameter group *x*=1,2,3
R1	Reactor 1
R2	Reactor 2
TNN	Total nitrite nitrogen (mg L^{-1})

2 Literature review

This chapter shall review factors that influence the startup process of a MBBR, such as biofilm carriers, microbiological processes, water quality parameters and startup criteria. This data shall then be a basis for comparison with the experiments in Chapter 3 and Chapter 4.

2.1 Carriers

Different types of biofilm carriers can be used in MBBR. Rusten et al. (2006) states that the K1 carrier from Krüger Kaldnes is the dominating type, however, more recent and new types are in the entering process of the aquaculture industry, such as BiofilmChip^{TM} M and P from Krüger Kaldnes. BiofilmChip^{TM} M has a fine grid and allows a very thin and effective biofilm to be established, however, in comparison to BiofilmChip^{TM} P, it cannot handle as large of an organic load.

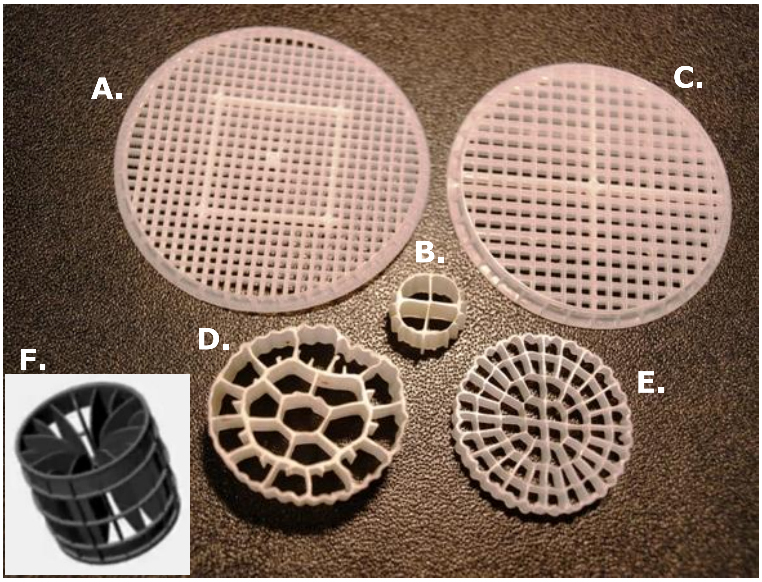


Figure 2.1: Types of biofilm carriers from Krüger Kaldnes (Holdhus 2012). A.: BiofilmChip^{TM} M, B.: K1, C.: BiofilmChip^{TM} P, D.: K3, E.: K5 and F.: F3.

Carriers scrub against each other as they are in constant movement within the MBBR. This prevents clogging and removes excess organic matter. This is where the term “protected biofilm surface area” comes in, a topic of discussion in MBBR dimensioning situations. Protected biofilm surface area is the area on which biofilm can grow and flourish without being disturbed i.e. media specific surface area minus vulnerable surface area. However, this term and concept are not often brought up when dimensioning MBBR.

The two terms used the most are the media specific surface area and specific biofilm surface area of the reactor. The media specific surface area is the total surface area divided by the volume of one media unit. The specific biofilm surface area of the reactor, on the other hand, is the media specific surface area multiplied by the fraction of the total reactor volume that the media occupies. This can also be seen as the total surface area of the media divided by the total reactor volume (Timmons & Ebeling 2007b).

Table 2.1: Overview over carrier type specifications from Krüger Kaldnes (Veolia 2011).

Carrier type	Specific surface area (m^2/m^3)	Diameter x Height (mm)
K1	500	11 x 7
K3	500	25 x 10
K5	800	25 x 4
BiofilmChip™ P	900	45 x 3
BiofilmChip™ M	1200	48 x 2.2
F3	200	Approx. 40 x 40

The fraction of the total reactor volume that the media occupies is also referred to as the filling degree. Filling degrees range from 40-70%, usually declining with increasing media specific surface area. Too high filling degrees would reduce mixing efficiency and the efficiency of the bioreactor (Timmons & Ebeling 2007b).

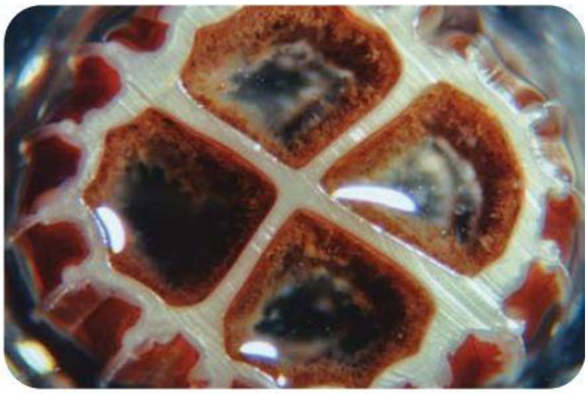


Figure 2.2: Close up photo of carrier type K1 with mature biofilm (Veolia 2011).

2.2 Nitrification

The nitrogen cycle is a vast natural process found in both natural and man-made ecosystems and is a key to sustaining life on earth. Various species have naturally embedded themselves and become part of this life cycle, becoming an important and sometimes significant step in the whole process (Campbell & Reece 2005). In this section, we shall focus on and take a deeper look into a significant and key part of this cycle, the nitrification process.

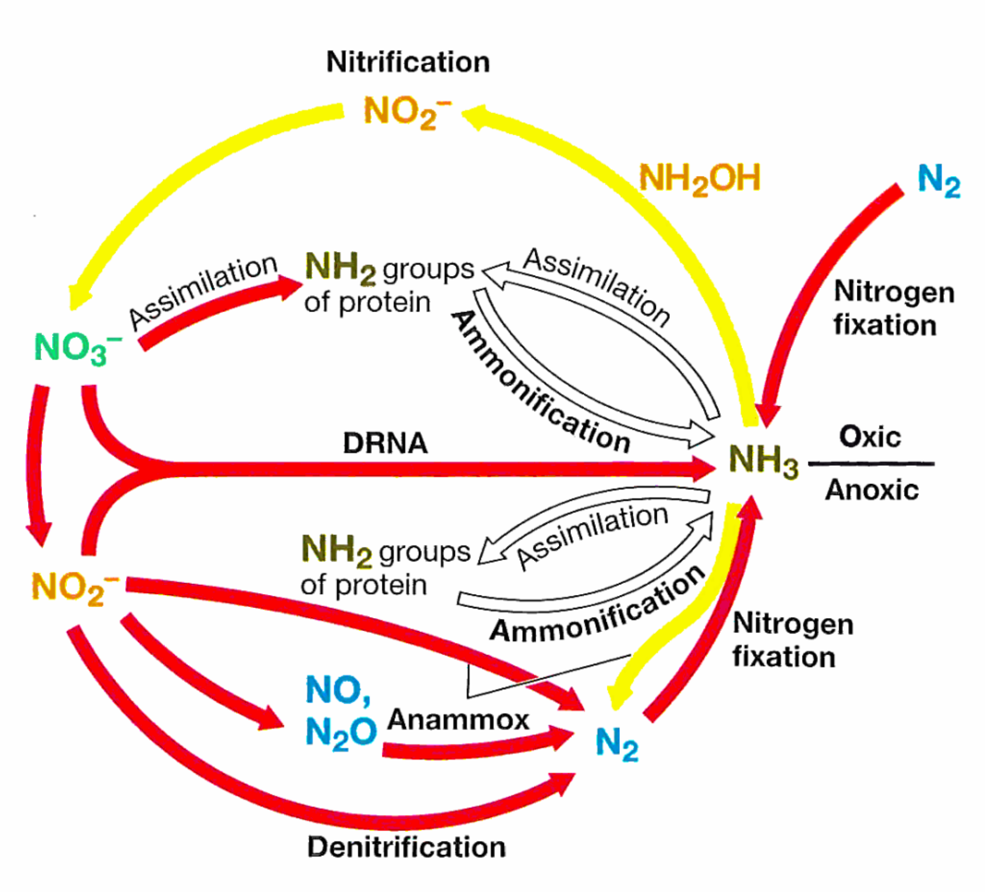


Figure 2.3: "Redox cycle for nitrogen" (Madigan et al. 2012b). "Oxidation reactions are shown by yellow arrows and reductions by red arrows. Reactions without redox change are in white. DRNA, dissimilative reduction of nitrate to ammonia". A number of steps in this cycle are mainly completed by a single enzyme found in a given organism. E.g. The two enzymes AMO and HAO, found in AOB, oxidise NH_4^+ and NH_2OH respectively resulting in NO_2^-.

The nitrification process relies on the production and presence of ammonia, which is credited to such processes as ammonification (the decomposition of organic nitrogen compounds such as amino acids and nucleotides), nitrogen fixation (N_2 as a cellular N source for a small number of prokaryotes) and dissimilative reduction of nitrate to ammonia (DRNA, respiratory reduction in reductant-rich anoxic environments) (Madigan et al. 2012b). In RAS however, the primary and main source of ammonia for MBBR's is the ammonification process found within rearing species.

The nitrification process itself is known as an aerobic microbial two-step process in which ammonia is oxidized to nitrate by two groups of bacteria i.e. aerobic ammonia-oxidizing bacteria (AOB), which oxidize ammonia to nitrite, and aerobic nitrite-oxidizing bacteria (NOB), which oxidize the nitrite further to nitrate (Sliekers & Stafsnes 2005; Suzuki et al. 1974). It is therefore reasonable to state that NOB relies on AOB. These two groups are referred to as nitrifying bacteria and grow chemolithotrophically through the above mentioned inorganic nitrogen compounds.

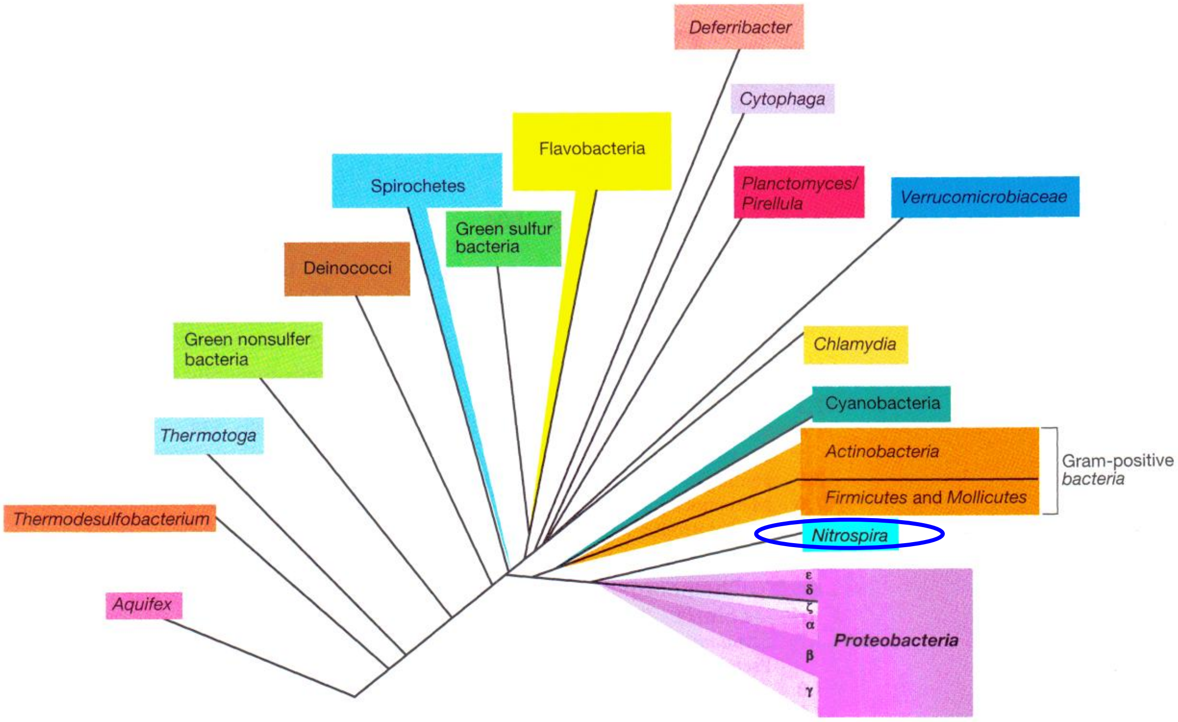


Figure 2.4: "Some major phyla of *Bacteria*" (Madigan et al. 2012e). The phyla of *Bacteria* in this figure are based on 16S ribosomal RNA gene sequence comparisons. The nitrifying bacteria *Nitrospira* is circled in blue.

Nitrifying bacteria are found in such places as in soil and water in great numbers. They flourish in areas and water sources which receive high inputs of ammonia (Madigan et al. 2012a). Koops and Pommerening-Röser (2001) state in their study that: "Cultures and distribution patterns of nitrifying bacteria depends a lot on various environmental parameters. Hence the composition of nitrifying bacterial communities is complex and diverse in heterogeneous habitats. Because of the above-mentioned problems, the representation of nitrifying community structures obtained from in situ investigations often has been incomplete and unbalanced in many respects". It is therefore reasonable to assume that still until today, only a part of all existing nitrifying bacteria have been defined and identified through isolation and physiological and molecular characterization (Koops & Pommerening-Röser 2001; Madigan et al. 2012e).

In earlier studies (Teske et al. 1994), all nitrifying bacteria were thought to be members of phylum *Proteobacteria*. However, later studies (Ehrich et al. 1995; Koops & Pommerening-Röser 2001) separated one genus to form its own phylum i.e. *Nitrospira* (Figure 2.4).

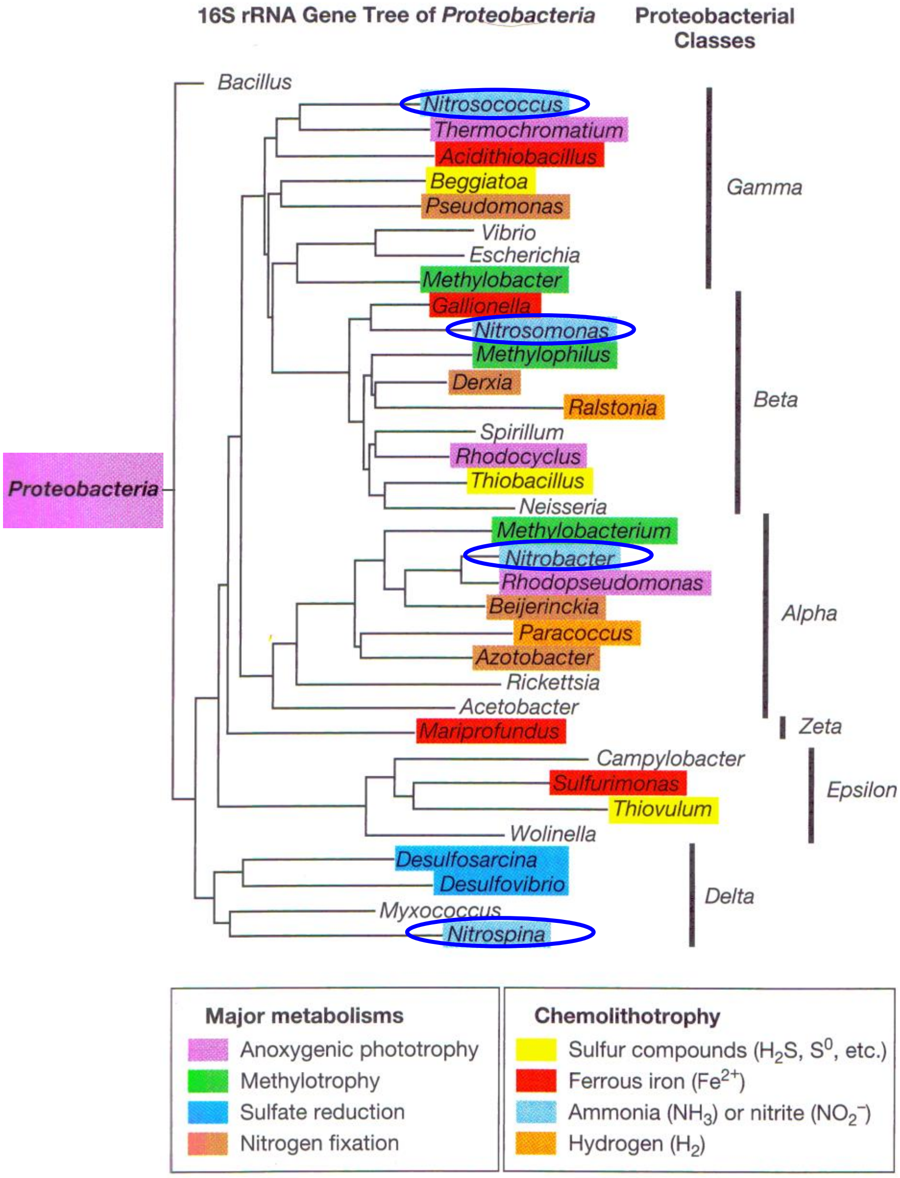


Figure 2.5: "Phylogenetic tree of some key genera of *Proteobacteria*" (Madigan et al. 2012e).
The nitrifying bacteria are circled in blue. The genera *Nitrosospira* and *Nitrococcus* belonging to the beta and gamma class, respectively, are missing in this illustration.

2.2.1 **Ammonia-oxidizing bacteria**

AOB are classified into three different genera (previously five (Teske et al. 1994)) i.e. Two which are closely related within the beta class, *Nitrosospira* and *Nitrosomonas,* and the third, *Nitrosococcus.* The *Nitrosococcus* genus is however quite special as it is divided into two species belonging to different classes, i.e. *Nitrosococcus mobilis* and *Nitrosococcus oceanus* which belong to the beta- and the gamma class, respectively. Within the genus *Nitrosospira*, are the species *Nitrosovibrio* and *Nitrosolobus*, which used to be classified as separate genera (Aakra 2000; Head et al. 1993).

The most extensively studied genus of AOB, and the most prominent is the *Nitrosomonas*. This might be due to the relatively rapid growth of many cultured strains (Aakra 2000) compared to other AOB. Some studies (Wallace & Nicholas 1969) state that *Nitrosomonas* are the primary (AOB) mediators of biological nitrification. However, other studies (Schramm et al. 1998) question this statement, showing no sign of *Nitrosomonas* but rather *Nitrosospira* in biofilters.

There are a number of species of *Nitrosomonas* each with their own strains. The most prominent species are the *Nitrosomonas europaea* and *Nitrosomonas eutropha (Wagner et al. 1995),* of which the first mentioned has been the most studied (Arp et al. 2002; Chain et al. 2003). "Most of the breakthroughs in our understanding of the biochemistry and molecular biology of AOB have been achieved using *Nitrosomonas europaea" (Arp et al. 2002)*.

AOB obtain energy solely by ammonia-oxidation and by assimilating CO_2 via the calvin cycle. Ammonia-oxidation consists of the successive action of two enzymes ammonia monooxygenase (AMO) and hydroxylamine oxidoreductase (HAO).

AMO: $NH_3 + O_2 + 2e^- + 2H^+ \rightarrow NH_2OH + H_2O$

HAO: $NH_2OH + H_2O \rightarrow NO_2 + 5H^+ + 4e^-$

Two of the four electrons return to the AMO reaction because of an electron-transfer protein, tetraheme cytochrome c (554). The other two are either reductant for biosynthesis or pass to a terminal electron acceptor (Figure 2.6)(Chain et al. 2003; Upadhyay et al. 2006).

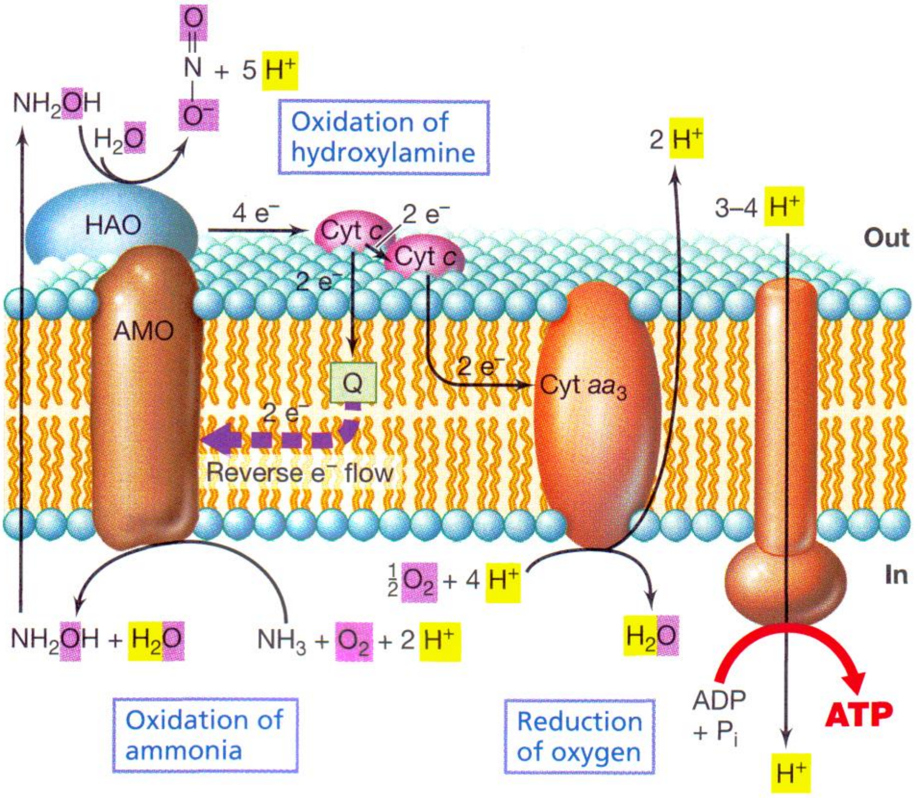


Figure 2.6: "Different enzymes and cytochromes and their functions in an AOB cell" (Madigan et al. 2012c).

Some studies have shown that species (*Nitrosomonas europaea* and *Nitrosomonas eutropha*) of *Nitrosomonas* grow slowly under anaerobic conditions (Abeliovich & Vonshak 1992; Schmidt & Bock 1997). However this form of growth is not assumed to be important in nature since ammonia tends to accumulate in anaerobic conditions (Aakra 2000).

2.2.2 Nitrite-oxidising bacteria

The nitrite-oxidising bacteria (NOB) are currently classified into four genera: *Nitrobacter*, *Nitrospina*, *Nitrococcus* and *Nitrospira*. *Nitrospina* belong in the delta class while the *Nitrococcus* and *Nitrobacter* belong to the gamma- and beta class, respectively (Madigan et al. 2012e; Teske et al. 1994). *Nitrospira* form its own phylum, as mentioned earlier. The genus *Nitrobacter* forms a tight group of very closely related species: *Nitrobacter winogradskyi*, *Nitrobacter hamburgensis*, *Nitrobacter vulgaris* and *Nitrobacter alkalicus*. Several strains have been determined within each species from places all over the world (Bock et al. 1990; Sorokin et al. 1998; Teske et al. 1994).

Throughout history, members of the *Nitrobacter* genus have received most attention and are studied the most as they have been used as primary model organisms for studying the physiology and biochemistry of NOB (Starkenburg et al. 2006; Starkenburg et al. 2008). Wallace and Nicholas (1969) also state that *Nitrobacter* are the primary (NOB) mediators of biological nitrification. However, many studies question this statement, suggesting that *Nitrospira* are the most abundant in both nature and biofilters (Madigan et al. 2012a; Schramm et al. 1998; Schreier et al. 2010).

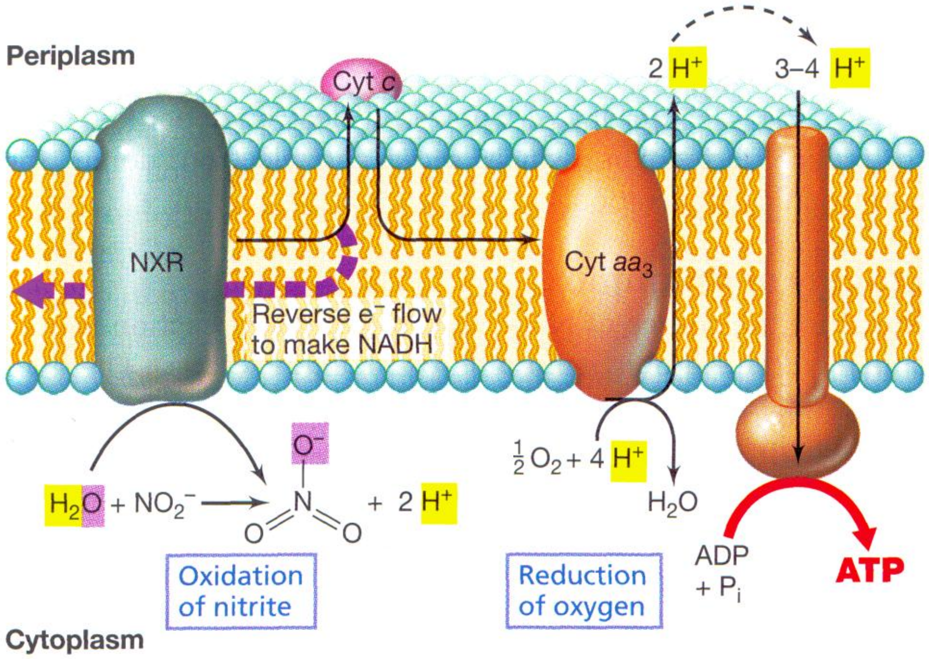


Figure 2.7: "Different enzymes and cytochromes and their functions in an NOB cell" (Madigan et al. 2012c).

A lot less is known about the genus *Nitrospira*. They inhabit the same environments as *Nitrobacter* and are close to other nitrifying bacteria in their physiological resemblance, but phylogenetically, they are quite distinct (Madigan et al. 2012c).

NOB gain their energy primarily from nitrite oxidation and fix CO_2 via the calvin cycle (Starkenburg et al. 2008). However, several *Nitrobacter* species have the ability to grow on simple organic carbon compounds, such as pyruvate, acetate, alpha-ketoglutarate and glycerol, in the absence of nitrite (Smith & Hoare 1968; Steinmuller & Bock 1976), and can also grow anaerobically if needed (Bock et al. 1988). However, growth is typically much slower (Starkenburg et al. 2008).

NOB oxidise nitrite through the enzyme nitrite oxidoreductase (NOR or NXR), which is a reversible process (Starkenburg et al. 2008).

2.2.3 Nitrification rate

There are two ways of expressing nitrification rates in a biofilter, i.e. through the use of either volume or surface area of the bio media, however the latter is the most common (Rusten et al. 1995) and will be the one referred to in this thesis. Nitrification rates can be expressed as:

$$g\, TAN\ removed/m^2\ media\ surface * \ Day$$

“The nitrification rate in the biofilter is a constant balance between the demand by the AOB and NOB for nutrients to promote growth and wellbeing and the supply of these nutrients determined by their bulk concentration and diffusion rate into the biofilm” (Timmons & Ebeling 2007b). One would therefore assume that it is a great measurement to analyse the efficiency and well being of a biofilter, however, it has shown to be difficult to compare between different biofilters due to a large number of factors, including rearing species, biofilter configuration, feed composition and strategy, temperature, inorganic nitrogen compounds , salinity, pH, type of media used, dissolved oxygen, organic matter, bacterial growth phases etc (Crab et al. 2007; Eding et al. 2006; Rusten et al. 2006). Hence, comparison of nitrification rates between biofilters seems to only be appropriate when the above mentioned conditions are close to equal. E.g.: in marine systems, nitrification rates are significantly lower than for comparable freshwater systems (Rusten et al. 2006).

However, Rusten et al. (2006) took a look into nitrification rates of both small and large scale MBBR’s and found much greater rates compared to earlier reports in literature.

Chen et al. (2006) classified more than 20 physical, chemical and biological influential factors of nitrification into three major categories:

- First: factors that affect the biochemical process of the microbes.
    - E.g.: temperature, pH, salinity
- Second: Factors that affect the supply of nutrients for the microbes.
    - E.g.: substrate concentration (ammonia), mixing regime
- Third: Factors that affect both growth and nutrient supply.
    - E.g.: nutrient and space competition with heterotrophic bacteria

2.3 Water quality and conditions

2.3.1 pH

There is a wide range of reported pH optima for nitrifying bacteria, and research has been going on for almost seventy years (Biesterfeld et al. 2003). Literature suggests that the optimum range of pH for nitrification is 7.2 – 9.0 (Chen et al. 2006; Timmons & Ebeling 2007b). For more specific species of bacteria, pH optima values range from 7.2 – 7.8 for *Nitrosomonas* and 7.2 – 8.2 for *Nitrobacter* (Timmons & Ebeling 2007b). However, growth has occurred in pure cultures of AOB and NOB at pH ranges of 5.8 – 8.5 and 6.5 – 8.5, respectively (Princic et al. 1998). There are records of biofilters that have operated over a pH range from 6.0 – 9.0, due to the adaption of bacteria over time (Timmons & Ebeling 2007b). Other suggestions have a probable range of pH 5 – 10, provided that the biofilm can adapt slowly. However, complete cessation of nitrification at a pH of 5.5 was also reported (Eding et al. 2006).

One should also keep in mind that due to mass transfer resistance, nitrifying bacteria in a biofilm ‘‘experience’’ a pH which is lower than in the surrounding water (Eding et al. 2006).

“It is probably a good idea to maintain pH near the lower end of the optimum pH for the nitrifying bacteria to minimize ammonia stress on the cultivated fish species. In addition, rapid changes in pH of more than 0.5 – 1.0 units over a short time span will stress the filter and require time for adaption to the new environment” (Timmons & Ebeling 2007b).

2.3.2 Temperature

It is well known fact that temperature has a significant effect on bacterial growth, where low and high temperatures (within the reasonable range of 1 – 40°C) delay and accelerate growth, respectively. For the nitrifying bacteria, optimal temperature ranges are reported in a wide range, from close to 20°C up until 30°C (Bock et al. 1990; Chen et al. 2006; Lekang 2007), however, little information exists of the any direct effects besides the above mentioned.

One source of information (WPC n.d.) suggests the following: "Nitrification reaches a maximum rate at temperatures between 30 and 35°C. At temperatures of 40°C and higher, nitrification rates fall to near zero. At temperatures below 20°C, nitrification proceeds at a slower rate, but will continue at temperatures of 10°C and less. However, if nitrification is lost, it will not resume until the temperature increases to well over 10°C".

The results of an experiment by Zhu and Chen (2002) showed that changes in temperature on nitrification rates were less significant than earlier predictions.

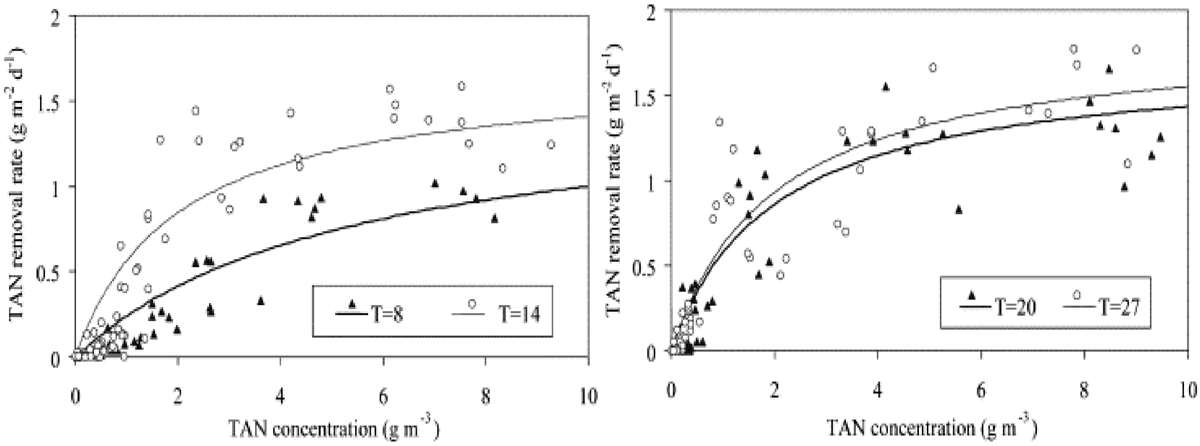


Figure 2.8: "Relationship between TAN concentration and removal rates at different temperatures" (Zhu & Chen 2002).

Timmons and Ebeling (2007b) also suggests that nitrifying bacteria are able to adapt to wide range of temperature, if acclimated slowly.

2.3.3 Nitrogenous substances

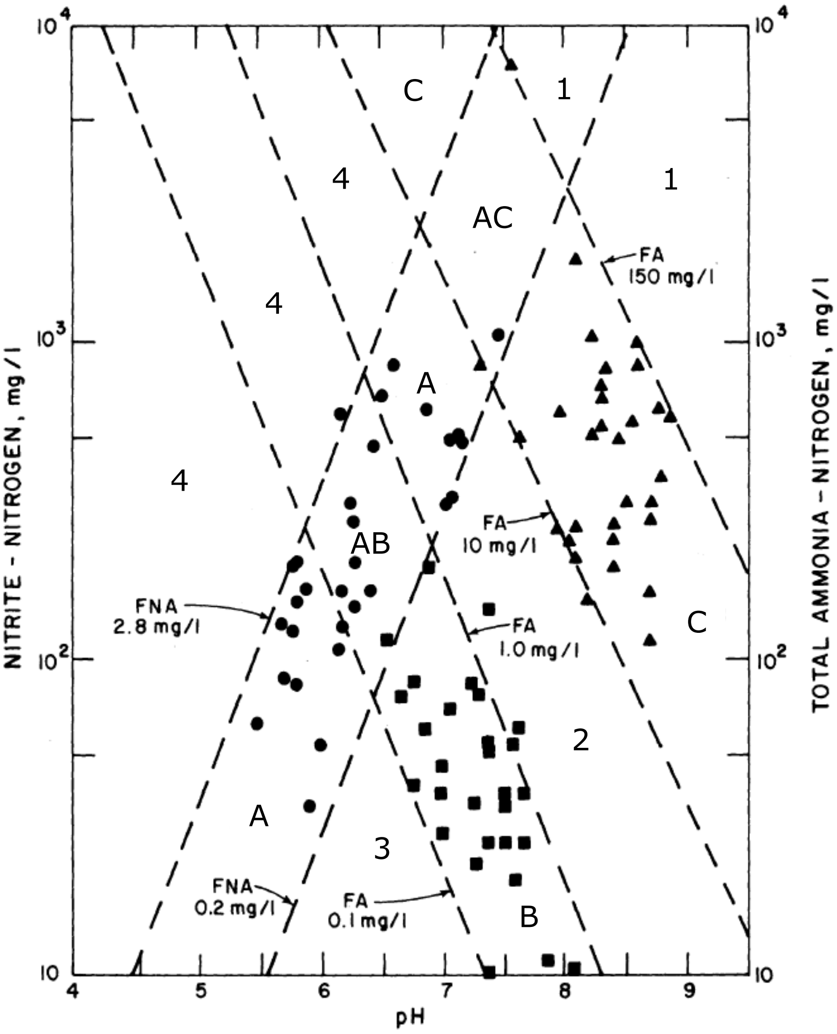


Figure 2.9: "Inhibition of Nitrification by Ammonia and Nitrous acid at 20°C" (Anthonisen et al. 1976).
Zone 1: NH_3 (FA) Inhibition to *Nitrobacter* & *Nitrosomonas*, Zone 2: NH_3 (FA) Inhibition to *Nitrobacter*, Zone 3: Complete nitirification, Zone 4: HNO_2 (FNA) Inhibition to *Nitrobacter*, A, B & C are boundary zones. The circles, squares and triangles are documented data which made it possible to quantify and scale their respective boundary zones.

2.3.3.1 Ammonia

Ammonium is mildly acidic and is in equilibrium with ammonia, dependent on the pH, temperature and salinity of the solution. If pH is low or high for example, the equilibrium shifts to the right or left, respectively.

$$H^+ + NH_3 \leftrightarrow NH_4^+$$

TAN expresses the total amount of ammonia nitrogen regardless of form, and its concentrations affect the nitrification rate of biofilters (Figure 2.8). Research (Anthonisen et al. 1976) has shown that unionized ammonia concentrations (freshwater at 20°C) greater than 0.1-1.0 mg L^{-1} and greater than 10-150 mg L^{-1} inhibit nitrite oxidation in *Nitrobacter* and ammonia oxidation in *Nitrosomonas*, respectively (Figure 2.9). At a pH 7 these values are approximately 20-200 mg L^{-1} and 2000-30000 mg L^{-1} TAN, respectively.

In previous startup experiments of MBBR and other bioreactors, TAN concentrations were kept from 1.2 – 5.0 mg L^{-1}, showing good results (Lekang & Kleppe 2000; Mydland et al. in press). However, Krüger Kaldnes (Personal Communication) advised that TAN concentrations should be kept between 5 – 10 mg L^{-1} and not more than 40 mg L^{-1} during the startup process of MBBR.

2.3.3.2 Nitrite

Alike ammonia, nitrite is in equilibrium with nitrous acid, also dependent on the pH, temperature and salinity of the solution. If pH is low or high, the equilibrium shifts to the right or left, respectively.

$$H^{+} + NO_2^{-} = HNO_2$$

Anthonisen et al. (1976) also showed that unionized nitrous acid concentrations (freshwater at 20°C) greater than 0.2-2.8 mg L^{-1} inhibit nitrite oxidation in *Nitrobacter* (Figure 2.9), and supposedly also ammonia oxidation in AOB (Kleppe 1998). At a pH 7 the above mentioned values are approximately 250-3500 mg L^{-1}.

2.3.3.3 Nitrate

Nitrate is only slightly toxic to AOB and NOB (Anthonisen et al. 1976), and can be assumed to cause no major problems in closed biofilter systems at concentration below 500-1000 mg L^{-1}.

2.3.4 Phosphorus

Phosphorus concentrations in the water can be limiting to nitrifying bacterial growth (Kaldnes Personal Communication; Ødegaard 1992), as it is one of the essential elements for microbial growth (Section 2.4.1). Phosphorus in the form of orthophosphate ($-PO_4$) will be removed from the bulk water body via adsorption to any form of medium (Zhang et al. 2011). It is therefore important to keep orthophosphate-phosphorus concentration above 0.3 mg L^{-1} during the startup phase of a MBBR (Kaldnes Personal Communication).

2.3.5 Dissolved oxygen

As mentioned in earlier parts of this chapter, oxygen is needed for the nitrification process to function. Theoretically 3.43 mg and 1.14 mg of oxygen is needed to oxidise 1 mg of NH_3-N and NO_2-N, respectively (Chen et al. 2006). Chen et al. (2006) made a collection of studies that examined limiting DO rates for different cultures of bacteria, both pure and mixed, and found that *Nitrosomonas* and *Nitrobacter* growth is limited at DO concentrations of 1-2 mg L^{-1} and 2-4 mg L^{-1}, respectively. One of the studies showed a maximum rate of nitrification in activated sludge at a DO concentration of 4 mg L^{-1}. Another (Haug & McCarty 1972), showed no inhibition or increase of nitrification rates up to DO concentrations of 60 mg L^{-1}. One can therefore assume that levels of at least 4 mg L^{-1} DO is adequate to maintain maximum nitrification rates.

2.3.6 Organics

Particulate and dissolved organics in a biofilter will contribute to the total oxygen demand of the system and provide substrates for growth of heterotrophic microorganisms that will compete with nitrifying bacteria (Ohashi et al. 1995; Zhang et al. 2011). Generally when space limitation and/or oxygen depletion take place, *Nitrobacter* will be the first to be displaced (Bergheim & Brinker 2003), leading to reduced nitrification rates and possible increases of nitrite.

"With the addition of organic matter, fast-growing heterotrophic bacteria which use organic carbon as their energy source will out-compete slow-growing nitrifying bacteria, resulting in a decrease in the nitrification rate" (Chen et al. 2006). In addition, Ohashi et al. (1995) states that the presence of organics in a biofilter will affect the composition of its microbial population. It is therefore an important factor to keep organic matter in the biofilter at a minimum level to ensure high efficiency.

Accumulation of organic matter in areas can also lead to such undesired events as anaerobic zones, fermentation etc.

2.3.7 Turbulence

"In properly designed moving bed biofilm reactors (MBBRs), the whole reactor volume is active, with no dead space or short circuiting." (Rusten et al. 2006). Water turbulence is a vital factor in ensuring this, and is usually ensured by the help of an aeration system and/or water pump/submerged mixer (Chapter 1).

Studies have shown that there is an increase in nitrification rates with increased turbulence as it reduces the thickness of stagnant water films covering the biofilm and increases availability of important nutrients for growth (Timmons & Ebeling 2007b).

It is therefore important to have an adequate turbulence and mixing in a MBBR, and some studies are looking into ways of improving and optimising this factor (Li et al. 2011).

2.3.8 Alkalinity

Alkalinity in a biofilter is an important factor as it provides a buffering capacity preventing changes in pH due to acid production from the nitrification process. Hence, alkalinity is used up by Nitrifying bacteria in their conversion process, and it has been shown through studies that for every gram of ammonia-nitrogen converted to nitrate-nitrogen 7.1 grams of alkalinity (as $CaCO_3$) is consumed (Chen et al. 2006; Timmons & Ebeling 2007b). Alkalinity in the form of carbonate and bicarbonate is in fact a nutrient element for nitrifying bacteria.

$$50\ g\ CaCO_3 = 1.00\ eq. of\ alkalinty$$

Chen et al. (2006) gathered some reports showing that alkalinity levels higher than 40-75 mg L^{-1} $CaCO_3$ were needed in order to ensure maximum nitrification rates and also recommended a level of 200 mg L^{-1} $CaCO_3$.

Krüger Kaldnes (Personal Communication) on the other hand, advised that alkalinity levels should always be kept at a minimum of 100 mg L^{-1} $CaCO_3$ in MBBR.

2.4 Microbial cultivation and growth

2.4.1 Nutrition and cell chemistry

To understand the nutritional requirements of nitrifying bacteria, one may first look into the general composition of a bacterial cell (Figure 2.10). "An approximate chemical formula for a cell is $CH_2O_{0.5}N_{0.15}$, indicating that carbon (C), oxygen (O), nitrogen (N) and hydrogen (H) constitute the bulk of all living organisms" (Madigan et al. 2012d).

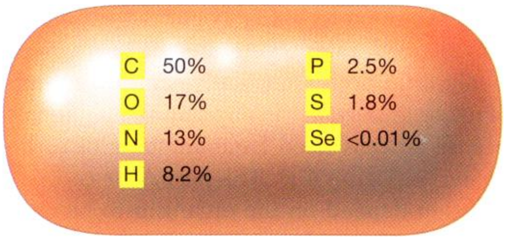


Figure 2.10: "Essential elements of a bacterial cell" (Madigan et al. 2012d). Values are given as percent of cell dry weight.

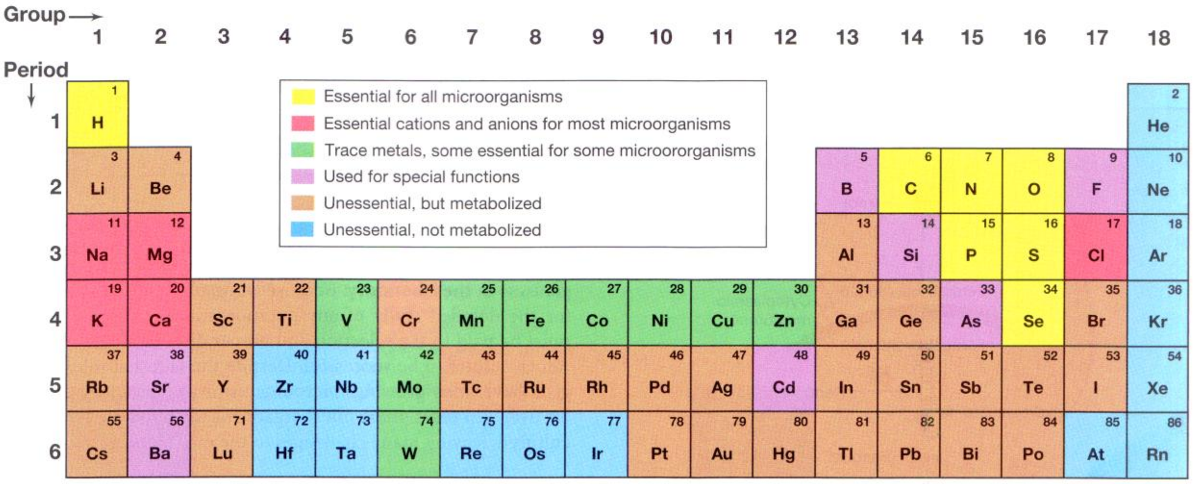


Figure 2.11: "A microbial periodic table of the elements" (Madigan et al. 2012d).

Other essential elements are: for all microorganisms: phosphorus (P), sulphur (S) and selenium (Se), and for most microorganisms: potassium (K), magnesium (Mg), calcium (Ca), sodium (Na) and chlorine (Cl) (Figure 2.11). Microorganisms also require a number of trace elements (Figure 2.11), of which iron (Fe) is the most important (Madigan et al. 2012d).

Cultures of nitrifying bacteria can therefore be cultivated in environments enriched with the above mentioned essential elements in addition to the compounds ammonia and/or nitrite.

2.4.2 Microbial growth

Microbial growth is defined as an increase in the number of cells in a given population. The time it takes for a cell or a population to double, is its generation time. Growth in this manner with a constant generation interval is referred to as exponential growth. The generation interval of a given microbial organism is dependent on the growth medium and its surrounding conditions (Madigan et al. 2012f).

For nitrifying bacteria, generation intervals have been reported to last from eight hours up to several day (Aakra 2000; MHN 2010). Aakra (2000) mentions in his study the following: “Since ammonia is a poor energy source and carbon dioxide fixation requires a lot of energy, the growth of AOB is very time demanding”. However, Marine Harvest Norway stated in a conference lecture that enough space and high ammonia concentrations can speed up growth (MHN 2010).

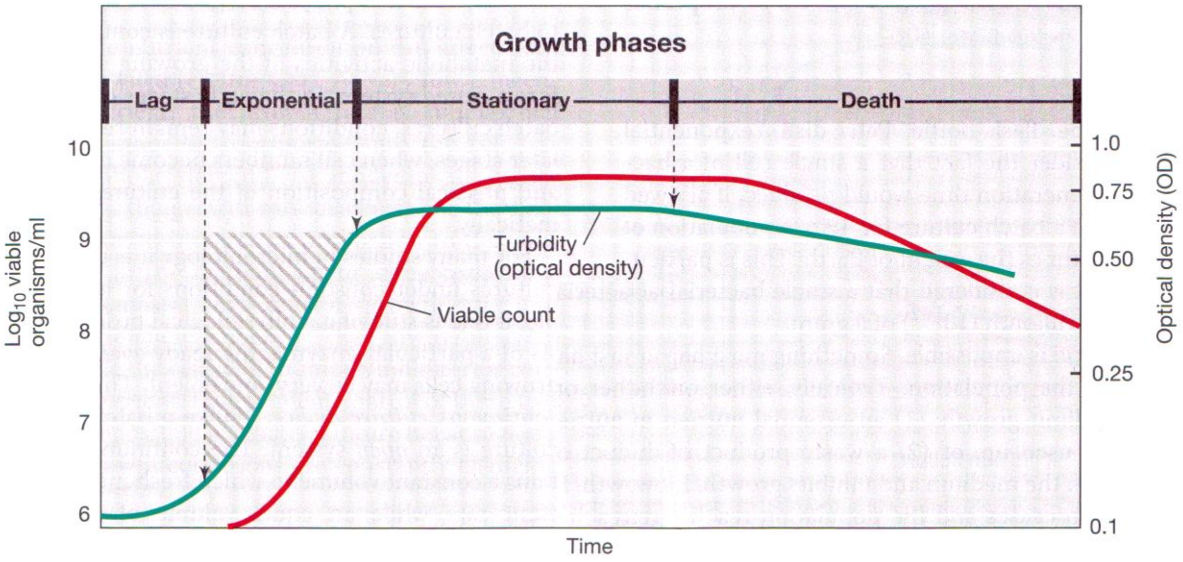


Figure 2.12: ”Typical growth curve for a bacterial population” (Madigan et al. 2012f). “This growth curve describes an entire bacterial growth cycle.”

Exponential growth in a closed environment (such as a closed MBBR) is not indefinite. Instead, growth in such a situation can be divided into 4 phases: lag phase, exponential phase, stationary phase and death phase (Figure 2.12).

Growth usually starts at a certain time after a microbial culture is introduced to a fresh medium; this time is referred to as the lag phase. The lag phase can also be regarded as an adaption period, i.e. if a bacterial population is transferred between identical environments and conditions, there should be no lag phase.

The lag phase can actually occur again at any time throughout the exponential growth phase if conditions are alternated (Madigan et al. 2012f). This is reflected in the fact that some studies have shown sudden nitrite peaks occurring whenever a nitrifying system is unstable (Mydland et al. in press; Rusten et al. 2006). The length of such reoccurring lag phases will depend on the degree of alternation or damage to the bacterial population (Madigan et al. 2012f).

The exponential growth phase can be referred to as the healthy phase, when bacteria thrive and optimal growth conditions are being met. The rate of exponential growth is influenced by all the previously mentioned environmental conditions as well as by the genetic characteristics of the organism itself (Madigan et al. 2012f).

The stationary phase and death phase are basically when the population reaches a limit found within the closed system and will in some cases eventually die out due to this limit (Madigan et al. 2012f). However, these last two phases are somewhat irrelevant for this thesis since the startup process of an MBBR would most likely end somewhere during the exponential phase.

When analysing or monitoring nitrifying bacterial growth in a MBBR, the most practical method would be to examine and follow up the concentrations of ammonia, nitrite and nitrate.

2.4.3 Biofilms

During the growth of a nitrifying bacterial population on a pre-attached surface area, a biofilm (an attached polysaccharide matrix containing bacterial cells) will eventually form. This happens by the secretion of slime or sticky materials from the cell surfaces and helps the bacteria bind essential nutrients, increase survival and prevent cell detachment. Biofilm typically consists of many species of bacteria and rarely as pure cultures unless cultivated in strict environments (Madigan et al. 2012g).

Biofilm formation is divided into three steps: the first being attachment, which seems to occur when a bacterial cell randomly collides with a surface area; second is colonization, including growth and biofilm development; the third stage is development, when growth continues and biofilm starts to reach out into the water body (Madigan et al. 2012g).

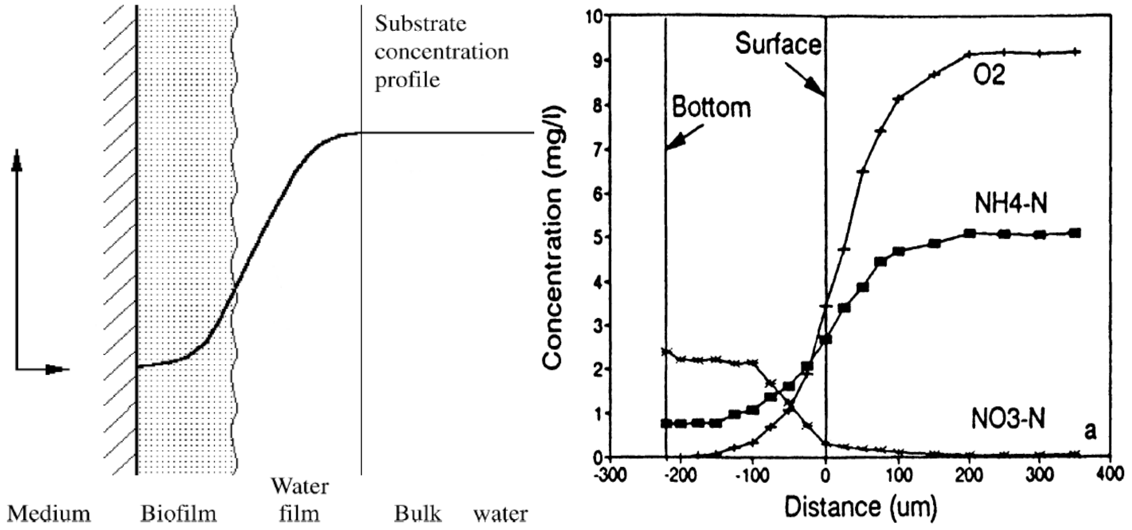


Figure 2.13: "Substrate concentration profiles of a fixed biofilm" (Chen et al. 2006; Zhang et al. 1995).
The conceptual illustration on the left helps to show substrate concentration changes throughout the different zones in a biofilter i.e. biofilm, water film & bulk water. The diagram to the right proves the conceptual illustration by showing actual experimental measurements of oxygen, ammonium-nitrogen & nitrate-nitrogen.

Substrate concentrations and some water quality factors in the bulk water will not be equal to those in or close to the biofilm (Figure 2.13). In fact, they will decrease throughout the depth of the surrounding water and biofilm. Metabolic products on the other hand would be opposite, with higher concentrations within the biofilm compared to the bulk water (Chen et al. 2006; Ulgenes 2009; Zhang et al. 1995).

2.5 Additives in previous startup experiments

During the startup process of a large scale MBBR at The Norfima Centre for Recirculation in Aquaculture in Norway (water source: ground water) the following additives were used to promote growth of nitrifying bacteria (Mydland et al. in press):

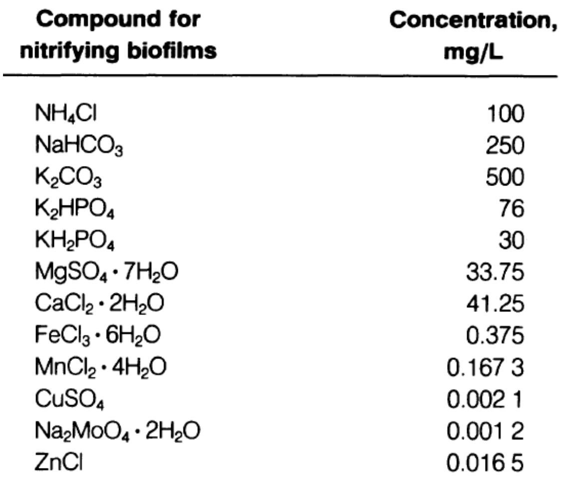
- feed extract
- ammonium chloride (NH_4Cl) up to 5 mg L^{-1} TAN
- sodium nitrite ($NaNO_2$) up to 0.5 mg L^{-1} NO_2^--N
- sodium bicarbonate ($NaHCO_3$) up to 75 mg L^{-1} $CaCO_3$
- inorganic phosphorus (NaH_2PO_4) up to 0.1 mg L^{-1} PO_4^{3-}–P

A small scale experiment (Lekang & Kleppe 2000) studying different types of biofilter media only used the following additives:

- ammonium chloride (NH_4Cl) up to 1.2 mg L^{-1} TAN
- phosphoric acid (H_3PO_4) up to 0.3 mg L^{-1} PO_4^{3-}–P

In a laboratory experiment (Zhang et al. 1995) monitoring biofilm growth in a rotating drum bio reactor, nitrifying bacteria were grown in synthetic wastewater composed of the compounds listed in Table 2.2.

Table 2.2: Compounds used in a rotating drum bio reactor experiment (Zhang et al. 1995).



Compound for nitrifying biofilms	Concentration, mg/L
NH_4Cl	100
$NaHCO_3$	250
K_2CO_3	500
K_2HPO_4	76
KH_2PO_4	30
$MgSO_4 \cdot 7H_2O$	33.75
$CaCl_2 \cdot 2H_2O$	41.25
$FeCl_3 \cdot 6H_2O$	0.375
$MnCl_2 \cdot 4H_2O$	0.167 3
$CuSO_4$	0.002 1
$Na_2MoO_4 \cdot 2H_2O$	0.001 2
$ZnCl$	0.016 5

Two other startup recipes can be found in the attachments (Attachment A and C).

2.6 Startup process

To sum up, the startup process of a biological filter is mainly influenced by the following factors:

- composition of the nitrifying bacterial communities and the genetic characteristics of their respective strains
- size of the nitrifying bacterial start culture
- habitable factors such as space, protection and competition
- water quality and condition factors
- substrate and nutrient availability

Once optimal conditions are present, growth is stimulated. Throughout the time span of the startup process, peaks of metabolic products will occur as they stimulate growth of the "next step consumers". A good example of this process can be seen in Figure 2.14. A somewhat similar process can be expected in the following experiments.

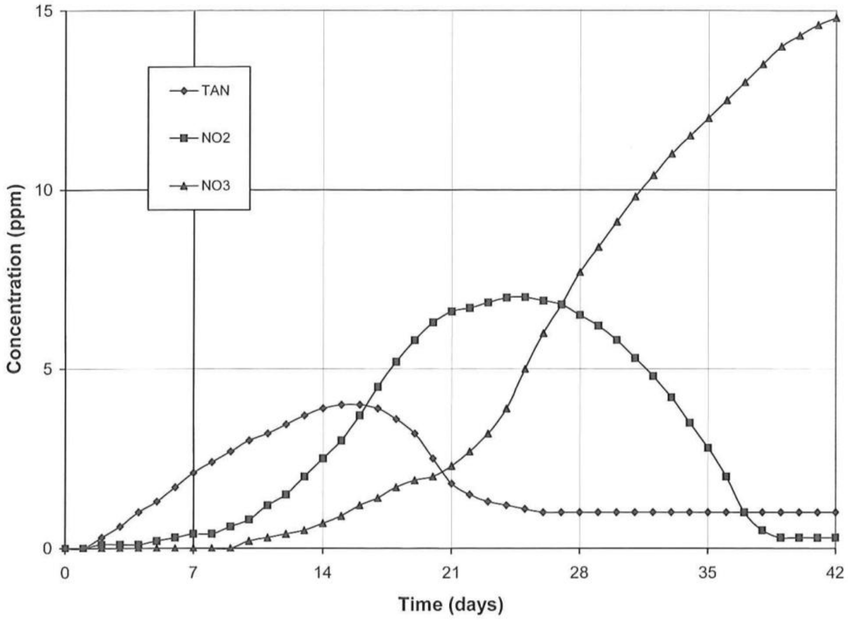


Figure 2.14 "A typical Startup Curve for a biological filter" (Timmons & Ebeling 2007b). Note how TAN is gradually added to the system, the nitrite peak and the accumulation of the end product, nitrate, occurs.

3 Startup of a large scale MBBR from Krüger Kaldnes

Krüger Kaldnes is part of the world wide company Veolia Water Solutions & Technologies and are primarily based in Norway. They deliver a large number of water treatment systems to the Norwegian market including MBBR's to the Norwegian aquaculture industry. One of these large scale industrial MBBR's was recently constructed at a Marine Harvest owned hatchery-smolt farm located in Dalsfjord, Norway. The objective of this experiment was to register and document the startup process of this specific MBBR, in relation to time and nitrite peak occurrence, increasing both understanding and knowledge for future projects.

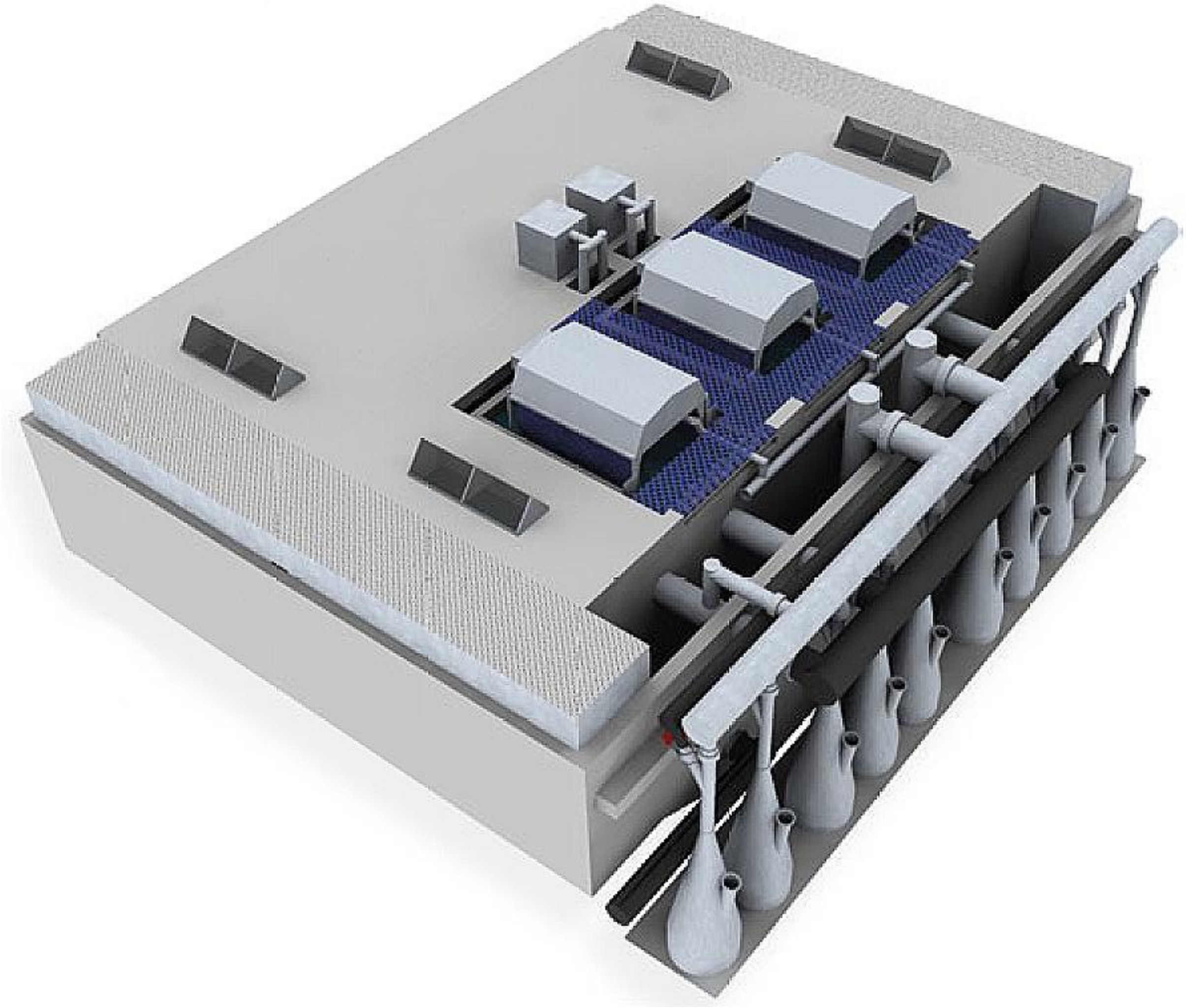


Figure 3.1: "Kaldnes^{tm} RAS" (Kaldnes 2011).
Reactor 1 is located under the three hydrotech drum filters and reactor 2 in the back (top-left) both with two large opening hatches at either end. The CO_2-strippers are located along both sides and the oxygen cones in the front. The two square box shapes in the middle with pipes going down into system are large air pumps connected to the aerating network below.

3.1 A little about the system

The MBBR itself consists of two reactors of equal size, both with an aeration network covering the bottom. As water enters the MBBR, it is pre-treated by three hydrotech drum filters before it flows gravitationally into reactor 1. The water will then overflow into reactor 2 before it flows out into a CO_2-stripper built up of cross flow media. The water is then collected again before it is oxygenated and pumped back to the fish tanks. The system itself is designed so that each fish tank can selectively be run on either recirculation or flow through.

The total water volume capacity of the MBBR is 467 m^3 with a height of approximately 3 meters. During the period of a startup process, the water level would however be lowered resulting in a closed system.

Carriers within the reactor 1 and reactor 2 are of type BiofilmChip^{TM} P and BiofilmChip^{TM} M respectively, summing up to a total volume of approximately 172 m^3 and a close to evenly distributed filling degree of approximately 37%. The specific biofilm surface area is approximately 154 800m^2 (when only the lower of the two media specific surface areas is used in the calculation, i.e. 900m^2/m^3). Reactor 1 is designed to handle a greater organic load than reactor 2 (Section 2.1).

The system has advanced online monitoring equipment, so real-time data and development curves for parameters such as oxygen concentration, temperature, pH and ammonium-nitrogen can be observed whenever needed.

At the end of a startup process, the water level in the MBBR can be raised, connecting it to the whole system. This will allow dilution to occur with new fresh water before fish are introduced to the system.

The MBBR reactor has a high capacity and is dimensioned to handle very large amounts of ammonia. One can therefore expect that no problems could arise in terms of not being able to handle added ammonia concentrations during a startup process and even many months beyond.

3.2 Material and methods

3.2.1 Equipment

The following startup additives were used for the experiment:

- industrial starter fish feed (1mm)
  - 2.26% phosphorus
  - 50% protein (8% nitrogen)
- industrial ammonium chloride (NH_4Cl, 99.5% purity)
- industrial $CaCO_3$ liquid mixture (70% $CaCO_3$)

Water analysis equipment used during the experiment:

- water sampling equipment: long sampling pole with large 500ml bottle attached to end, several 250ml bottles
- Finnpipette* F2 Adjustable-Volume Pipetters – 0.5-5ml w/tips (Attachment Gb)
- Finnpipette* F2 Adjustable-Volume Pipetters – 100-1000µl w/tips (Attachment Gb)
- alkalinity equipment: 50ml Class A Burette with clamp & stand, 0.1M HCl and 100ml glass beaker
- vacuum filtration equipment: fine filter paper (Whatman® Glass microfiber filters GF/A 70mm 1.6µm), water drainage system and measuring cylinder

Water analysis and other instruments used during the experiment:

- HACH LANGE DR2800 spectrophotometer (Attachment E)
- MERCK NOVA 60 Spectroquant® photometer (Attachment F)
- HANNA instruments HI 83203 photometer (Attachment Ga)
- HACH LANGE LT200 Thermostat
- HACH LANGE HQ11D Portable pH meter
- Ohaus MB45 Moisture analyser
- Kitchen scale, 5000g x 1g

The following water analysis cuvette, reagent and cell tests were used during the experiment (Attachment H):

- HACH LANGE cuvette tests:
    - NH_4^+-N cuvette tests
        - LCK304 0.015-2.0 mg/l
        - LCK305 1-12 mg/l
    - NO_2^--N cuvette test
        - LCK341 0.015-0.6 mg/l
    - NO_3^--N cuvette test
        - LCK340 5-35 mg/l
    - COD cuvette tests
        - LCI500 0-150 mg/l
        - LCK314 15-150 mg/l
        - LCK114 150-1000 mg/l
    - PO_4^{3-}-P/TP cuvette tests
        - LCK349 0.05-1.5 mg/l
        - LCK348 0.5-5 mg/l
- MERCK cell tests:
    - NO_2^--N cell test
        - 14547 0.010-0.7 mg/l
    - NO_3^--N cell test
        - 14764 1.0-50 mg/l
- HANNA instruments reagent test:
    - NO_3^--N reagent test
        - HI 93728-0 0.0-30.0 mg/l

3.2.2 Experimental method

The experiment was carried out over the period of 46 days from 12th March to 27th April 2012, lasting from the day NH_4Cl was added to the reactors until the end of the startup process marked by dilution of the system.

The goal of the startup process was to reach a nitrification rate of 0.06 g TAN/m^2 day, equal to 9.36 kg TAN nitrified per day. This was equal to the expected amount of TAN the 1.2 million fry (at 5.27g) would produce when introduced to the system. Once reached, the startup process would continue for a few more days due to security measures, before concluding.

The water used in the experiment came from the natural water source inlet of the facility, a nearby river, and was assumed to already contain nitrifying bacterial populations.

There was a short period before this experiment started of twelve days (1st-12th March), in which the aeration system of the MBBR was turned on giving the carriers time to immerse themselves in the water body.

3.2.2.1 Startup additives

Industrial NH_4Cl was added to both reactors on day 0 (12th March) and spread out as evenly a possible over the water surface below the four opening hatches (Figure 3.1), bringing the ammonium-nitrogen concentration in the whole MBBR rapidly up to 10 mg L^{-1}. This concentration was as much as possible held constant throughout the experiment up until conclusion (Section 2.3.3.1). Concentrations of ammonium-nitrogen were also preferred to be kept below 40 mg L^{-1}, meaning that if the system required higher quantities in one day, then NH_4Cl additions would have to be divided accordingly.

Industrial starter fish feed was also added to the MBBR on day 0 in an equal manner as with NH_4Cl, however only through the two hatches of reactor 1 (Figure 3.1). It was important that the feed was spread out as much as possible in the bulk water body (Section 2.3.6). PO_4^{3-}–P concentrations in the MBBR were to be kept higher than 0.3 mg L^{-1} (Section 2.3.4) throughout the whole startup process in this manner.

An industrial 70% $CaCO_3$ solution was added whenever the pH started to descend towards 6.8 (Section 2.3.1). This was added to the MBBR by dividing the quantity equally among the four opening hatches mentioned earlier.

3.2.2.2 Registered and recorded parameters

The following parameters were measured and recorded throughout the experimental time period:

- NH_4^+–N
- NO_2^-–N
- NO_3^-–N
- PO_4^{3-}–P
- TP
- pH
- alkalinity
- temperature
- O_2
- COD
- SS

NH_4^+–N, pH, temperature and O_2 were constantly monitored and logged by stationed instrument placed in reactor 1 (Attachment J). All the remaining parameters were measured through water sampling and analysis.

NO_2^-–N and NO_3^-–N were measured for when accumulations were clearly present or assumed based expectations.

PO_4^{3-}–P and TP were measured mostly when needed in order to obtain an idea of when and how much industrial starter fish feed needed to be added to the system.

Alkalinity was only measured when needed since changes in pH were the main decisive factor for when to add the industrial 70% $CaCO_3$ solution.

COD and SS were parameters of somewhat lesser importance, which were only measured a few times throughout the experimental period.

3.2.2.3 Water sampling and analysis

Water samples were taken by help of a long rod, with a bottle attached to the end, which reached down into the reactors through the opening hatches. The attached bottle had an opening just large enough to not allow carries in and was rinsed out, in the respective area of sampling, 3-4 times before used. Water collected in this manner was then transferred into small 250ml bottles before being transported to desired location for analysis or frozen immediately for later analysis. The same opening hatch of the respective reactors was used each time a sample was taken.

One water sample was taken each day during the experiment. Or two in some cases to compare between samples. From day 15 (27th March) until the end of the experiment, all water samples were only taken from reactor 2.

Diluting the analyte, to a concentration that could be measured with the respective water analysis cuvette, reagent or cell test (Section 3.2.1), was one of the forms of sample preparation carried out in this experiment. Dilutions were made with tap water (allowed to run for a little in order to minimize influence from the water system) and the Finnpipette* F2 Adjustable-Volume Pipetters.

The only other form of sample preparation carried out in this experiment was filtering the analyte, using vacuum filtration equipment (Section 3.2.1). This was done for orthophosphate-phosphorus measurements, ensuring minimal influence from particle bound phosphates (such as polyphosphates and organophosphates) during analysis.

Further details on the measuring procedure and quality of the respective water analysis cuvette, reagent or cell test can be found in Attachment H.

Replicate measurements of one analyte were not made in this experiment as single measurements provided enough data to observe a trend over time. Another aliquot would however be taken if a gross error is assumed due to unexpected measurements from the first aliquot.

Alkalinity measurements followed standard procedures with a 50ml burette, 0.1M HCl and a 100ml glass beaker. However, the HACH LANGE HQ11D Portable pH meter was used to stir between readings due to the lack of a magnet stirrer.

Due to the lack of equipment (moisture analyser), SS measurements had to be done partly on site, using vacuum filtration equipment (Section 3.2.1), and in the fish laboratory of the Norwegian University of Life Sciences, i.e. utilised filter papers were carefully transported down in separate closed containers, before being dried and weighed using the University's Ohaus MB45 Moisture analyser.

All sample preparations, measurements and calculations were registered and managed using Microsoft Excel.

3.3 Results

The startup process concluded on day 44 (25th April) and the MBBR was diluted the same day. The last experimental water sample was taken on day 46.

The nitrification rate started to rise above 0.015 gTAN/m^2·day from day 32 and reached the startup process goal on day 34 at 0.060 gTAN/m^2·day.

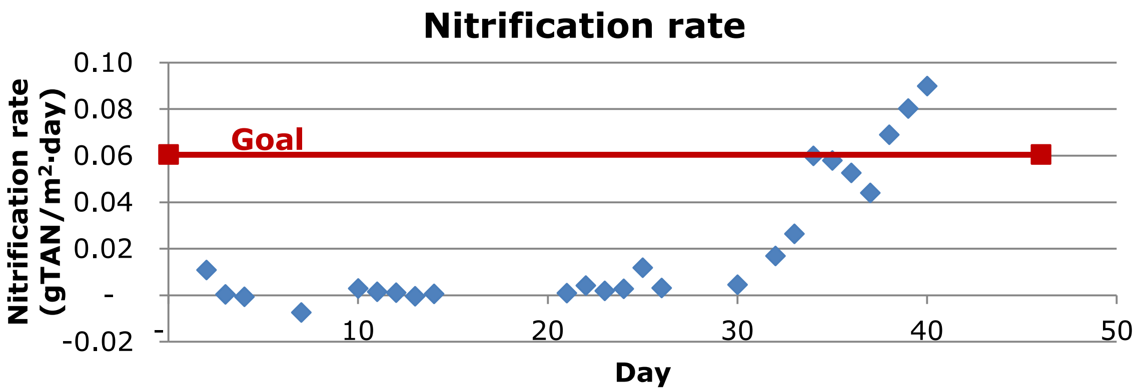


Figure 3.2: Daily nitrification rates throughout the startup process.

However, the trend then started to decline until it picked up again from day 37, at 0.044 gTAN/m^2·day. The nitrification rate reached 0.069 gTAN/m^2·day and 0.090 gTAN/m^2·day on day 38 and 40, respectively (Figure 3.2).

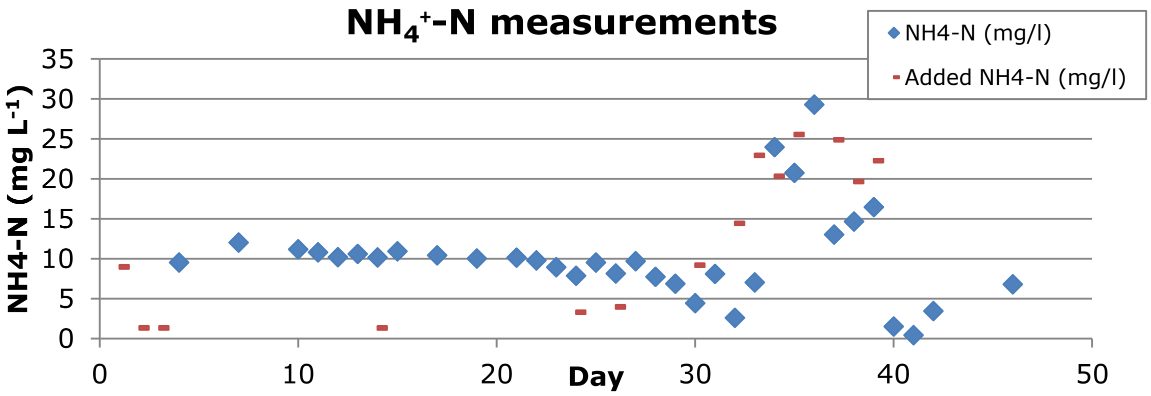


Figure 3.3: Ammonium-nitrogen measurements and added amounts

Ammonium-nitrogen measurements started to form a decreasing trend from day 20, becoming very unstable and varying from 29 – 0.4 mg L^{-1} after day 30 (Figure 3.3).

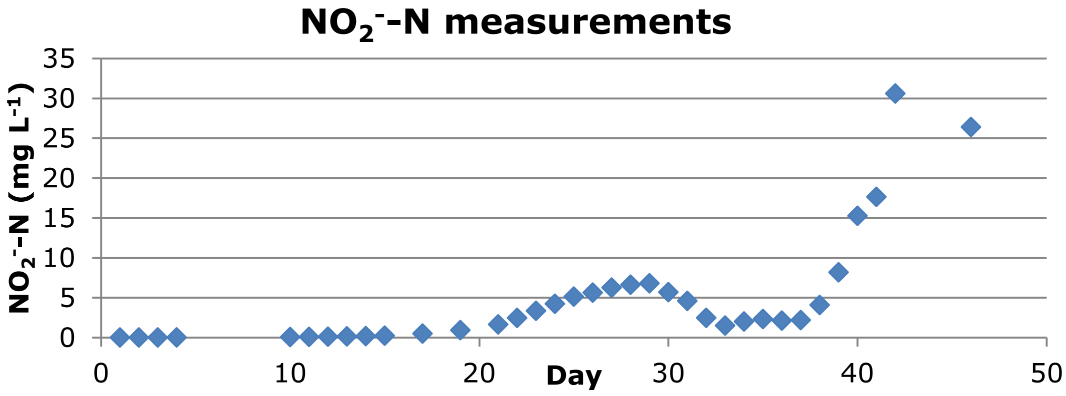


Figure 3.4: Nitrite-nitrogen measurements.

Nitrite-nitrogen measurements started to increase from above 1 mg L^{-1} from day 21, leading to a peak top of 6.8 mg L^{-1} on day 29. From day 32 until 37, measurements were stable under 2.5 mg L^{-1} with a lowest value of 1.5 mg L^{-1} on day 33. A close to exponential trend was then observed from day 37 until 42. On day 46, nitrite-nitrogen was measured to 26.4 mg L^{-1} (Figure 3.4).

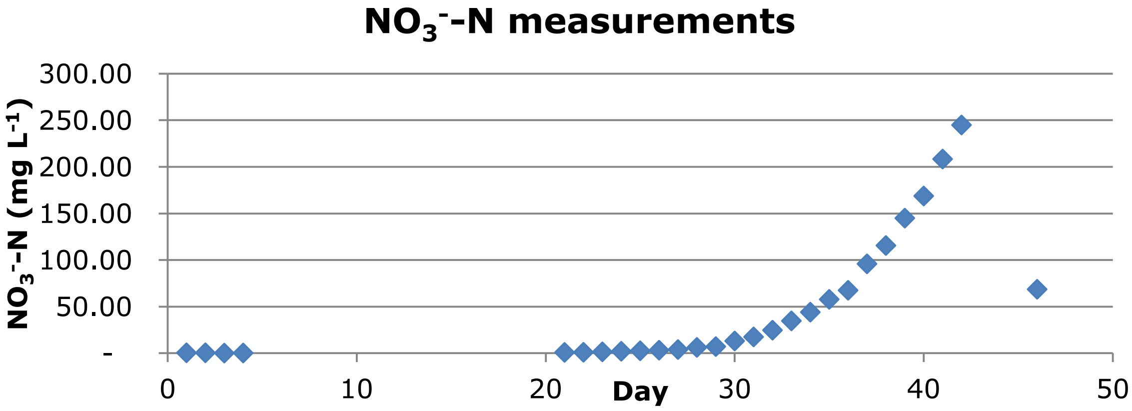


Figure 3.5: Nitrate-nitrogen measurements.

The first measurements of nitrate-nitrogen were made with frozen samples sent down to the University, making it possible to read lower concentrations than 1 mg L^{-1}. Detectable concentrations on site (>1 mg L^{-1}) were otherwise not present until day 21. From then on, measurements of nitrate-nitrogen concentrations grew gradually, reaching 13.1 mg L^{-1}, 57.8 mg L^{-1} and 245 mg L^{-1} on day 30, 35 and 42 respectively. On day 46, nitrate-nitrogen was measured to 68.6 mg L^{-1} (Figure 3.5).

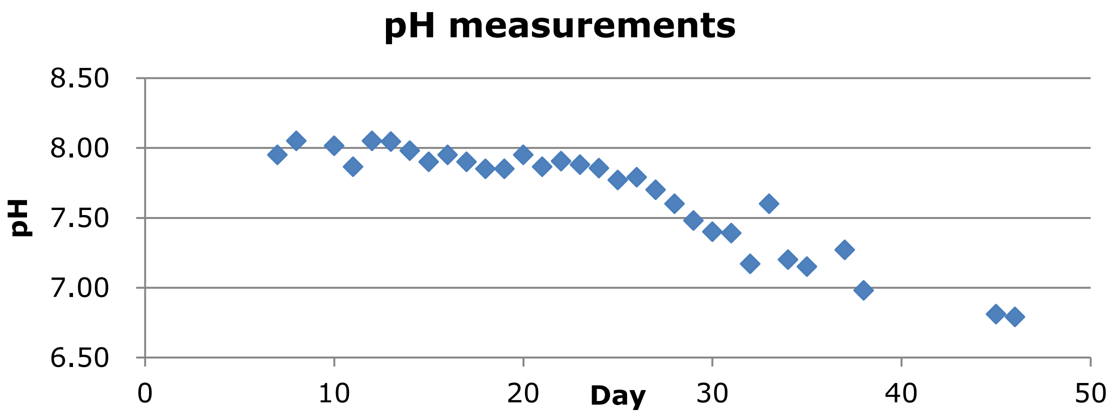


Figure 3.6: pH measurements.

pH readings in the MBBR started to decline from 7.91 on day 22, reaching 7.17 on day 32. After this, measurements showed variations from pH 7.60 – pH 6.98. On day 45 and 46 the pH values were 6.81 and 6.79, respectively (Figure 3.6).

Large amounts of $CaCO_3$ were added from day 31 until the end of the startup period ranging from 40-80 litres of the solution. $CaCO_3$ was added shortly after the pH readings were taken on day 46.

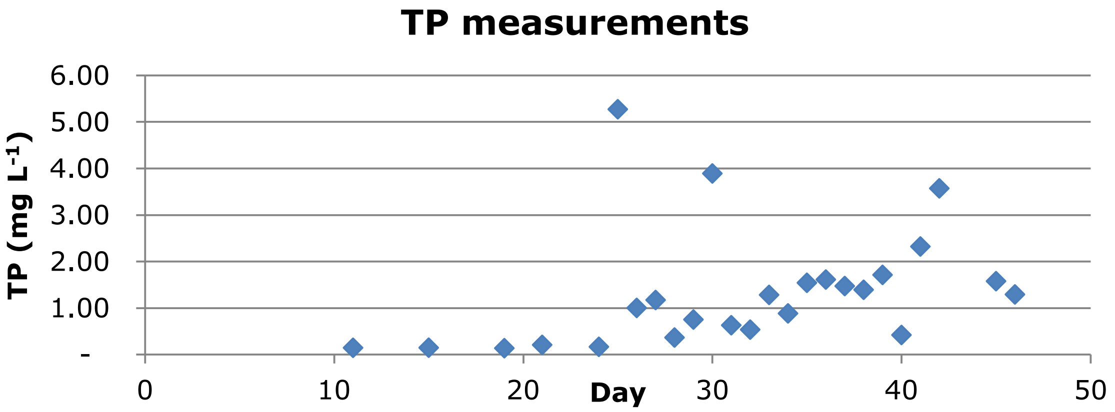


Figure 3.7: Total phosphorus measurements.

Total phosphorus measurements between day 11 and day 24 ranged from 0.13 mg L^{-1} to 0.16 mg L^{-1}. Measurements from day 25 until 42 varied between 5.27 mg L^{-1} and 0.36 mg L^{-1}, with a slightly increasing trend. Two measurements were then taken after MBBR dilution, i.e. 1.58 mg L^{-1} and 1.29 mg L^{-1} on day 45 and 46, respectively (Figure 3.7).

Industrial starter fish feed was added as followed: 4 kg on day 1, 1 kg on day 2, 8 kg on day 14, 15 kg on day 24, 8 kg on day 26, 6 kg on day 31 and 4 kg on day 32. From day 33 until the end of the startup period larger amounts were added almost every day ranging from 16-36 kg.

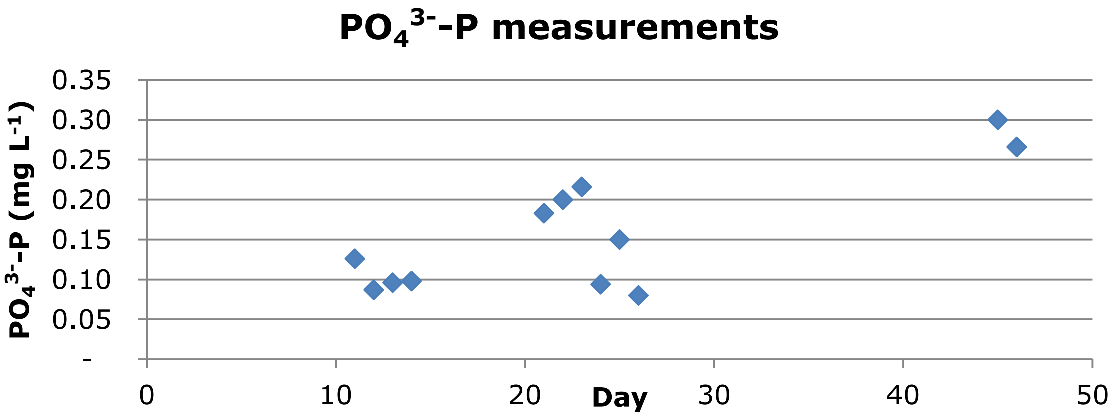


Figure 3.8: Orthophosphate-phosphorus measurements.

Orthophosphate-phosphorus measurements varied between 0.09 mg L^{-1} and 0.22 mg L^{-1} during the period from day 11 – 26. Two measurements were then taken after MBBR dilution, i.e. 0.30 mg L^{-1} and 0.27 mg L^{-1} on day 45 and 46, respectively (Figure 3.8).

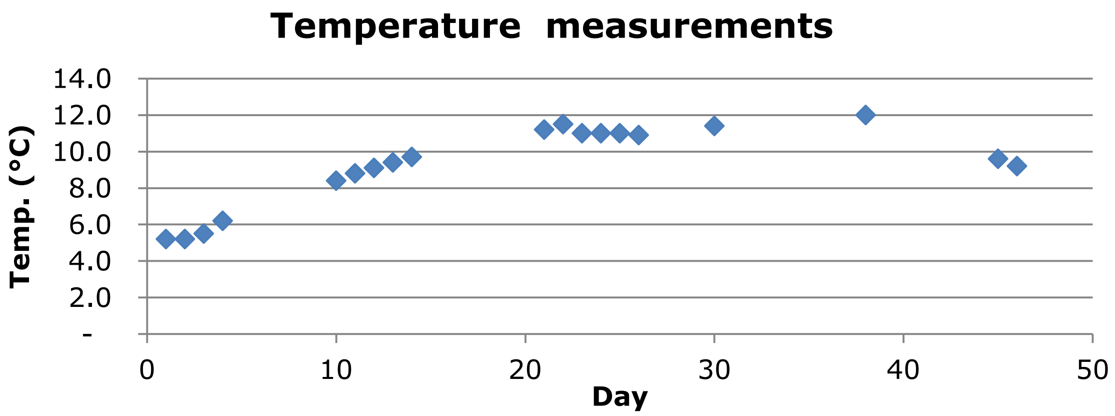


Figure 3.9: Temperature measurements.

The temperature in the MBBR showed a clear increasing trend throughout the first 20 days, from 5.2°C to 11.2°C on day 1 and 21, respectively. Between day 20 - 40 it stabilized, ranging between 10.9°C and 12.0°C. On day 45 and 46, after dilution, the temperature was 9.6°C and 9.5°C, respectively (Figure 3.9).

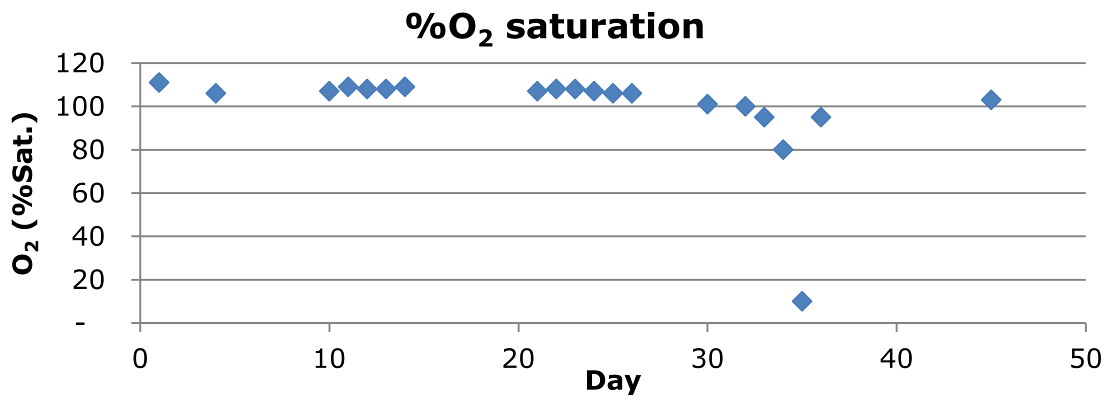


Figure 3.10: Oxygen saturation measurements.

Oxygen levels were stable between 112% saturation and 100% saturation throughout the whole experiment, besides a four day period from day 33 – 36. Oxygen levels reached 10% saturation on day 35, before rising up again shortly after (Figure 3.10).

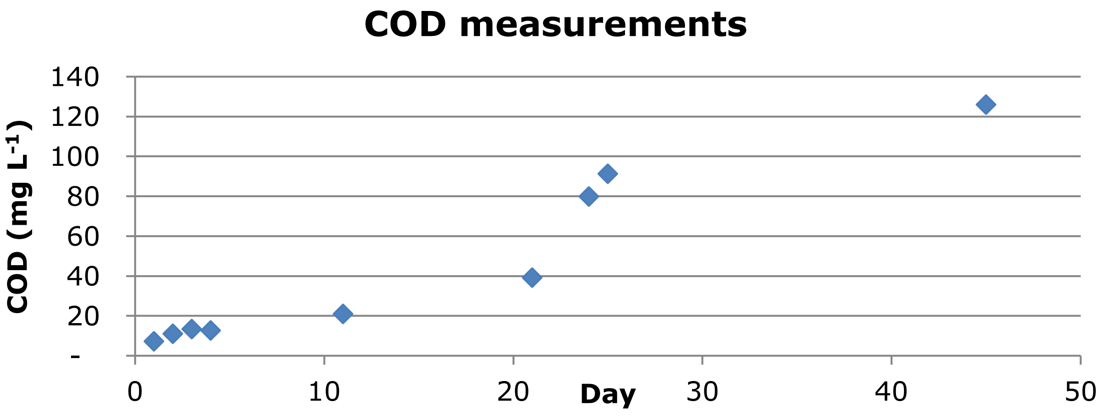


Figure 3.11: COD measurements.

COD measurements showed a gradually increasing trend from day 7 at 7 mg L^{-1} to day 21 at 39 mg L^{-1}. Just three days later, on day 24 the values had already doubled to 80 mg L^{-1}, reaching 91 mg L^{-1} on day 25. From then on, no more measurements were taken until after MBBR dilution, i.e. 126 mg L^{-1} on day 45 (Figure 3.11).

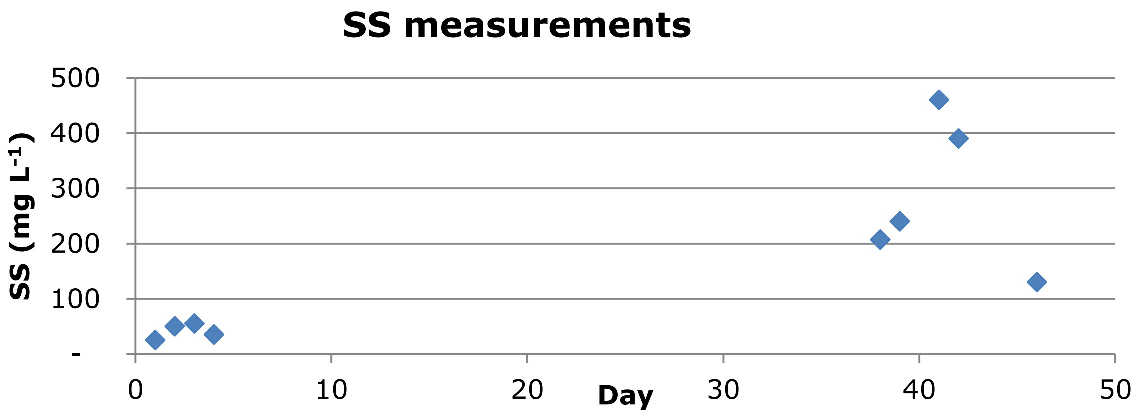


Figure 3.12: SS measurements.

SS measurements showed a gradually increasing trend, starting from an average value of 41 mg L^{-1} between day 1 – 4 and ending at an average value of 324 mg L^{-1} between day 38 – 42. On day 46, SS was measured to 130 mg L^{-1} (Figure 3.12).

Alkalinity measurements varied within the range of 1.02 meq L^{-1} - 2.00 meq L^{-1} from day 1 – 26. Only one measurement was taken after this, on day 37: 4.00 meq L^{-1}.

For more details such as measurement methods and accuracies, analyses repetitions, rejected values, dilutions etc. refer to Attachment K.

3.4 Discussion

Overall the startup process of the MBBR was successful in that the process went very well and the nitrification rate goal was achieved in good time.

3.4.1 Discussion of experimental setup

The registration and documentation process went well throughout the experimental time period, besides the fact that some final data was lacking i.e. water samples for day 43 and 44 were not taken due to a misunderstanding between those involved in the experiment. Samples and/or data were otherwise collected for all the other days.

Ammonium chloride as a startup additive work really well, the chemical dissolved and dispersed itself quickly throughout the MBBR.

Orthophosphate-phosphorus concentrations in the MBBR couldn’t be brought up to the level desired (0.3 mg L^{-1}) and were hard to control. This could be due to the usage of fish feed pellets with high water stability as a source of phosphorus, i.e. it is hard to know how fast the fish feed is degraded and the rate that phosphorus is released out into the bulk water body. Also making it difficult to predict how much feed needs to be added to the MBBR at a given time. There was still, however, good bacterial development, suggesting sufficient amounts of Orthophosphate-phosphorus.

$CaCO_3$ functioned well as a startup additive and effects were observed shortly after additions to the MBBR. When comparing the continuously online measurements of pH to the time consuming and “in need of manpower” alkalinity measurements, it is easy to understand that $CaCO_3$ was added to the MBBR according to changes in pH and not alkalinity.

The total water volume of the MBBR was estimated to 400 m^3 since the water level was approximately 60 cm lower than what it was meant to be while connected to the whole RAS. Hence, the filling degree during the startup process was 43%.

MBBR dilution took place on day 44. It can be discussed whether this could have been done earlier, an issue which has to be weighed up against a security factor for successful transition from the startup phase to the fish introduction phase.

3.4.2 Discussion of experimental results

The MBBR was mostly stable for the first 20 days, besides the fact that the temperature was gradually increasing (Figure 3.6).

One point which should be brought up is the drop in oxygen saturation towards day 35. The drop started to occur already a few days before, as the nitrification rate increased, meaning that AOB were most likely connected in some manner. Also due to the fact that the nitrification rate sank and recovered, at approximately the same time as the oxygen problem and after, respectively. The NOB on the other hand didn't seem to be effected at all as the nitrate-nitrogen trend curve continued undisturbed. Ammonia oxidation was in other words sufficient to keep the NOB growing, despite the disturbed NOB population. One could notice that it took approximately 3 days before the nitrification rate was restored, a time period which can be regarded as a reoccurring lag phase for the AOB (Section 2.4.2).

The large variation and instability of ammonium-nitrogen measurements after day 30 is due to the fact that large amounts of NH_4Cl were being added to the system at varying times of the day.

If water samples for day 43 and 44 had been taken, nitrite-nitrogen concentrations for those days could be assumed to approximately 42 and 59 mg L^{-1}, respectively, given that they follow the growth trend. The same can be calculated for nitrate-nitrogen, which would be approximately 298 and 356 mg L^{-1}, respectively.

The time and magnitude of nitrite-nitrogen peak and nitrate-nitrogen increase fit very well with the "typical Startup Curve for a biological filter" from Timmons and Ebeling (2007b) (Section 2.6).

One could also observe a clear increasing trend for total phosphorus measurements, so some fish feed degradation was occurring. If one looks at the total amount of phosphorus added to the MBBR through fish feed (2.26% phosphorus) up to day 39 i.e. approximately 10.3 mg L^{-1}, and subtract the total phosphorus from the water sample measurement for that same day i.e. 1.7 mg L^{-1}, one is left with an estimate for particle bound phosphorus i.e. 8.9 mg L^{-1}. This could have been bound as feed/organic matter or by bacteria.

If one would assume that all particle bound phosphorus is bound as bacterial cells, one could find the approximate weight of the developed bacteria using % phosphorus of a bacterial cell values (Section 2.4.1). This results in a total bacterial weight of 142.5 kg or 920 mg per m^2 MBBR surface area. This would result in an average biofilm depth of 0.9 µm throughout the whole MBBR, if one assumes a bacterial cell density close to that of water. In comparison to a fully developed biofilm this is close to nothing (Section 2.4.3).

Very few COD measurements were taken during the experimental time period. It was therefore difficult to state how high COD values actually were before the dilution process.

Carbon dioxide concentrations were assumed constant at levels close to 1 mg L^{-1}, and were therefore not measured. This was due to the high amounts of aeration in the MBBR.

3.5 Conclusion

- The registration and documentation process of the startup process of the large scale industrial MBBR went well, besides the fact that some final data was lacking.

- The startup process went very well in relation to time, nitrite peak occurrence and bacterial growth of both AOB and NOB, observed through NO_2^--N and NO_3^--N measurements.

- There was little control over the addition of the orthophosphate-phosphorus source “Industrial starter fish feed”. Due to the fact that additions couldn’t be related to measurements.

4 Comparing startup methods of MBBR – A small scale experiment

The following experiment was carried out in the fish laboratory of the Norwegian University of Life Sciences. The objective was to attain more knowledge on how different startup additives and bacterial start culture sizes affect the startup process of MBBRs.

Four different startup methods were therefore compared:

1. Krüger Kaldnes method
2. Prof. Jon Fredrik Hanssen's method
3. Krüger Kaldnes method with close to zero bacterial start culture
4. Krüger Kaldnes method with bacterial start culture boost

The idea of the first startup method was to mimic as much possible the method used in the previous experiment, however on a much smaller scale and with slightly different water- and additive sources.

The second was a method introduced by Prof. Jon Fredrik Hanssen from the IKBM department of the Norwegian University of Life Sciences (Attachment A).

The last two were similar to the first startup method, however with different bacterial start culture sizes i.e. bigger and smaller.

All other experimental variables between the different startup methods were kept as equal as possible, such as filling rate, aeration, water volume, possible contaminants, temperature, lighting etc.

A small 3-day technical pre-trial experiment was carried out beforehand to test out how a fill rate of 40% would influence the circulating movement of the carriers in a 10 litre bucket with an active aerator stone placed inside. Good results were observed even though a lot of water was lost due to evaporation. The carriers circulated well already after day 1. Conclusions were that lids should be added to buckets, and that RO water should be added to correct for evaporation.

4.1 Material and methods

4.1.1 Equipment

The following equipment was in the technical setup of the experiment:

- 8 x 10 litre buckets w/lids (with at least 4 cm of extra height above 10 litre mark)
- 8 x 600 grams ±1 (approximately 4 litres) of BiofilmChips^{TM} P
- aeration equipment: air pump (large enough to ensure adequate turbulence), distributor with at least 8 outlet valves, piping, 8 air stones and 8 suction cups

Water types used for the experiment were:

- 60 l of natural untreated raw lake water from water source (Attachment B)
- 20 l of treated drinking water from water source (Attachment B)
- RO water

The following startup additives were used for the experiment:

- Krüger Kaldnes startup additives:
    - ammonium chloride, NH_4Cl
    - starter fish feed (1 mm)
    - calcium carbonate, $CaCO_3$
- Prof. Jon Fredrik Hanssen's startup additives:
    - dipotassium phosphate, K_2HPO_4
    - magnesium sulfate heptahydrate, $MgSO_4 * 7H_2O$
    - ferrous sulfate heptahydrate, $FeSO_4 * 7H_2O$
    - ammonium sulfate, $(NH_4)_2SO_4$
    - sodium nitrite, $NaNO_2$
    - calcium carbonate, $CaCO_3$
- EasyLife® Easy Start Beneficial Bacteria Booster (Attachment D)

Water analysis equipment used during the experiment:

- water sampling equipment: a couple of small 50 ml glass beakers and minimum 8 small 15 ml glass screw top containers
- Finnpipette* F2 Adjustable-Volume Pipetters – 0.5-5ml w/tips
- Finnpipette* F2 Adjustable-Volume Pipetters – 100-1000µl w/tips
- 25ml and 50ml Class A volumetric flasks
- alkalinity equipment: 50ml Burette with clamp & stand, 0.1M HCl, magnet stirrer and 25ml glass beaker
- vacuum filtration equipment: fine filter paper (PALL Life Sciences GH Polypro 47 mm 0.45 µm), water drainage system and measuring cylinder

Water analysis and other instruments used during the experiment:

- WTW Thermoreactor CR 3200
- OxyGuard Handy MK
- OxyGuard CO_2 analyser
- PHM 80 Portable pH Meter
- Ohaus MB45 Moisture analyser
- MERCK NOVA 60 Spectroquant® photometer

The following MERCK water analysis tests and cell tests were used (Attachment I):

- NH_4^+–N test
  - 14752 0.05 – 3.00 mg/l 10-mm cell
    0.01 – 0.5 mg/l 50-mm cell
- NO_2^-–N test
  - 14776 0.02 – 1.00 mg/l 10-mm cell
    0.002 – 0.2 mg/l 50-mm cell
- NO_3^-–N test
  - 09713 1.0 – 25.0 mg/l 10-mm cell
    0.1 – 5.0 mg/l 50-mm cell
- PO_4^{3-}–P test
  - 14848 0.05 – 5.0 mg/l 10-mm cell
    0.01 – 1.0 mg/l 50-mm cell
- COD cell test
  - 14560 4.0 – 40.0 mg/l

4.1.2 Experimental method

The experiment was carried out over the period of 84 days from 14th March – 6th June 2012, lasting from the day substrates were added to their respective bucket until a clear nitrite peak had passed and it seemed reasonable to conclude.

2 experimental repetitions were made for each of the four different startup methods, thus, resulting in a total of 8 identical individual setups.

4.1.2.1 Technical setup

Each individual setup consisted of a 10 litre bucket (with a clear 10 litre mark), a lid and 600 grams ±1 (approximately 4 litres) of BiofilmChips^{TM} P, and was stationed equally on a flat levelled surface, to minimize water loss over the edges. A little outlet on the centre of the lid was created to prevent the build-up of unwanted gases during the experiment (Figure 4.1).

Figure 4.1: The technical setup of the small scale experiment (Holdhus 2012).

The aeration equipment was then assembled by first placing the air pump, with the attached distributor, somewhere safe and above the overall maximum water level of the experiment.

Eight equal lengths of air piping were then cut and attached to different outlet valves of the distributor. The equal lengths of piping and their respective valves allowed minimization of aeration differences between each individual setup during the experiment.

Air stones with attached suction cups were then attached to their respective pipe ends and attached to the bottom of each bucket.

Each individual setup was marked from B1-B8.

The individual setups themselves and all equipment which had direct access to each setup were thoroughly rinsed with tap water (allowed to run for a little in order to minimize influence from the water system) before utilized to minimize outside influence during the experiment.

Aeration equipment was turned on after water was added to all the individual setups.

4.1.2.2 Startup additives

The different startup methods were each connected to two individual setups before water and additives (Section 4.1.1) were added to each setup on day 1 as followed:

startup method 1:

- individual setups: B1 and B2

addition:	*amount/concentration:*
- natural untreated raw lake water	10L
- ammonium chloride	10mg NH_4^+–N L^{-1}

startup method 2:

- individual setups: B3 and B4

addition:	*amount/concentration:*
- natural untreated raw lake water	10L
- ammonium sulfate	10mg NH_4^+–N L^{-1}
- sodium nitrite	3.5mg NO_2^-–N L^{-1}
- dipotassium phosphate	1g L^{-1}
- magnesium chloride hexahydrate	0.5g L^{-1}
- ferric chloride hexahydrate	0.4g L^{-1}

startup method 3:

- individual setups: B5 and B6

addition:	*amount/concentration:*
treated drinking water	10L
ammonium chloride	10mg NH_4^+–N L^{-1}

startup method 4:

- individual setups: B7 and B8

addition:	*amount/concentration:*
natural untreated raw lake water	10L
bacterial booster	0.2ml L^{-1}
ammonium chloride	10mg NH_4^+–N L^{-1}

Calcium carbonate was added to each individual setup whenever the pH started to descend towards 6.8 (Section 2.3.1).

Starter fish feed for Krüger Kaldnes startup methods were added when needed. PO_4^{3-}–P concentrations were to be kept higher than 0.3 mg L^{-1} (Section 2.3.4) throughout the whole startup process in this manner.

Ammonium-nitrogen additions were added to their respective individual setups whenever a concentration below 10 mg L^{-1} was expected or measured. This concentration was as much as possible held constant throughout the experiment up until conclusion (Section 2.3.3.1). Concentrations of ammonium-nitrogen where also preferred to be kept below 40 mg L^{-1}, meaning that if the higher quantities were required in one day, then additions would have to be divided accordingly.

Sodium nitrite was added again to B3 and B4 on day 14 bringing the NO_2^-–N concentration up to 10 mg L^{-1}.

All chemicals were first weighed out, using the Ohaus MB45 Moisture analyser, and dissolved in small 50ml beakers with RO water before being added to the respective individual setups.

4.1.2.3 Registered and recorded parameters

The following parameters were measured and recorded throughout the experimental time period:

- NH_4^+–N
- NO_2^-–N
- NO_3^-–N
- PO_4^{3-}–P
- pH
- alkalinity
- temperature
- O_2
- CO_2
- COD
- SS

NH_4^+–N and NO_2^-–N were constantly monitored through water sampling and analysis and pH constantly through direct measurements.

O_2, CO_2, temperature and alkalinity were also measured constantly, however only for the first 35 days. From day 37 until the end of the experiment, they were only measured as needed.

NO_3^-–N was also measured constantly at first. However, as this proved out to be too costly, fewer measurement were taken, and only when needed.

PO_4^{3-}–P was measured mostly when needed in order to obtain an idea of when starter fish feed needed to be added to the system. This parameter couldn't actually be measured until after day 27 due to the lack of a PO_4^{3-}–P analysis test kit.

COD and SS were parameters of somewhat lesser importance and were only measured as start and end values throughout the experimental period.

4.1.2.4 Water sampling and analysis

Water samples were taken from their respective individual setups using the Finnpipette* F2 Adjustable-Volume Pipetters and disposable head tips. Water collected in this manner was then transferred directly into small clean 15ml glass screw cap containers for analysis. In some cases however (some NO_3^-–N measurements), small 2ml samples would be frozen immediately for later analysis.

Water samples were taken one time a day with 1-3 day intervals depending on the nitrification rate and bacterial activity.

Diluting the analyte, to a concentration that could be measured with the respective water analysis tests and cell tests (Section 3.2.1), was carried out when needed, in this experiment. Dilutions were made with RO water and tap water (allowed to run for a little in order to minimize influence from the water system) with the Finnpipette* F2 Adjustable-Volume Pipetters and Class A volumetric flasks, respectively. The first mentioned method would be used with dilutions equal and up to x50, whilst the later for all greater than x50.

Filtering analytes for orthophosphate-phosphorus measurements was not done on a regular basis, in this experiment. This was due to the fact that, with the available equipment (Section 3.2.1), it was a very time consuming procedure. An approximate error of analysis was therefore estimated by comparing sample measurements before and after filtration.

Further details on the measuring procedure and quality of the respective water analysis tests and cell test can be found in Attachment I.

Replicate measurements of one analyte were in general not made in this experiment as single measurements provided enough data to observe a trend over time. Another aliquot would however be taken if a gross error is assumed due to unexpected measurements from the first aliquot.

Alkalinity measurements were made following standard procedures and equipment (Section 3.2.1). However, 25ml instead of 100ml glass beakers were used due to the size of the experimental individual setups.

SS measurements were done following standard procedures with vacuum filtration equipment (Section 3.2.1).

No water sampling was done for parameters such as pH, O_2, CO_2 and temperature, as measurement took place directly in the respective individual setups with their respective instruments (Section 3.2.1). All instruments were rinsed thoroughly with tap water (allowed to run for a little in order to minimize influence from the water system) before and between individual measurements.

All water samples taken were done with the awareness that as little water as possible should be removed from the respective individual setups, due the size of the experiment. As water levels did however decrease over time, RO water was added, bringing the respective water levels up to 10 litres again. This was always done in good time before or after measurements, in order to minimize possible influence.

All sample preparations, measurements and calculations were registered and managed using Microsoft Excel.

4.1.2.5 Changes in experiment

On day 37 a major change occurred in the experimental setup. Before day 37 the whole setup was kept on a levelled table exposed to 24 hour light from the lights in the room (Figure 4.1). After day 37, 1 individual setup from each of the respective startup methods was moved into dark black tanks, so they were exposed to almost no light at all (besides when taking water samples).

The following 4 individual setups were kept where they were: B2, B4, B6 and B8. And following 4 where moved into total darkness: B1, B3, B5 and B7.

Another small adjustment was made after observing lack of dissolving fish feed two days after the first addition on day 15. Fish feed was from then on allowed to dissolve a little prior to addition by intensely shaking it in DO water, in small 15 ml glass screw top containers.

4.2 Results

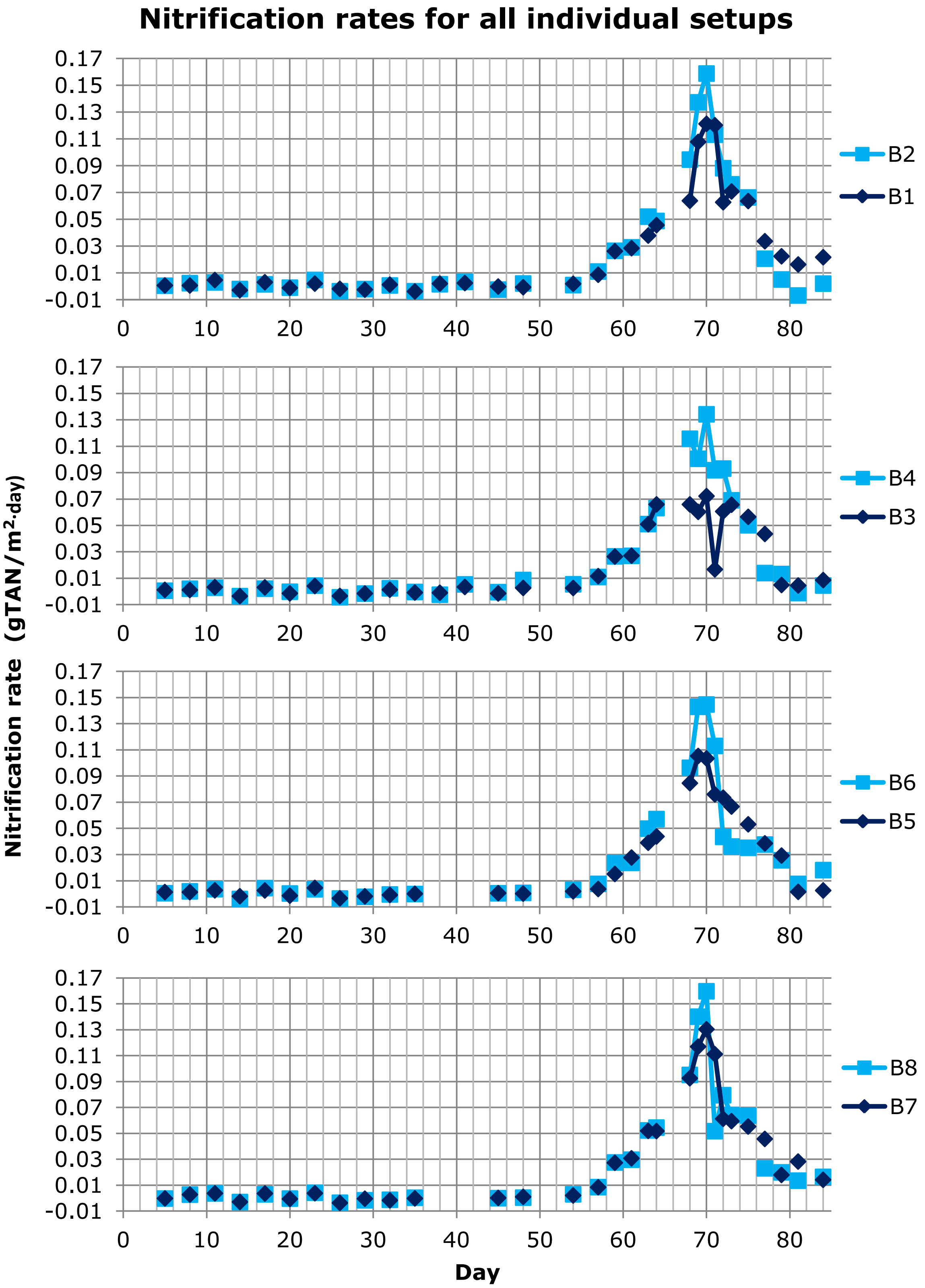


Figure 4.2: Daily nitrification rates throughout the experiment for individual setups. Lines between measurements are for guideline purposes and do not indicate actual values.

Nitrification rates for the individual setups started to rise from day 37 and reached their peaks on day 69-70 (Figure 4.2) with an average maximum nitrification rate of 0.13 gTAN/m^2·day. The setups in the light and dark showed an average maximum rate of 0.11 gTAN/m^2·day and 0.15 gTAN/m^2·day, respectively (Figure 4.3).

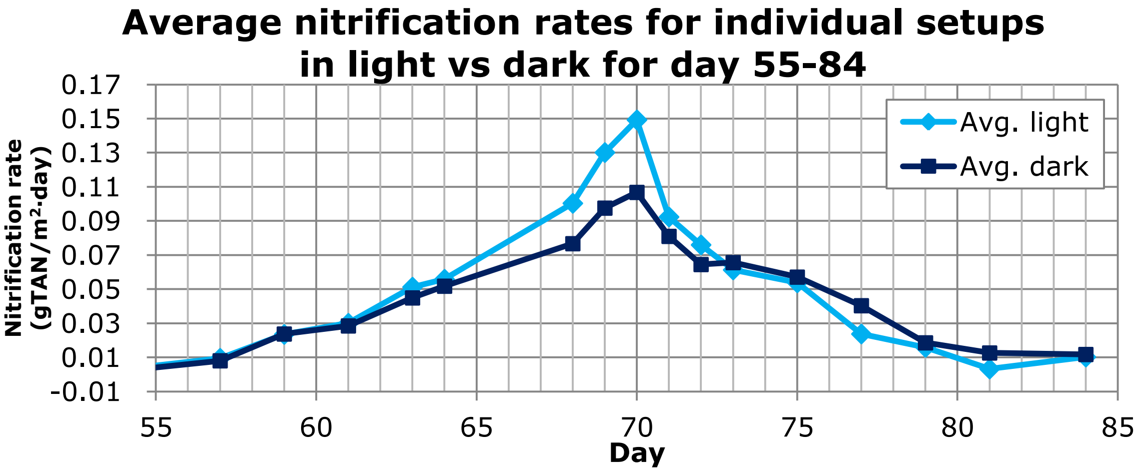


Figure 4.3: Average nitrification rates for individual setups in light vs. dark for day 55-84, were individual setups in light = "Avg. light" and individual setups in dark = "Avg. dark". Lines between measurements are for guideline purposes and do not indicate actual values.

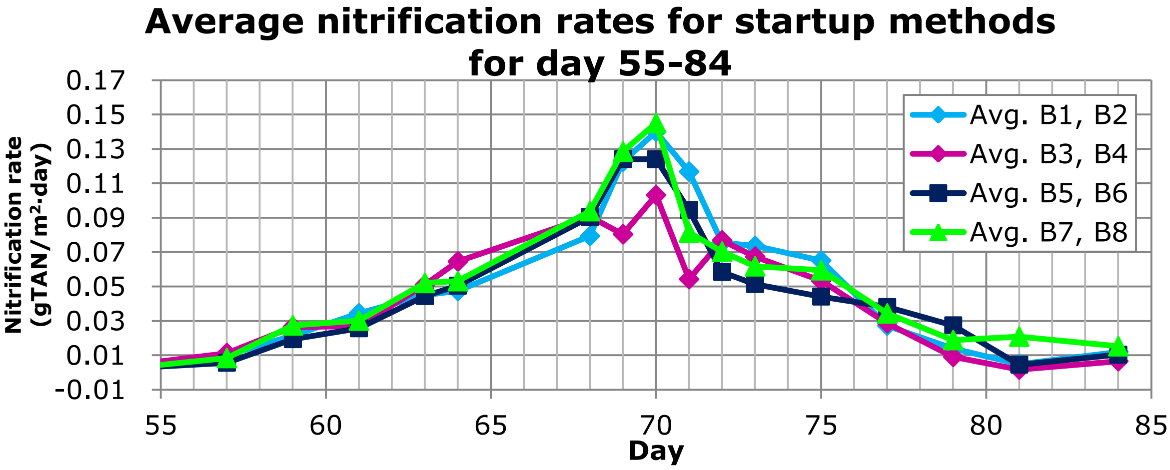


Figure 4.4: Average nitrification rates for all four startup methods for day 55-84, were startup method 1 = "Avg. B1, B2", startup method 2 = "Avg. B3, B4", startup method 3 = "Avg. B5, B6" and startup method 4 = "Avg. B7, B8". Lines between measurements are for guideline purposes and do not indicate actual values.

Startup methods 1 and 4 showed the highest average nitrification rates with peaks measured at 0.140 and 0.145 gTAN/m^2·day, respectively. Startup method 3 followed up at a peak of 0.124 gTAN/m^2·day, whilst startup method 4 peaked at a mere average of 0.103 gTAN/m^2·day (Figure 4.4).

Individual setups exposed to light showed a significantly higher nitrification rate than those in the dark, on day 70. From day 69 to 71, startup method 1 showed significantly higher nitrification rates than startup method 2. No other significant differences for nitrification rates between startup methods or light vs. dark regimes were found throughout the whole experiment.

Ammonium-nitrogen measurements for a majority of the individual setups were rather stable for the first 54 days of the experiment, varying close to 10 mg L^{-1}. After day 54, measurements varied from 74.0 mg L^{-1} in B3 to undetectable values in all individual setups, averaging at 14.7 mg L^{-1} (Figure 4.5 – 4.8).

Nitrite-nitrogen peaks for startup method 2 were significantly lower than for all other startup methods, averaging at 0.42 mg L^{-1}. Average peak for all setups, disregarding startup method 2, was 14 mg L^{-1}.

Individual setup B1 reached the highest nitrite-nitrogen peak of all setups, measuring 47 mg L^{-1} on day 61 (Figure 4.5).

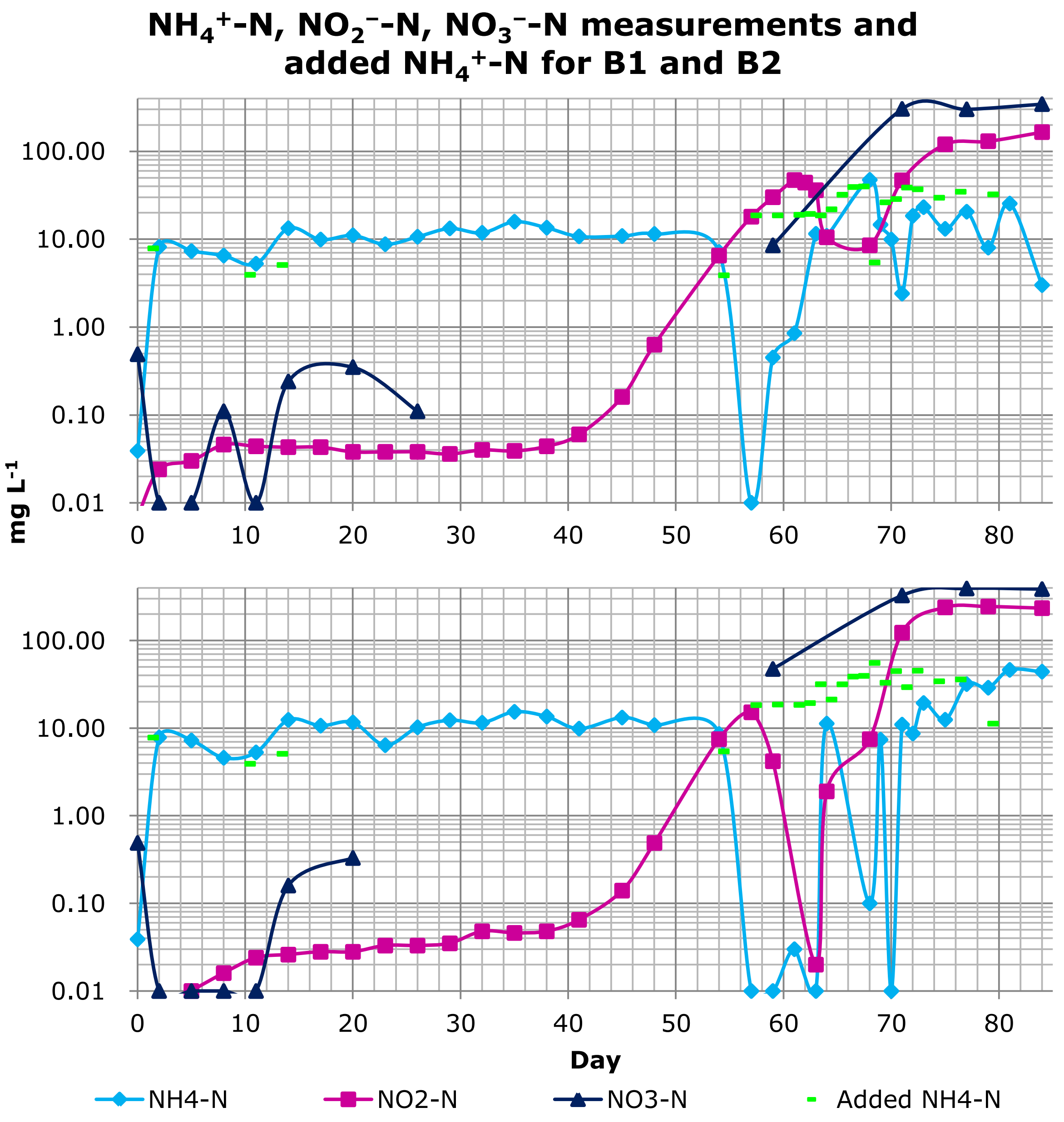


Figure 4.5: NH_4^+-N, NO_2^--N, NO_3^--N measurements and added NH_4^+-N for B1 and B2 were B1 = top and B2 = bottom. Lines between measurements are for guideline purposes and do not indicate actual values.

Nitrite-nitrogen measurements for B1 and B2 showed accumulation from after day 40. Nitrite-nitrogen peak of B2 was 15.2 mg L^{-1} on day 57. Nitrate-nitrogen measurements for day 59 where: 8.5 and 47.5 mg L^{-1} for B1 and B2, respectively (Figure 4.5).

Towards the end of the experiment, nitrite-nitrogen accumulated to values of 165 and 235 mg L^{-1} for B1 and B2, respectively, and nitrate-nitrogen to 344 and 390 mg L^{-1} for B1 and B2, respectively (Figure 4.9).

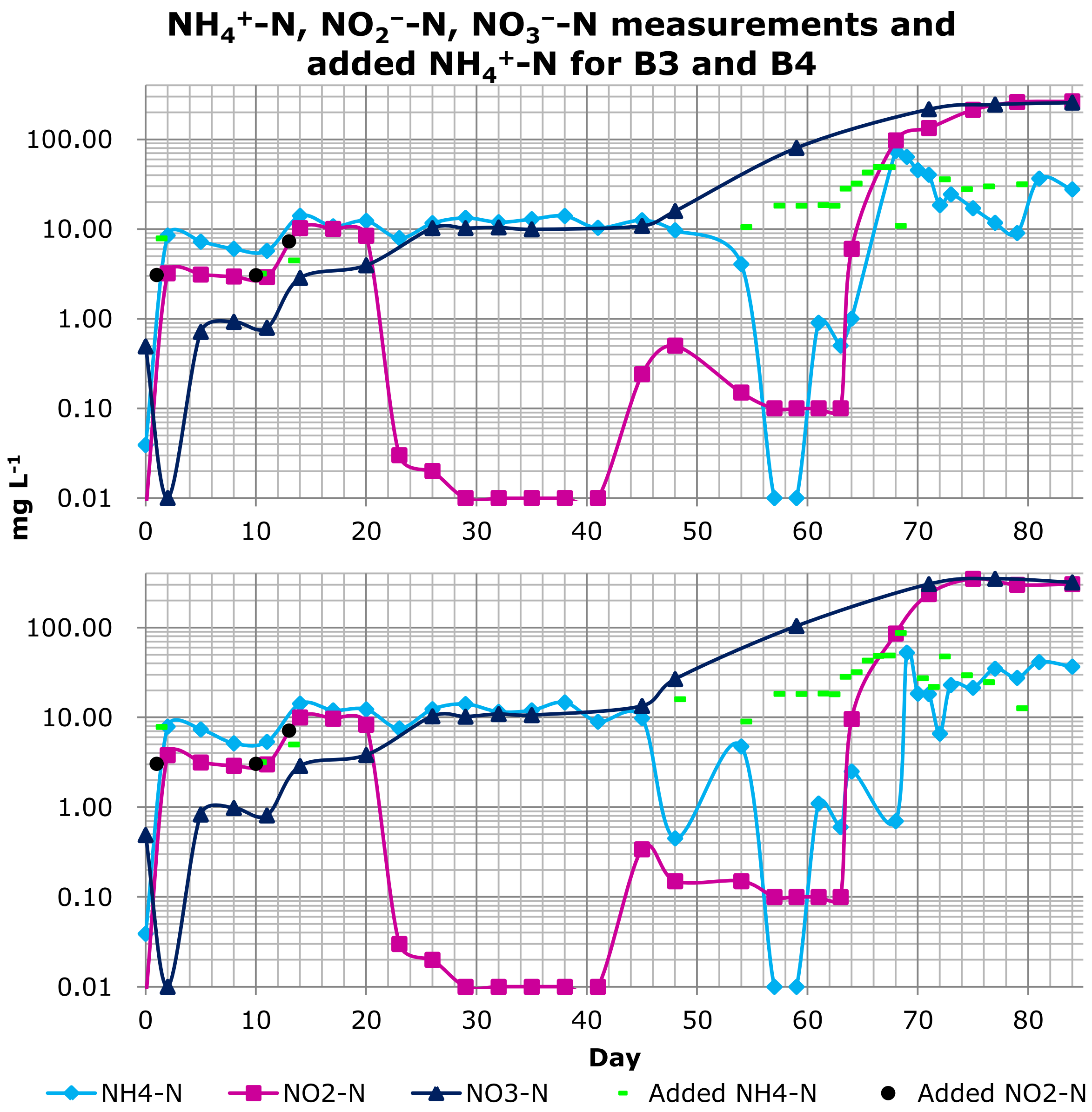


Figure 4.6: NH_4^+-N, NO_2^--N, NO_3^--N measurements and added NH_4^+-N for B3 and B4 were B3 = top and B4 = bottom. Lines between measurements are for guideline purposes and do not indicate actual values.

Nitrate-nitrogen measurements for B3 and B4 showed accumulation from after day 5, accumulating to 10 mg L^{-1} by day 26. Nitrate-nitrogen measurements for day 59 where: 80.0 and 104.0 mg L^{-1} for B3 and B4, respectively (Figure 4.6).

Nitrite-nitrogen measurements showed a small peak between day 45-48, at 0.50 and 0.34 mg L^{-1} for B3 and B4, respectively (Figure 4.6).

Towards the end of the experiment, nitrite-nitrogen accumulated to values of 265 and 305 mg L^{-1} for B3 and B4, respectively, and nitrate-nitrogen to 256 and 319 mg L^{-1} for B3 and B4, respectively (Figure 4.9).

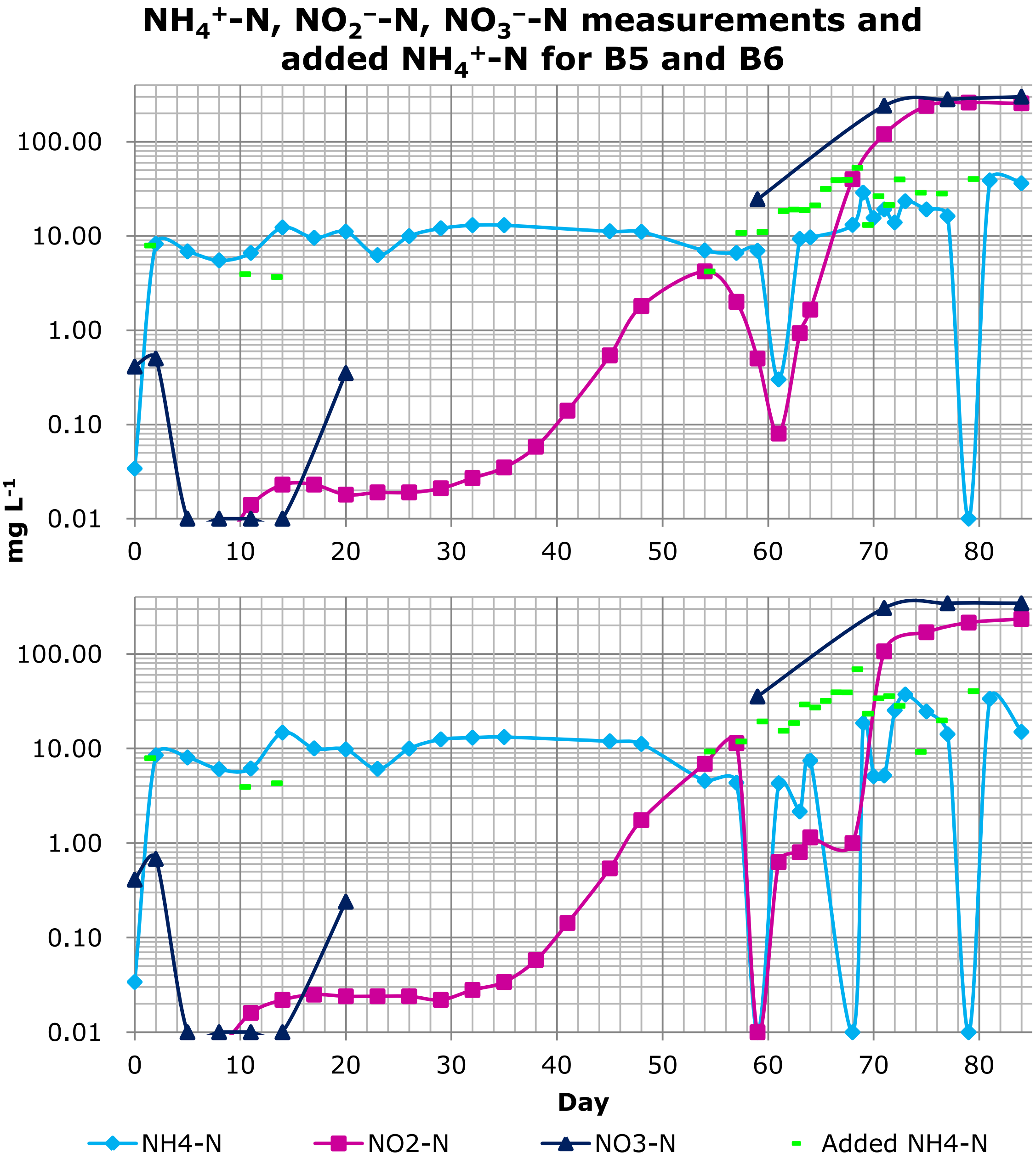


Figure 4.7: NH_4^+-N, NO_2^--N, NO_3^--N measurements and added NH_4^+-N for B5 and B6 were B5 = top and B6 = bottom. Lines between measurements are for guideline purposes and do not indicate actual values.

Nitrite-nitrogen measurements for B5 and B6 showed accumulation from after day 35. Nitrite-nitrogen measurements showed peaks between day 54-57, at 4.2 and 11.4 mg L^{-1} for B5 and B6, respectively. Nitrate-nitrogen measurements for day 59 where: 24.5 and 35.5 mg L^{-1} for B5 and B6, respectively (Figure 4.7).

Towards the end of the experiment, nitrite-nitrogen accumulated to values of 255 and 235 mg L^{-1} for B5 and B6, respectively, and nitrate-nitrogen to 300 and 344 mg L^{-1} for B5 and B6, respectively (Figure 4.9).

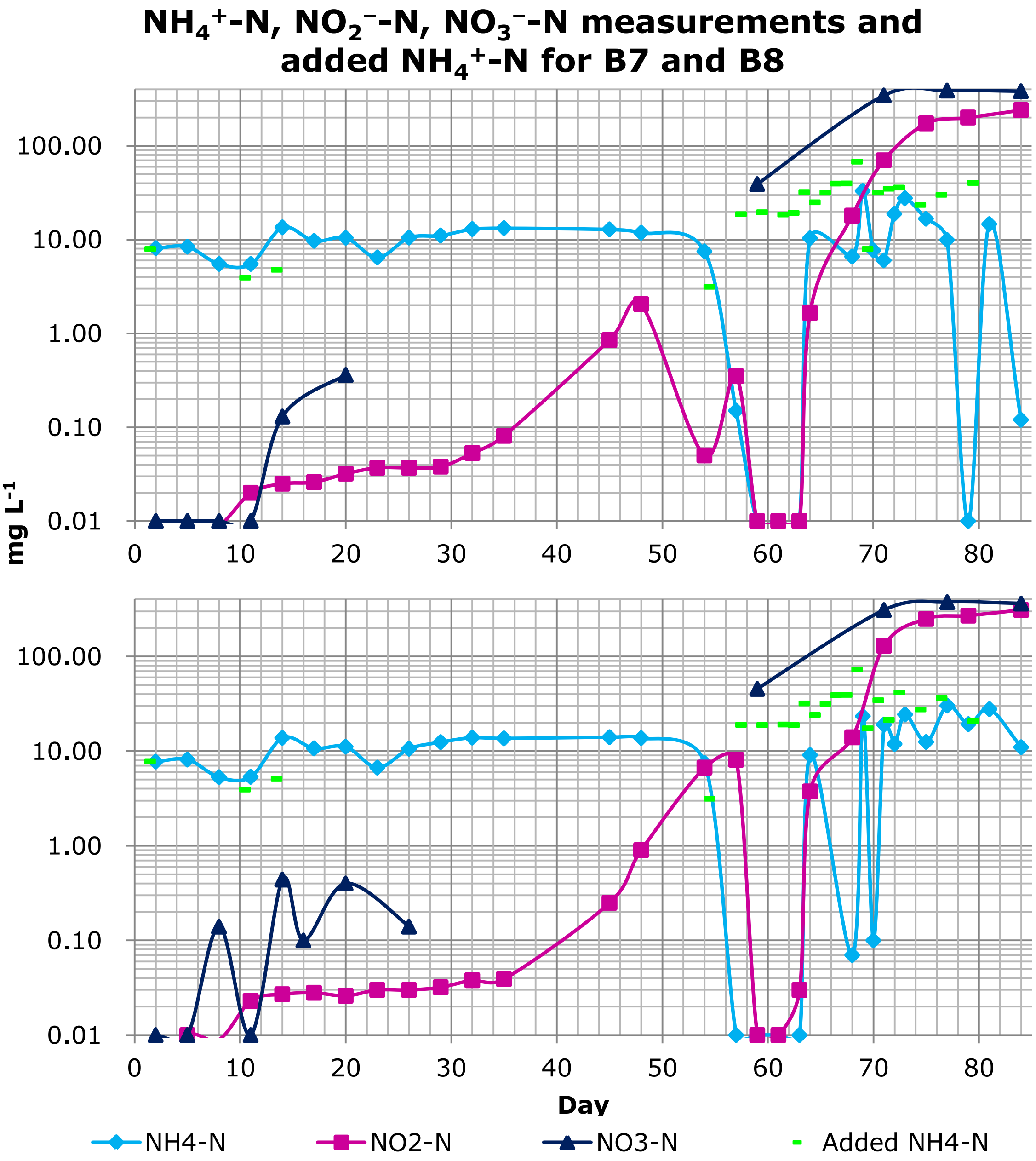


Figure 4.8: NH_4^+-N, NO_2^--N, NO_3^--N measurements and added NH_4^+-N for B7 and B8 were B7 = top and B8 = bottom. Lines between measurements are for guideline purposes and do not indicate actual values.

Nitrite-nitrogen measurements for B7 and B8 showed accumulation from after day 35. Nitrite-nitrogen measurements showed peaks between day 48-57, at 2.1 and 8.1 mg L^{-1} for B7 and B8, respectively. Nitrate-nitrogen measurements for day 59 where: 39.0 and 45.5 mg L^{-1} for B7 and B8, respectively (Figure 4.8).

Towards the end of the experiment, nitrite-nitrogen accumulated to values of 240 and 310 mg L^{-1} for B3 and B4, respectively, and nitrate-nitrogen to 381 and 363 mg L^{-1} for B3 and B4, respectively (Figure 4.9).

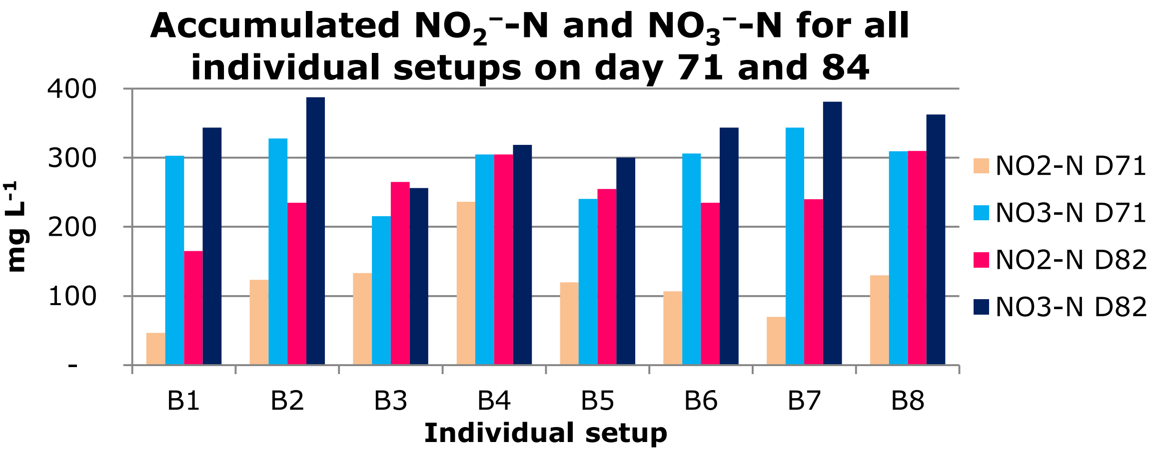


Figure 4.9: Accumulated levels of NO_2^--N and NO_3^--N for all individual setups on day 71 and 84.

pH measurements were mostly stable for the first 50 days. A large drop in all startup methods, besides method 2, occurred on day 54, followed by a period with decreasing trends in all methods. Startup method 2 showed lower pH levels (average 6.87), compared to all other startup methods (average 7.76) for the first 50 days (Figure 4.12). Most of the $CaCO_3$ added in the experiment occurred in the later time period (Figure 4.10), with no significant differences between startup methods or light vs. dark regimes (Figure 4.11).

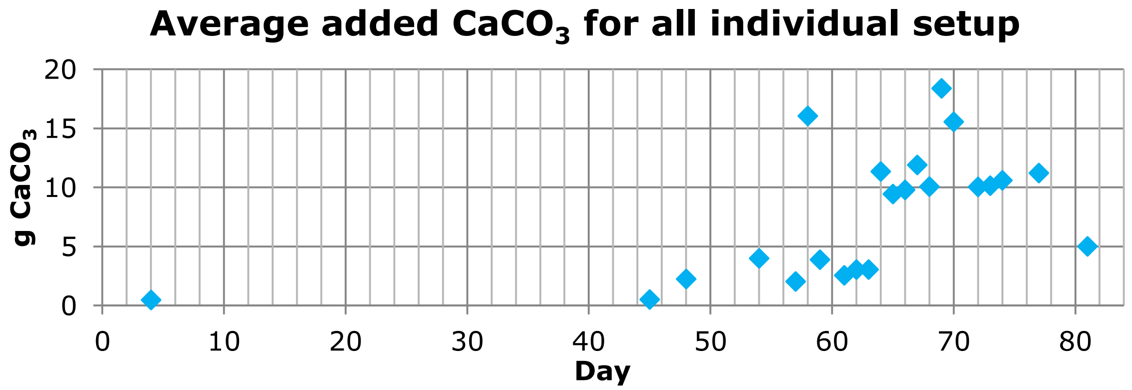


Figure 4.10: Average added $CaCO_3$ for all individual setup.

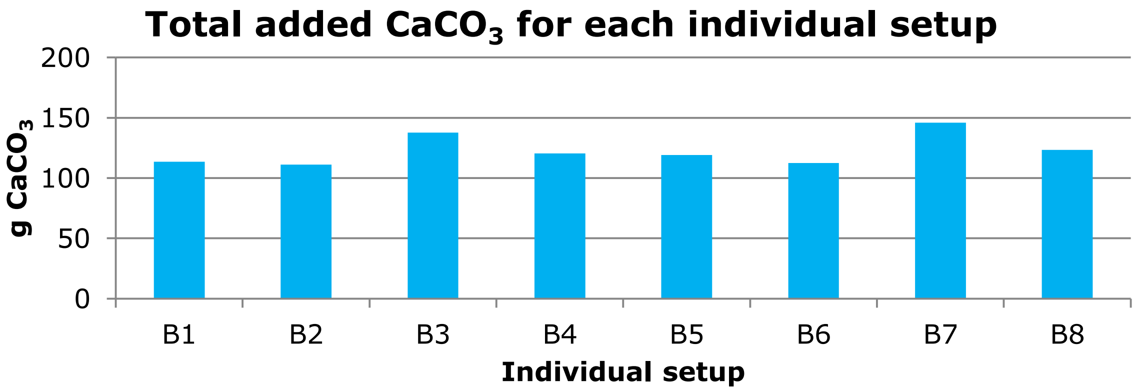


Figure 4.11: Total added $CaCO_3$ for each individual setup.

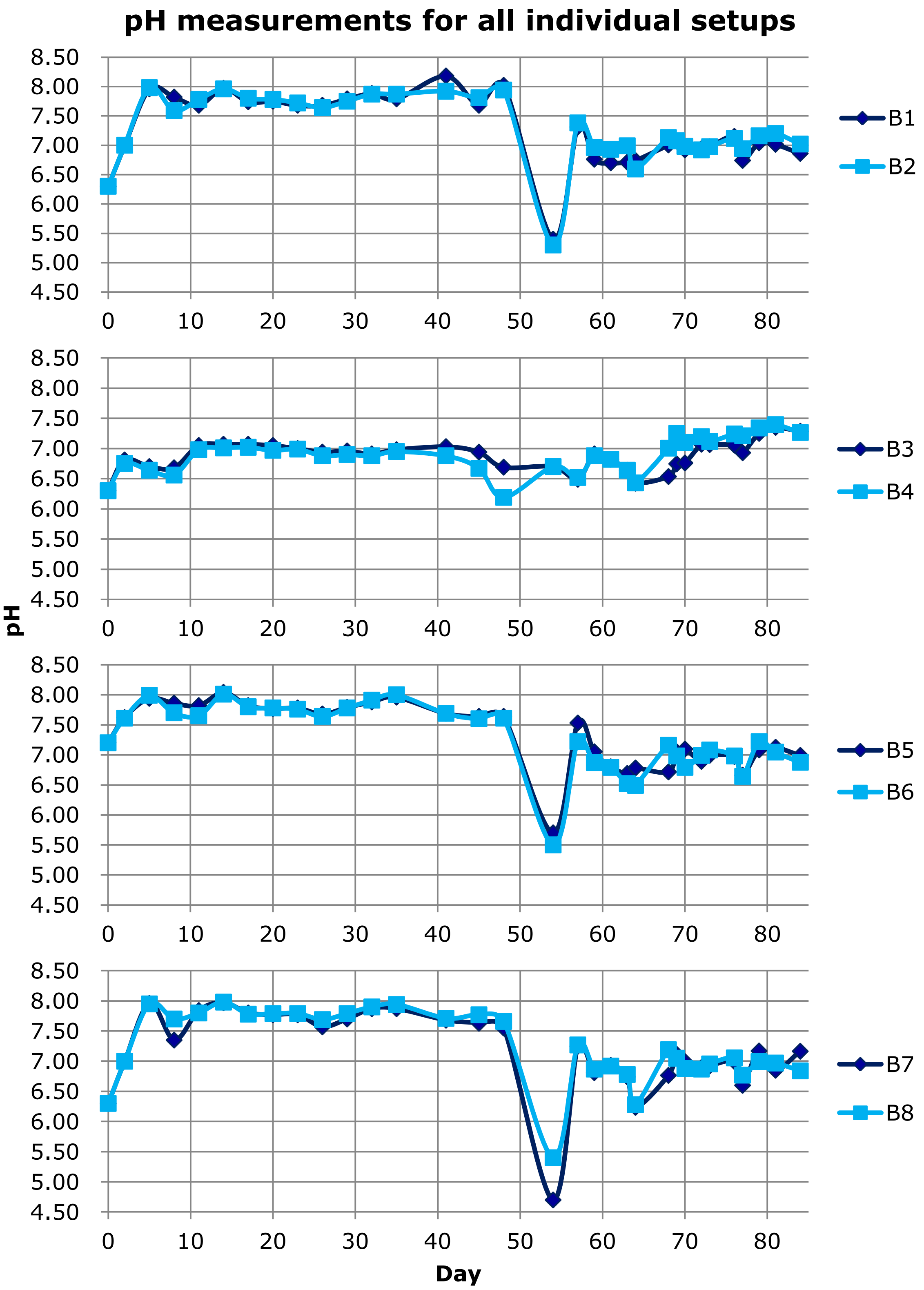


Figure 4.12: pH measurements for all individual setups throughout the experiment. Lines between measurements are for guideline purposes and do not indicate actual values.

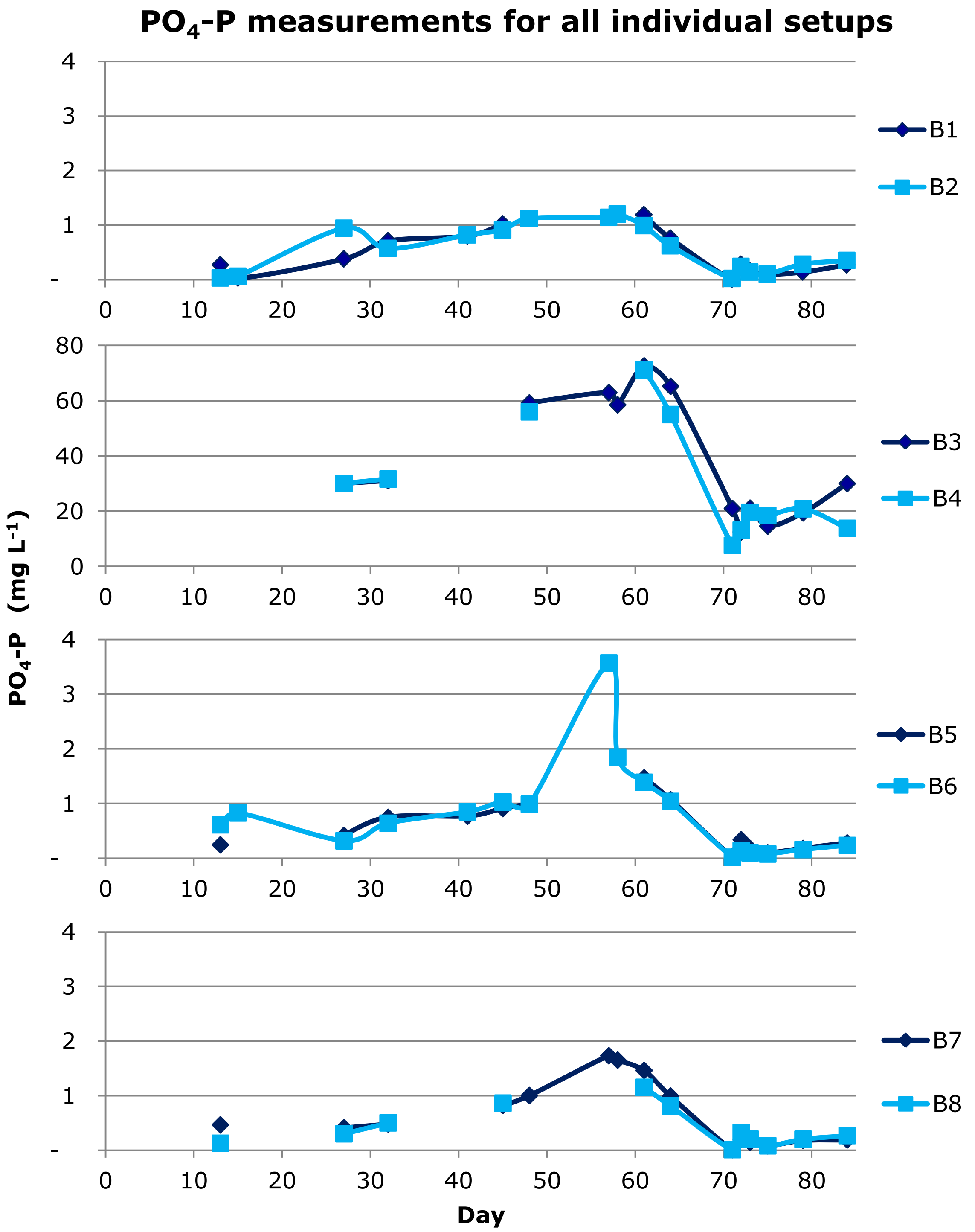


Figure 4.13: Orthophosphate-phosphorus measurements for all individual setups throughout the experiment. Lines between measurements are for guideline purposes and do not indicate actual values.

Orthophosphate-phosphorus measurement showed significantly higher concentrations in startup method 2. One could also observe a declining trend from day 60 – 70 in all individual setups (Figure 4.13).

Significant differences were found for orthophosphate-phosphorus measurements before and after filtering for all startup methods (Figure 4.14).

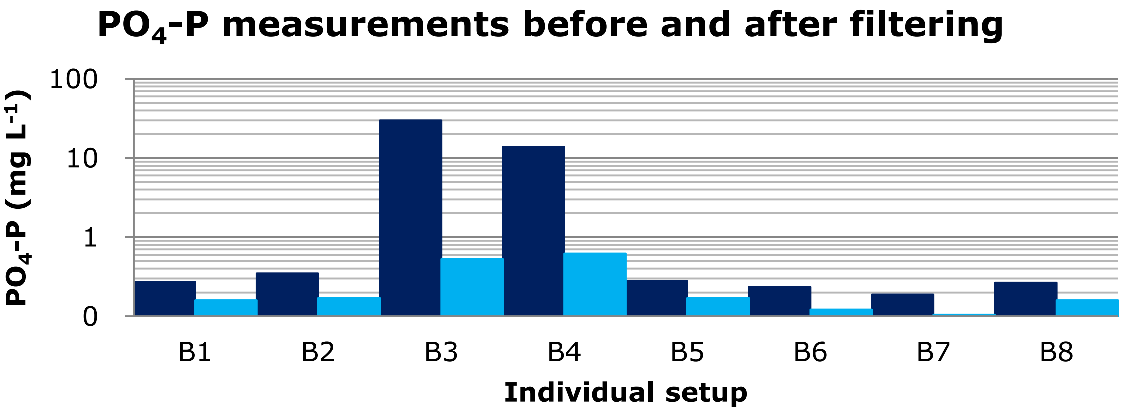


Figure 4.14: PO_4-P measurements before and after filtering for all individual setups. Samples were taken on day 84.

The water temperature for all the individual setups varied throughout the experiment, with a slightly increasing trend. Average temperatures for all setups were 15.6 and 17.3 °C, before and after day 42, respectively. The lowest temperature recorded was in individual setup B1 at 14.0 °C on day 20, the highest was in setup B8 at 19.5 °C on day 73 (Figure 4.15). Average water temperatures after day 37 for individual setups exposed to light were significantly higher than those in the dark.

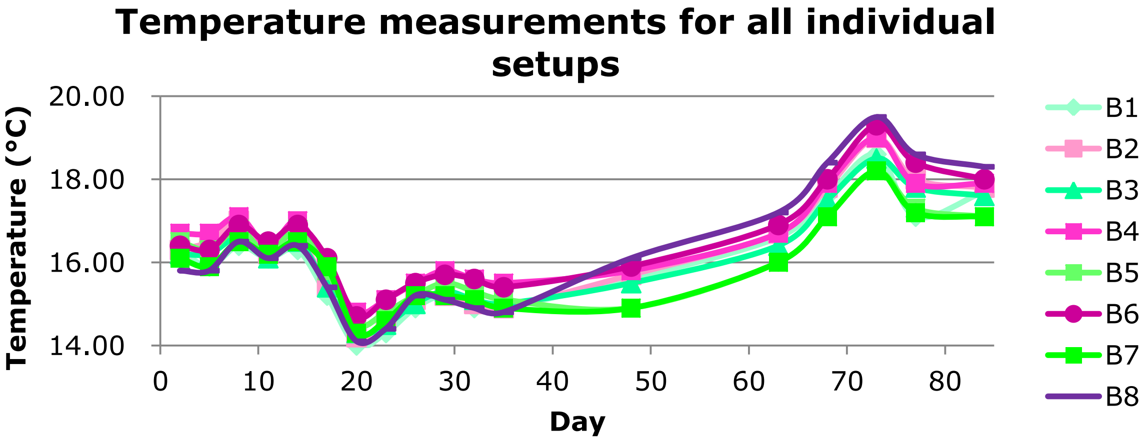


Figure 4.15: Temperature measurements for all individual setups throughout the experiment. Lines between measurements are for guideline purposes and do not indicate actual values.

Oxygen measurements varied throughout the experiment, between 92% and 100% saturation (Figure 4.16). Averages for all setups were 97 and 96%, before and after day 42, respectively. No significant differences between startup methods or light vs. dark regimes were found.

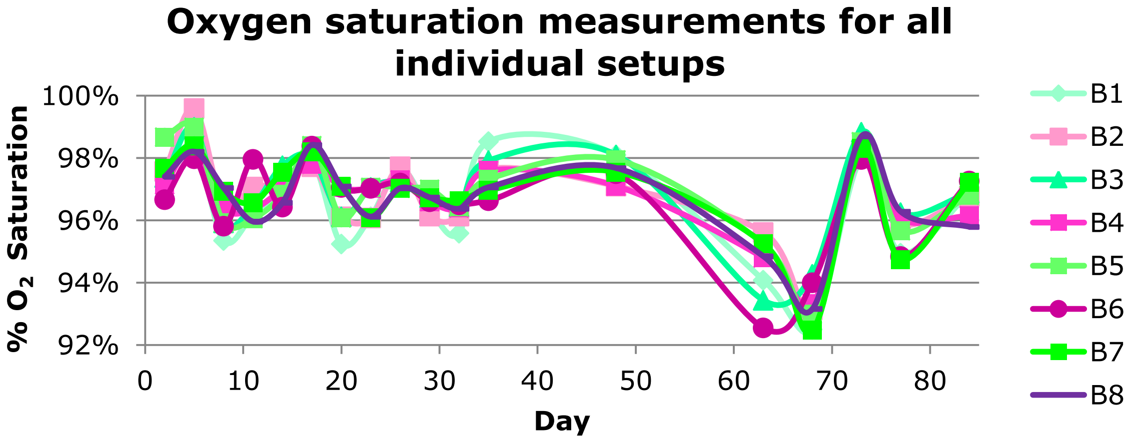


Figure 4.16: Oxygen saturation measurements for all individual setups throughout the experiment. Lines between measurements are for guideline purposes and do not indicate actual values.

Carbon dioxide measurements were stable throughout the whole experiment in all individual setups, showing no significant differences within range of error between startup methods or light vs. dark regimes. Measurements varied between 1 and 2 mg L^{-1}, with a total experimental average of 1.15 mg L^{-1}.

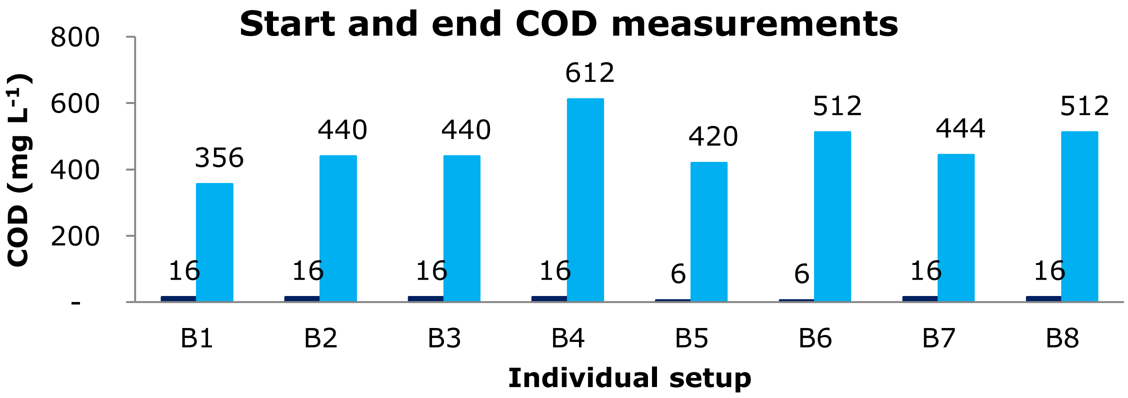


Figure 4.17: Start and end COD measurements.

End COD measurements for the individual setups exposed to light were significantly higher than those for setups in the dark. Measurements showed a clear increase in all individual setups, from start to end, with averages from 13.5 to 146 mg L^{-1}, respectively (Figure 4.17).

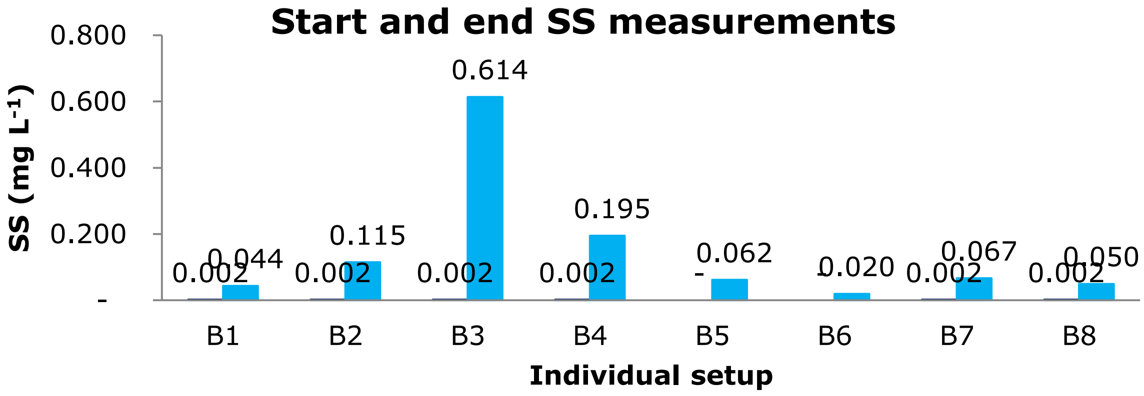


Figure 4.18: Start and end SS measurements

End SS measurements for startup method 2 were significantly higher than the rest of the startup methods together, however, not with each individual startup method by itself. Measurements showed an increase in all individual setups (Figure 4.18). Water volumes filtered for SS measurements can be found in Table 4.1.

Table 4.1: Water volumes filtered for SS measurements

	B1	B2	B3	B4	B5	B6	B7	B8
Start:	1000ml	1000ml	1000ml	1000ml	0ml	0ml	1000ml	1000ml
End:	250ml	147ml	44ml	92ml	146ml	150ml	149ml	160ml

4.3 Discussion

4.3.1 Discussion of experimental setup

**Figure 4.19: All individual setups on day 17.
From top left: B1, B2, B3, B4, B5, B6, B7 and B8 (Holdhus 2012).**

The immersion process of the carriers took considerably longer than in the small 3-day technical pre-trial experiment, where carriers were fully immersed already after one day. Images taken on day 17 of all individual setups, showed a majority of the carriers in setup B5 still afloat and carriers in setup B6 only partly immersed (Figure 4.19). Carriers in all other setups were partly immersed between day 3-7 and fully immersed between day 10-13. This, however didn't seem to have any effect on the results of the experiment.

Another point to mention regarding the carriers and their immersion was the fact that throughout the experiment, it seemed as though a large percentage of the carriers stayed at the bottom of all the individual setups after the immersion process (Figure 4.19). The technical setup of the setups didn't seem to allow all the carriers to properly circulate once immersed, a problem related to either the bucket shape, aeration equipment or a too high fill rate. According to previous literature (Section 2.3.7), this complication could have affected the performance of the experiment considerably.

Figure 4.20: Undissolved starter fish feed at the bottom of individual setups B5 and B6, two day after addition on day 15 (Holdhus 2012).

The first time starter fish feed was added to the respective individual setups, it seemed to all gather at the bottom. This fact could be observed two days after addition, in setup B5 and B6, since the carriers in those specific setups were still afloat and not yet covering the bottom of the buckets (Figure 4.20). A somewhat identical scenario could be expected in the other setups in which feed was added, as technical conditions were almost identical. Changes were made in the method of addition (Section 4.1.2.5) however, completely dissolving the fish feed seemed difficult. One could therefore assume that feed stayed at the bottom of the respective individual setups for longer periods of the experiment.

After concluding the experiment and removing both water and carriers from all the individual setups, a lot of sedimented $CaCO_3$ and fish feed was observed in the setups in which the respective additions had been added. The sedimented layers varied from approximately 0.5 – 1.5 cm in depth and could have affected the performance of the experiment (Section 2.3.6 and 2.3.7).

In terms of light vs. dark regimes and their possible influence on results, a layer of biomass along the rim of buckets above the water surface was observed towards the end of the experiment (>day 50); where the layer of biomass was green and brown respectively, for the light and dark regimes.

4.3.2 Discussion of experimental results

Nitrification rates for individual setups exposed to light showed significantly higher values on day 70. However, this is most likely due to the fact that temperature readings were also significantly higher during the same time period. Higher water temperatures seemed to have been due to the location in the room in which the experiment took place and not directly connected to the fact that the individual setups were exposed to light or not, i.e. there is reason to believe that the room temperature in the dark tanks was slightly lower than in the rest of the room. Hence, the lower water temperatures. This could also be connected to the fact that end COD measurements were also significantly higher for setups exposed to light compared to those in the dark.

There was also a significant difference in nitrification rates between startup method 1 and 2 from day 69 to 71. However, it is hard to draw any conclusions regarding this matter, since individual setup B3 showed uniquely lower rates by itself compared to all other setups.

When it comes to nitrite-nitrogen peaks, on the other hand, the only clear significant difference between all startup methods was that startup method 2 showed remarkably lower peak measurements. After keeping concentrations up to 10 mg NO_2^--N L^{-1} for the 20 first days of the startup process, measurements stayed below 0.6 mg NO_2^--N L^{-1} until accumulations occurred towards the end of the experiment. This suggests that a population of NOB grew very early in the startup process and then stayed there, oxidising any signs of nitrite without hesitation; possibly also proved by the fact that nitrite-nitrogen concentrations were undetectable from day 30 – 40. It could be however, that this NOB population was slowly decreasing due to depleted levels of nitrite for a longer period of time, hence the slight nitrite peak between day 45 – 49.

It could be possible that the period without added nitrite could be reduced, i.e. adding nitrite later and only in small amounts, thus building up the NOB population slower and more gradually. This could be a solution to preventing large nitrite peaks during the startup process of biofilters, e.g. if the total amount of nitrite-nitrogen that was added to B3 and B4, was instead spread out gradually over first 40 days, then there could have been a smoother transition.

Similar actions have been done in previous experiments, where added nitrite-nitrogen concentrations were held below 0.5 mg L^{-1} (Section 2.5).

When it comes to the collapse in nitrification rates after day 70, this was most likely caused by the high levels of accumulated nitrite-nitrogen (Section 2.3.3.2), and possibly also nitrate-nitrogen, towards the end of the experiment. However, this is also hard to state as a fact as nitrite-nitrogen concentrations were, on day 71, only at 47 and 70 mg L^{-1} for B1 and B7, respectively.

Orthophosphate-phosphorus concentrations for startup methods 1, 3 and 4 were hard to keep above the desired concentration (0.3 mg L^{-1}) and were hard to control. However, during the period of increased nitrification rates from day 60 – 70, one could also notice how orthophosphate-phosphorus concentration measurements declined for all individual setups.

One can also see clearly, through the significant differences found in orthophosphate-phosphorus measurements before and after filtering, that orthophosphate-phosphorus concentrations were significantly lower than measured throughout the experiment in all individual setups.

pH levels at times were a little low for a number of individual setups, however, there are no signs of any distinctly related effects in other measurements.

High end SS measurements for individual setup B3 could be somehow connected to the poor nitrification rates towards the end of the experiment. It is however quite difficult to state how well SS measurements represent their respective individual setups, due to the small sample volumes filtered for measurements.

All methods seem to reflect the fact that AOB take a very long time to grow while NOB grow considerably faster.

No clear significant differences can be found between the startup methods 3 and 4 with smaller and bigger bacterial start culture sizes, respectively.

4.4 Conclusion

- Nitrite-nitrogen additions affect and potentially reduce nitrite-nitrogen peaks throughout the startup period of MBBRs.

- Light vs. dark regimes for MBBRs have no significant effects on their startup process.

- No significant differences were found between using smaller and bigger bacterial start culture sizes in the startup process of MBBRs.

- Additives such as calcium carbonate and starter fish feed didn’t dissolve as well as expected and accumulated at the bottom of the MBBRs.

- No differences were observed in terms of startup time between all MBBR startup methods included in the experiment.

- There are possibilities that sub-optimal conditions were present during periods of startup processes in this experiment.

5 Overall discussion

When comparing results from both experiments one could see that the average maximum nitrification rate was slightly higher in the small scale experiment, however took much longer to get there. Water temperatures in the small scale experiment where also much higher, affecting the nitrification rate positively. The most significant difference is, however, the startup time, e.g. after just 42 days (54 including immersion process) the MBBR in the large scale experiment reached accumulated nitrate-nitrogen concentrations of 250 mg L^{-1}, while the MBBRs in the small scale experiment took more than 70 days to achieve the same results.

The two experiments together showed great results in terms revealing different key areas of improvement in starting up a MBBR in relation to time, bacterial growth and nitrite peak occurrence, and can be a basis for future experiments and developmental studies.

The immersion process for the carriers could have been avoided if the carriers had been soaked in water beforehand, however it can be mentioned that it’s practically not that easy to do, especially on a large scale. This process can however be seen upon as a topic of somewhat importance, since the soaking/immersion process can take up to 25% of the total startup process time of MBBR.

Aeration, mixing and startup additive sedimentation are also important topics of attention. As observed in the small experiment, chalk solutions and start feeding feed accumulated at the bottom the MBBRs. Probably not only as a result of just sedimentation, but also due to the heavy amounts of aeration in the systems. Even though one observes dilution and milky water, bigger particles may collect at the bottom of the reactor and accumulate below the top level of the aeration system. Here, there would be least water movement in the system, decreasing with increasing water viscosity due to higher concentrations of particulate matter. An important decisive factor of whether or not this occurs is how large the volume is between the base of the reactor and the top of the aeration system in the reactor (Figure 5.1).

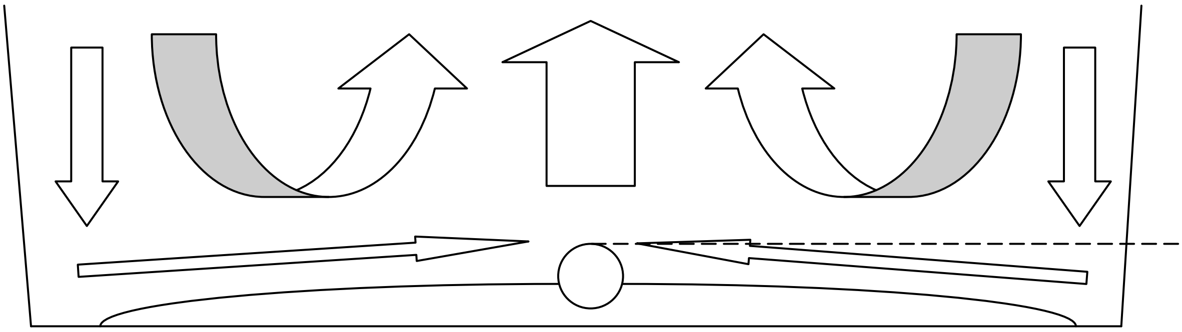


Figure 5.1: Estimated water flow patterns at the bottom of a well aerated water body. Were the circular shape in the middle represents an aeration system and the long shape below represents organic matter accumulations. Arrows show water movement and dotted line indicates top of aeration system

One can question whether sedimentation during the startup period of a large scale MBBR would have such a large affect after the startup period itself. Maybe not in the case of starter fish feed, as it may slowly degrade away, and quantities added during the startup period compared to the volume of the MBBR itself, lead to insignificant considerations. However, in the case of a pH regulator like $CaCO_3$ which is added even after the startup period concludes, accumulations can continue over time, becoming a larger cost for the company the bigger the problem get.

It would have maybe been better to use easier biodegradable sources of organic matter for bacterial cell growth, e.g. fish feed extract, and more water soluble additives as orthophosphate-phosphorus additions and pH regulators, e.g. monosodium phosphate and sodium bicarbonate.

Further studies need to be done in the following areas:

- Study optimal bacterial growth conditions in terms of using more water soluble additives, thus gaining better control and knowledge over direct affects of startup additives.
- Study possibilities for a smoother quicker transition from the startup period to addition of fish through the usage of different startup additives.

6 Overall conclusion

- Fish feed pellets with high water stability should not be used in the startup process of MBBRs. An easier biodegradable source of organic matter should be found, e.g. fish feed extract.

- A different, more water soluble phosphorus source should be used for startup processes of MBBRs, e.g. monosodium phosphate, providing more control over additions to the system.

- A more water soluble pH regulator is advised as calcium carbonate solutions showed signs of sedimentation and accumulation during the startup process in the small scale experiment.

- Nitrite-nitrogen additions affect and potentially reduce nitrite-nitrogen peaks throughout the startup period of MBBRs.

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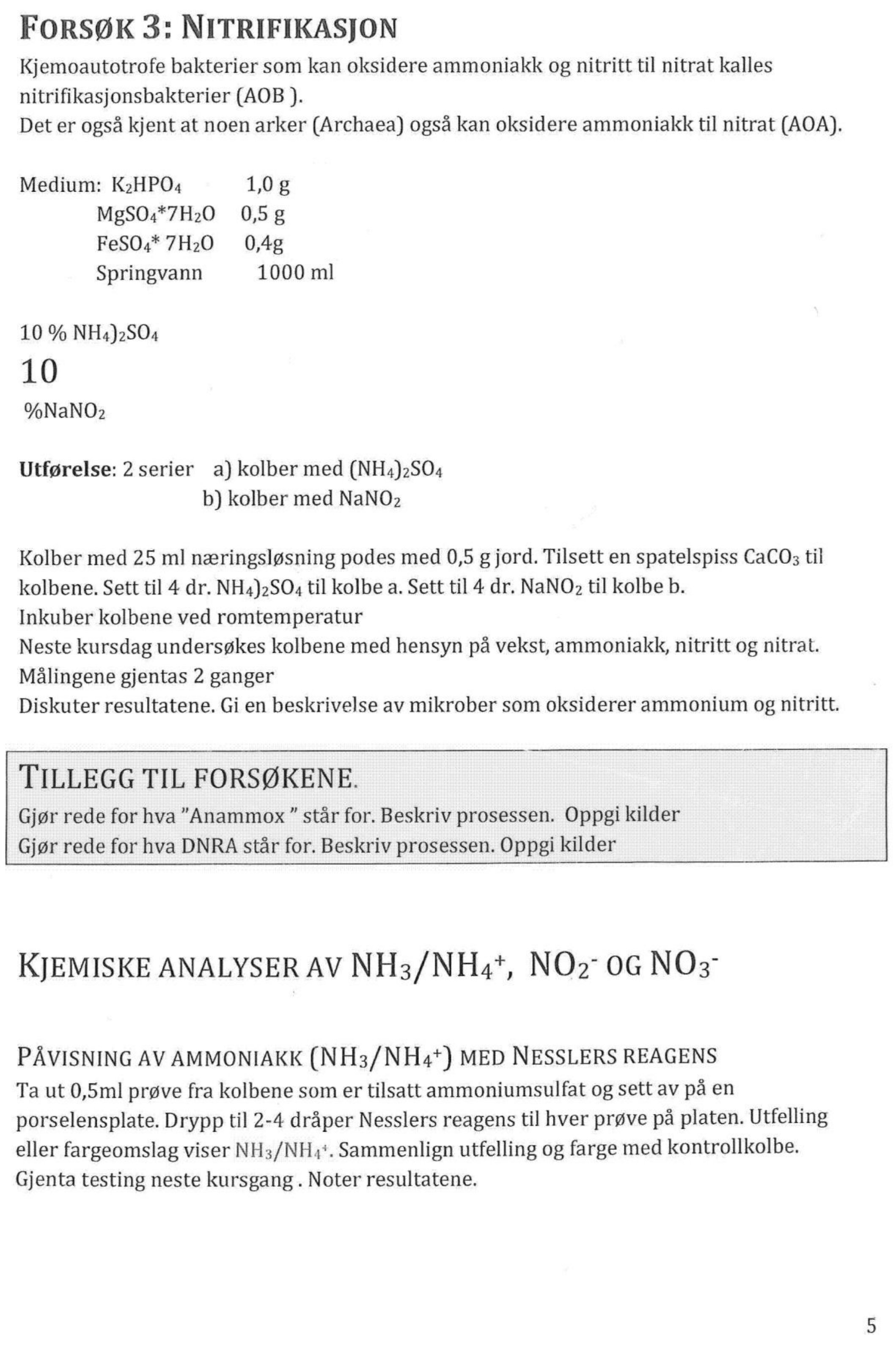
Attachments

A – Prof. Jon Fredrik Hanssen's method



FORSØK 3: NITRIFIKASJON

Kjemoautotrofe bakterier som kan oksidere ammoniakk og nitritt til nitrat kalles nitrifikasjonsbakterier (AOB).
Det er også kjent at noen arker (Archaea) også kan oksidere ammoniakk til nitrat (AOA).

Medium:	K_2HPO_4	1,0 g
	$MgSO_4{*}7H_2O$	0,5 g
	$FeSO_4{*}\,7H_2O$	0,4g
	Springvann	1000 ml

10 % $NH_4)_2SO_4$

10

%$NaNO_2$

Utførelse: 2 serier a) kolber med $(NH_4)_2SO_4$
b) kolber med $NaNO_2$

Kolber med 25 ml næringsløsning podes med 0,5 g jord. Tilsett en spatelspiss $CaCO_3$ til kolbene. Sett til 4 dr. $NH_4)_2SO_4$ til kolbe a. Sett til 4 dr. $NaNO_2$ til kolbe b.
Inkuber kolbene ved romtemperatur
Neste kursdag undersøkes kolbene med hensyn på vekst, ammoniakk, nitritt og nitrat.
Målingene gjentas 2 ganger
Diskuter resultatene. Gi en beskrivelse av mikrober som oksiderer ammonium og nitritt.

TILLEGG TIL FORSØKENE.

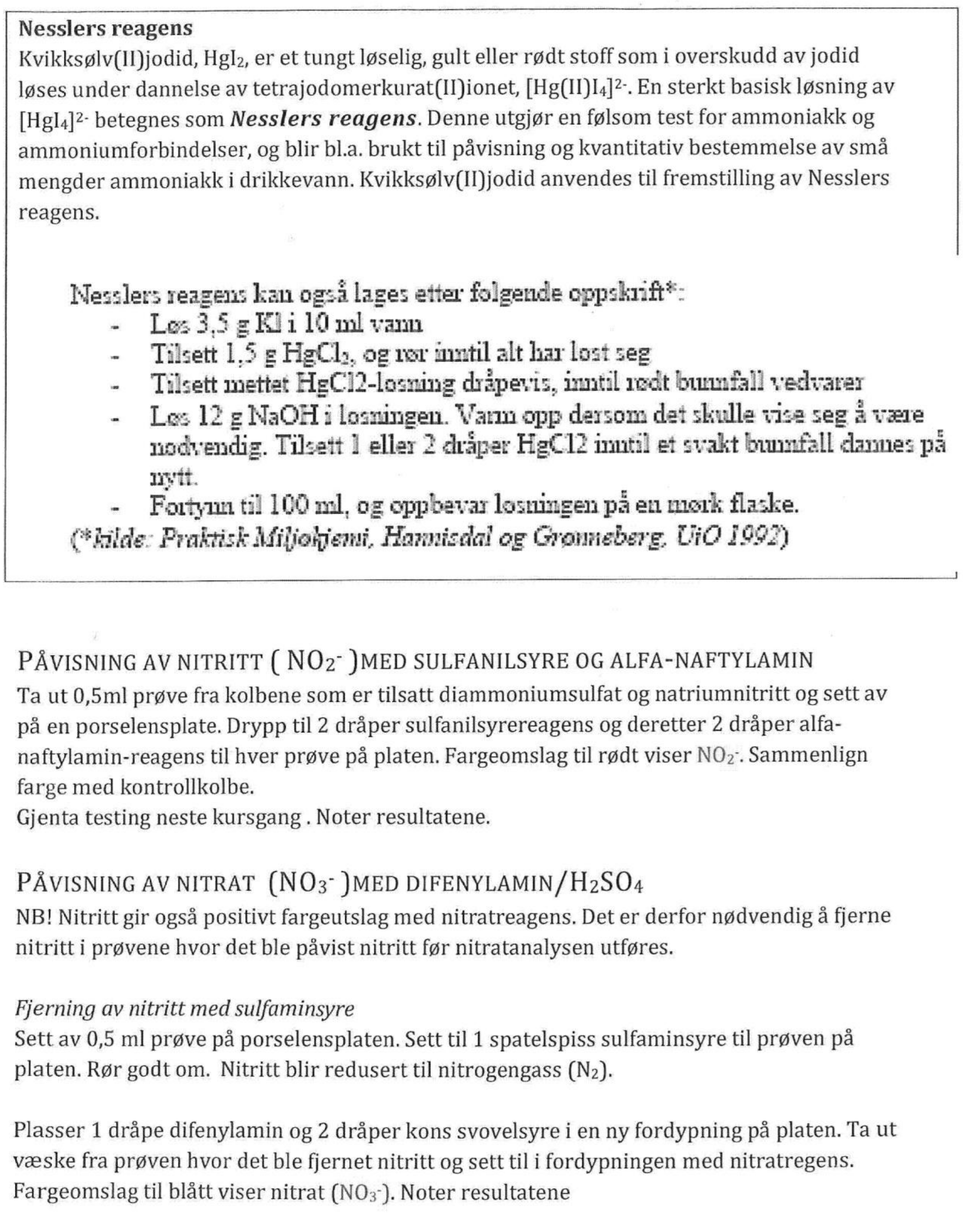
Gjør rede for hva "Anammox " står for. Beskriv prosessen. Oppgi kilder
Gjør rede for hva DNRA står for. Beskriv prosessen. Oppgi kilder

KJEMISKE ANALYSER AV NH_3/NH_4^+, NO_2^- OG NO_3^-

PÅVISNING AV AMMONIAKK (NH_3/NH_4^+) MED NESSLERS REAGENS

Ta ut 0,5ml prøve fra kolbene som er tilsatt ammoniumsulfat og sett av på en porselensplate. Drypp til 2-4 dråper Nesslers reagens til hver prøve på platen. Utfelling eller fargeomslag viser NH_3/NH_4^+. Sammenlign utfelling og farge med kontrollkolbe. Gjenta testing neste kursgang . Noter resultatene.

5



Nesslers reagens

Kvikksølv(II)jodid, HgI_2, er et tungt løselig, gult eller rødt stoff som i overskudd av jodid løses under dannelse av tetrajodomerkurat(II)ionet, $[Hg(II)I_4]^{2-}$. En sterkt basisk løsning av $[HgI_4]^{2-}$ betegnes som ***Nesslers reagens***. Denne utgjør en følsom test for ammoniakk og ammoniumforbindelser, og blir bl.a. brukt til påvisning og kvantitativ bestemmelse av små mengder ammoniakk i drikkevann. Kvikksølv(II)jodid anvendes til fremstilling av Nesslers reagens.

Nesslers reagens kan også lages etter følgende oppskrift*:

- Løs 3,5 g KI i 10 ml vann
- Tilsett 1,5 g $HgCl_2$, og rør inntil alt har løst seg
- Tilsett mettet HgCl2-løsning dråpevis, inntil rødt bunnfall vedvarer
- Løs 12 g NaOH i løsningen. Varm opp dersom det skulle vise seg å være nødvendig. Tilsett 1 eller 2 dråper HgCl2 inntil et svakt bunnfall dannes på nytt.
- Fortynn til 100 ml, og oppbevar løsningen på en mørk flaske.

*(*kilde: Praktisk Miljøkjemi, Hannisdal og Grønneberg, UiO 1992)*

PÅVISNING AV NITRITT (NO_2^-)MED SULFANILSYRE OG ALFA-NAFTYLAMIN

Ta ut 0,5ml prøve fra kolbene som er tilsatt diammoniumsulfat og natriumnitritt og sett av på en porselensplate. Drypp til 2 dråper sulfanilsyrereagens og deretter 2 dråper alfa-naftylamin-reagens til hver prøve på platen. Fargeomslag til rødt viser NO_2^-. Sammenlign farge med kontrollkolbe.

Gjenta testing neste kursgang . Noter resultatene.

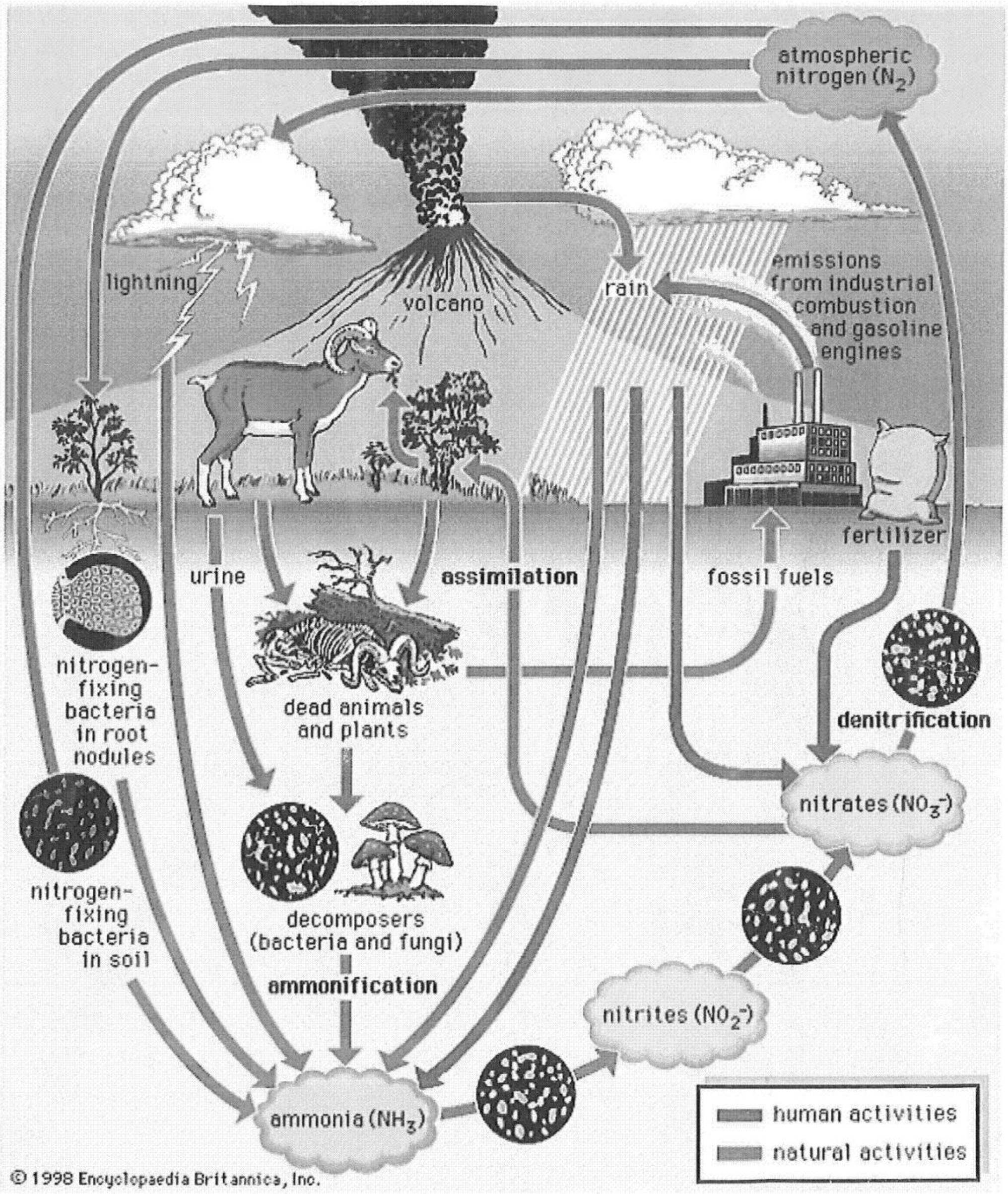
PÅVISNING AV NITRAT (NO_3^-)MED DIFENYLAMIN/H_2SO_4

NB! Nitritt gir også positivt fargeutslag med nitratreagens. Det er derfor nødvendig å fjerne nitritt i prøvene hvor det ble påvist nitritt før nitratanalysen utføres.

Fjerning av nitritt med sulfaminsyre

Sett av 0,5 ml prøve på porselensplaten. Sett til 1 spatelspiss sulfaminsyre til prøven på platen. Rør godt om. Nitritt blir redusert til nitrogengass (N_2).

Plasser 1 dråpe difenylamin og 2 dråper kons svovelsyre i en ny fordypning på platen. Ta ut væske fra prøven hvor det ble fjernet nitritt og sett til i fordypningen med nitratregens. Fargeomslag til blått viser nitrat (NO_3^-). Noter resultatene


atmospheric nitrogen (N_2)
lightning
volcano
rain
emissions from industrial combustion and gasoline engines
fertilizer
urine
assimilation
fossil fuels
nitrogen-fixing bacteria in root nodules
dead animals and plants
denitrification
nitrates (NO_3^-)
nitrogen-fixing bacteria in soil
decomposers (bacteria and fungi)
ammonification
nitrites (NO_2^-)
ammonia (NH_3)
human activities
natural activities

B – Analysis report for water used in small scale experiment

Eurofins Environment Testing Norway AS (Moss)
F. reg. 965 141 618 MVA
Møllebakken 50PB 3055
NO-1506 Moss

Tlf: +47 69 00 52 00

Kirkebygden og Ytre Enebakk Vannverk SA
Børterveien 4
1912 ENEBAKK
Attn: Torgeir Svensen

AR-12-MM-003636-01

EUNOMO-00049684

Prøvemottak: 07.03.2012
Temperatur:
Analyseperiode: 07.03.2012-14.03.2012
Referanse: Drikkevann uke 10

ANALYSERAPPORT

Prøvenr.: **439-2012-03070166**
Prøvetype: Råvann
Prøvemerking: *Råvann
Prøvetakingsdato: 07.03.2012
Prøvetaker: Torgeir Svensen
Analysestartdato: 07.03.2012

Analyse	Resultat:	Enhet:	MU	Metode:	LOQ:
Kimtall 22°C	40	cfu/ml		ISO 6222	
Turbiditet	0.42	ftu	30%	Intern metode	0.1
Fargetall	40	Fargeenheter	15%	NS 4787	2
* UV-transmisjon 1cm	57.3	%		STM	
Jern (Fe)	330	µg/l	15%	NS EN ISO 11885	5
Mangan (Mn)	30	µg/l	10%	NS EN ISO 11885	1
Koliforme	11	MPN/100 ml		Colilert-18/Quantitray	

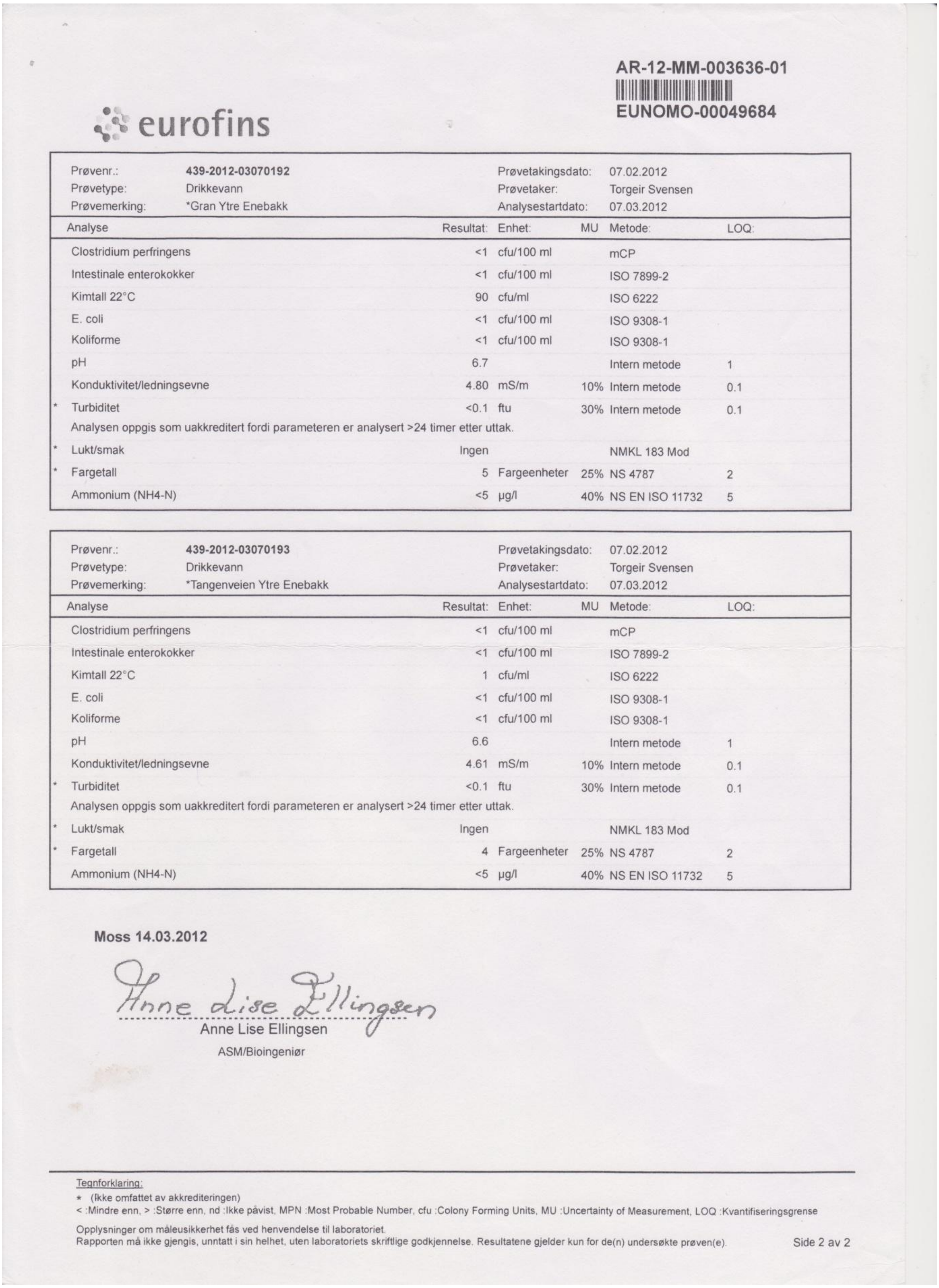
Prøvenr.: **439-2012-03070167**
Prøvetype: Drikkevann
Prøvemerking: *Vannbehandlingsanlegget
Prøvetakingsdato: 07.03.2012
Prøvetaker: Torgeir Svensen
Analysestartdato: 07.03.2012

Analyse	Resultat:	Enhet:	MU	Metode:	LOQ:
Clostridium perfringens	<1	cfu/100 ml		mCP	
Intestinale enterokokker	<1	cfu/100 ml		ISO 7899-2	
Kimtall 22°C	1	cfu/ml		ISO 6222	
E. coli	<1	cfu/100 ml		ISO 9308-1	
Koliforme	<1	cfu/100 ml		ISO 9308-1	
pH	7.5			Intern metode	1
Konduktivitet/ledningsevne	4.68	mS/m	10%	Intern metode	0.1
Turbiditet	<0.1	ftu	30%	Intern metode	0.1
* Lukt/smak	Ingen			NMKL 183 Mod	
Fargetall	5	Fargeenheter	25%	NS 4787	2
Ammonium (NH4-N)	15	µg/l	40%	NS EN ISO 11732	5

Tegnforklaring:
* (Ikke omfattet av akkrediteringen)
< :Mindre enn, > :Større enn, nd :Ikke påvist, MPN :Most Probable Number, cfu :Colony Forming Units, MU :Uncertainty of Measurement, LOQ :Kvantifiseringsgrense

Opplysninger om måleusikkerhet fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjennelse. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Side 1 av 2



AR-12-MM-003636-01

EUNOMO-00049684

eurofins

Prøvenr.: **439-2012-03070192**
Prøvetype: Drikkevann
Prøvemerking: *Gran Ytre Enebakk
Prøvetakingsdato: 07.02.2012
Prøvetaker: Torgeir Svensen
Analysestartdato: 07.03.2012

	Analyse	Resultat:	Enhet:	MU	Metode:	LOQ:
	Clostridium perfringens	<1	cfu/100 ml		mCP	
	Intestinale enterokokker	<1	cfu/100 ml		ISO 7899-2	
	Kimtall 22°C	90	cfu/ml		ISO 6222	
	E. coli	<1	cfu/100 ml		ISO 9308-1	
	Koliforme	<1	cfu/100 ml		ISO 9308-1	
	pH	6.7			Intern metode	1
	Konduktivitet/ledningsevne	4.80	mS/m	10%	Intern metode	0.1
*	Turbiditet	<0.1	ftu	30%	Intern metode	0.1
	Analysen oppgis som uakkreditert fordi parameteren er analysert >24 timer etter uttak.					
*	Lukt/smak	Ingen			NMKL 183 Mod	
*	Fargetall	5	Fargeenheter	25%	NS 4787	2
	Ammonium (NH4-N)	<5	µg/l	40%	NS EN ISO 11732	5

Prøvenr.: **439-2012-03070193**
Prøvetype: Drikkevann
Prøvemerking: *Tangenveien Ytre Enebakk
Prøvetakingsdato: 07.02.2012
Prøvetaker: Torgeir Svensen
Analysestartdato: 07.03.2012

	Analyse	Resultat:	Enhet:	MU	Metode:	LOQ:
	Clostridium perfringens	<1	cfu/100 ml		mCP	
	Intestinale enterokokker	<1	cfu/100 ml		ISO 7899-2	
	Kimtall 22°C	1	cfu/ml		ISO 6222	
	E. coli	<1	cfu/100 ml		ISO 9308-1	
	Koliforme	<1	cfu/100 ml		ISO 9308-1	
	pH	6.6			Intern metode	1
	Konduktivitet/ledningsevne	4.61	mS/m	10%	Intern metode	0.1
*	Turbiditet	<0.1	ftu	30%	Intern metode	0.1
	Analysen oppgis som uakkreditert fordi parameteren er analysert >24 timer etter uttak.					
*	Lukt/smak	Ingen			NMKL 183 Mod	
*	Fargetall	4	Fargeenheter	25%	NS 4787	2
	Ammonium (NH4-N)	<5	µg/l	40%	NS EN ISO 11732	5

Moss 14.03.2012

Anne Lise Ellingsen

Anne Lise Ellingsen
ASM/Bioingeniør

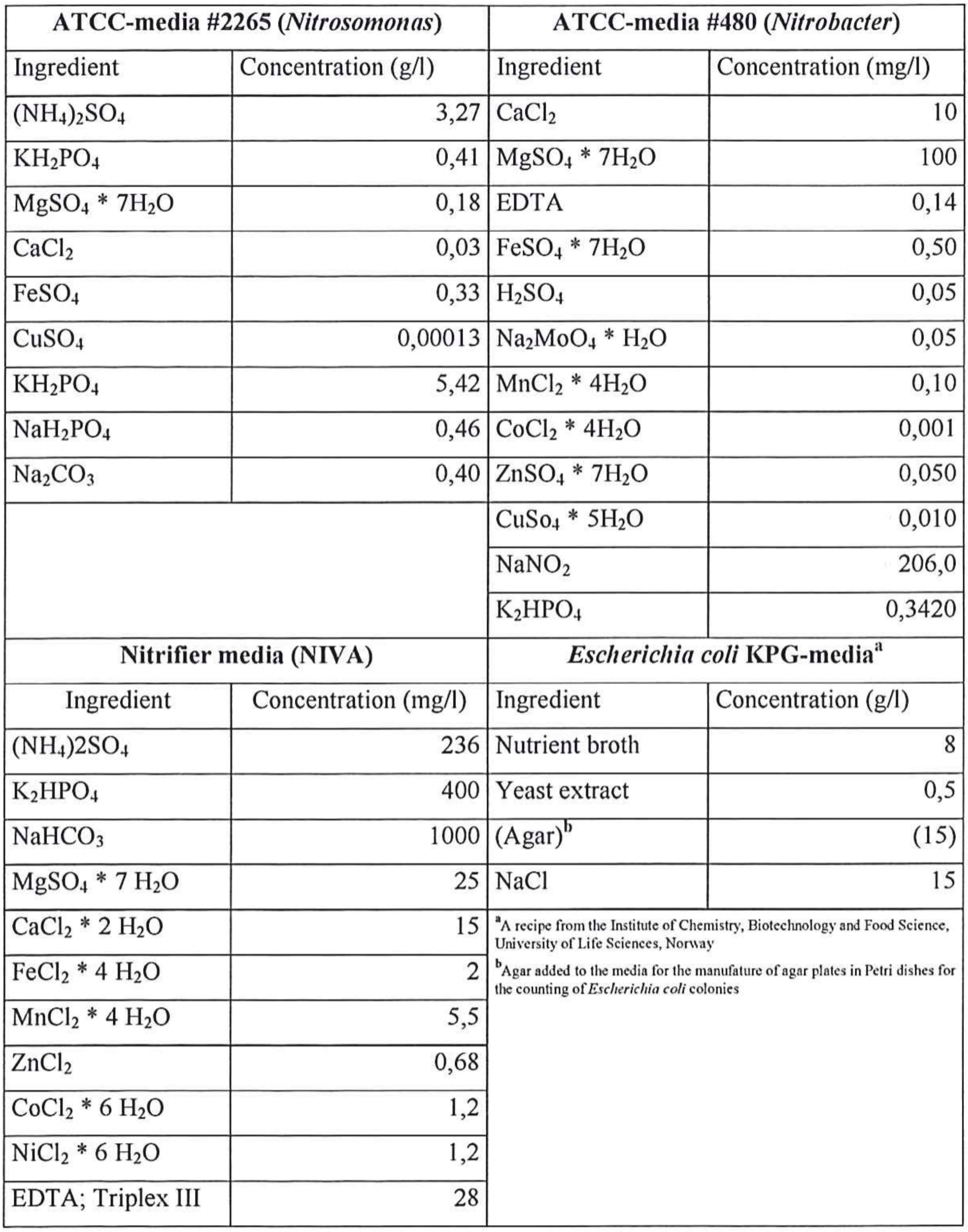
Tegnforklaring:
* (Ikke omfattet av akkrediteringen)
< :Mindre enn, > :Større enn, nd :Ikke påvist, MPN :Most Probable Number, cfu :Colony Forming Units, MU :Uncertainty of Measurement, LOQ :Kvantifiseringsgrense

Opplysninger om måleusikkerhet fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjennelse. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Side 2 av 2

C – Cultivation recipe from the Norwegian Institute for Water Research

Table 1: Media for the cultivation of pure strains of Nitrosomonas and Nitrobacter, nitrifying communities and Escherichia coli.



ATCC-media #2265 (*Nitrosomonas*)		**ATCC-media #480 (*Nitrobacter*)**	
Ingredient	Concentration (g/l)	Ingredient	Concentration (mg/l)
$(NH_4)_2SO_4$	3,27	$CaCl_2$	10
KH_2PO_4	0,41	$MgSO_4 * 7H_2O$	100
$MgSO_4 * 7H_2O$	0,18	EDTA	0,14
$CaCl_2$	0,03	$FeSO_4 * 7H_2O$	0,50
$FeSO_4$	0,33	H_2SO_4	0,05
$CuSO_4$	0,00013	$Na_2MoO_4 * H_2O$	0,05
KH_2PO_4	5,42	$MnCl_2 * 4H_2O$	0,10
NaH_2PO_4	0,46	$CoCl_2 * 4H_2O$	0,001
Na_2CO_3	0,40	$ZnSO_4 * 7H_2O$	0,050
		$CuSo_4 * 5H_2O$	0,010
		$NaNO_2$	206,0
		K_2HPO_4	0,3420

Nitrifier media (NIVA)		***Escherichia coli* KPG-media**[a]	
Ingredient	Concentration (mg/l)	Ingredient	Concentration (g/l)
$(NH_4)2SO_4$	236	Nutrient broth	8
K_2HPO_4	400	Yeast extract	0,5
$NaHCO_3$	1000	(Agar)[b]	(15)
$MgSO_4 * 7 H_2O$	25	NaCl	15
$CaCl_2 * 2 H_2O$	15		
$FeCl_2 * 4 H_2O$	2		
$MnCl_2 * 4 H_2O$	5,5		
$ZnCl_2$	0,68		
$CoCl_2 * 6 H_2O$	1,2		
$NiCl_2 * 6 H_2O$	1,2		
EDTA; Triplex III	28		

[a] A recipe from the Institute of Chemistry, Biotechnology and Food Science, University of Life Sciences, Norway

[b] Agar added to the media for the manufature of agar plates in Petri dishes for the counting of *Escherichia coli* colonies

D – Easy-Life® Easy Start Beneficial Bacteria Booster

Highly active beneficial bacterial cultures eliminate toxins.

Reduces toxic nitrite & ammonia in new or existing aquariums.

Quickly gives a healthy boost to keep your aquarium clear, clean, & healthy.

Cycle new freshwater and marine aquariums faster with EasyStart. Highly-active beneficial bacteria cultures boost natural nitrifying bacteria to help break down fish waste in your aquarium. Multifunctional EasyStart also removes heavy metals and other chemical pollutants. The accelerated increase in beneficial bacterial also competes with harmful bacteria present in aquarium water. The result is a healthy aquarium with lively and brightly colored fish!

Dosage

Method of use: Shake vigorously and add to the water immediately.

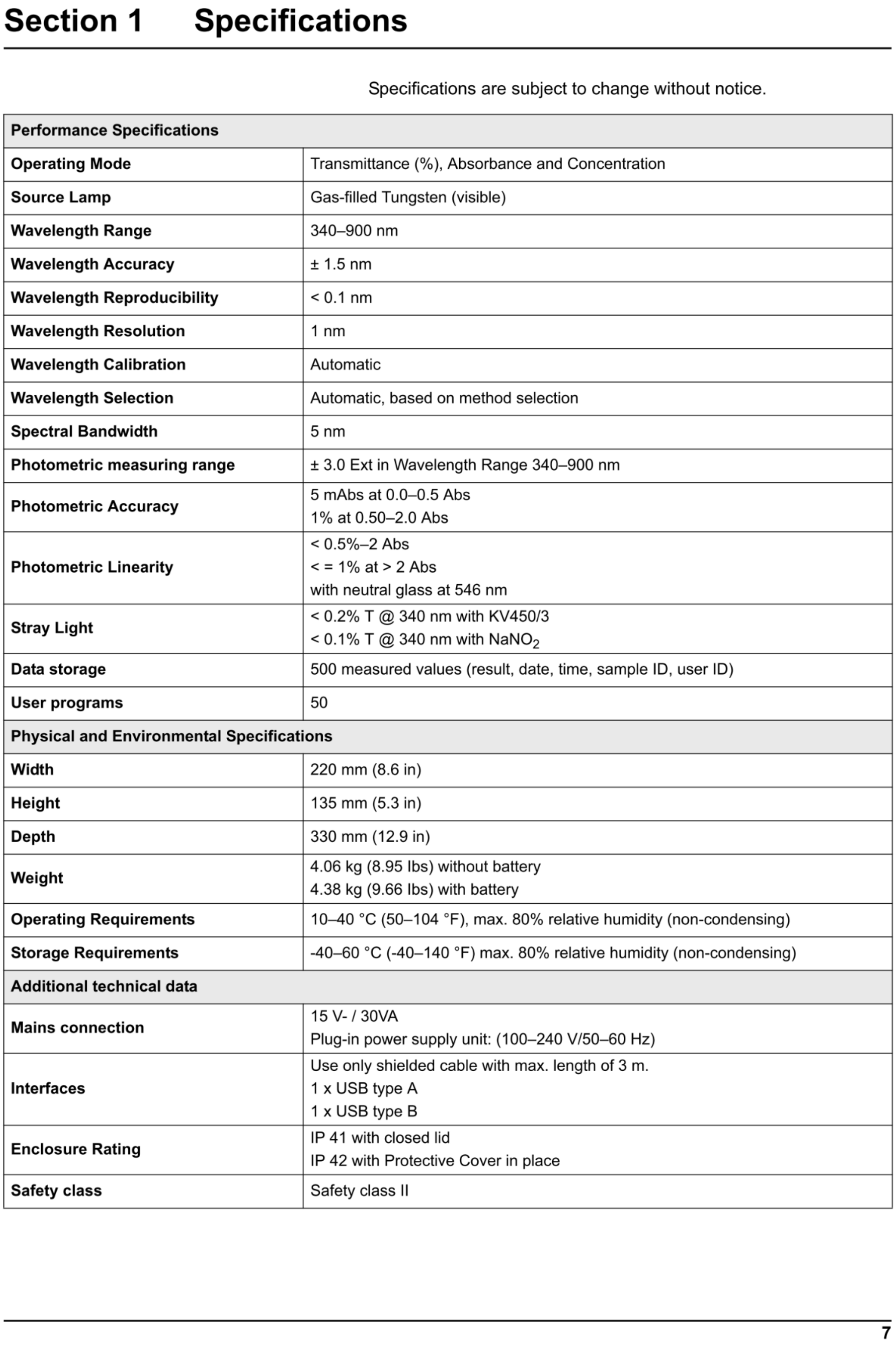
For starting aquariums and filters: 1 fl oz per 40 gallons (10 ml per 50 liter) aquarium water on day 1, day 7 and day 14. The cloudiness of the water will disappear after a couple of hours.

In case of Nitrite problems: dosage every day.

After opening, store in a cool, dark place. Keep out of reach of children and pets.

All on this page is collected from:
http://www.drsfostersmith.com/product/prod_display.cfm?pcatid=24099

E – Technical specification for HACH LANGE DR2800 spectrophotometer

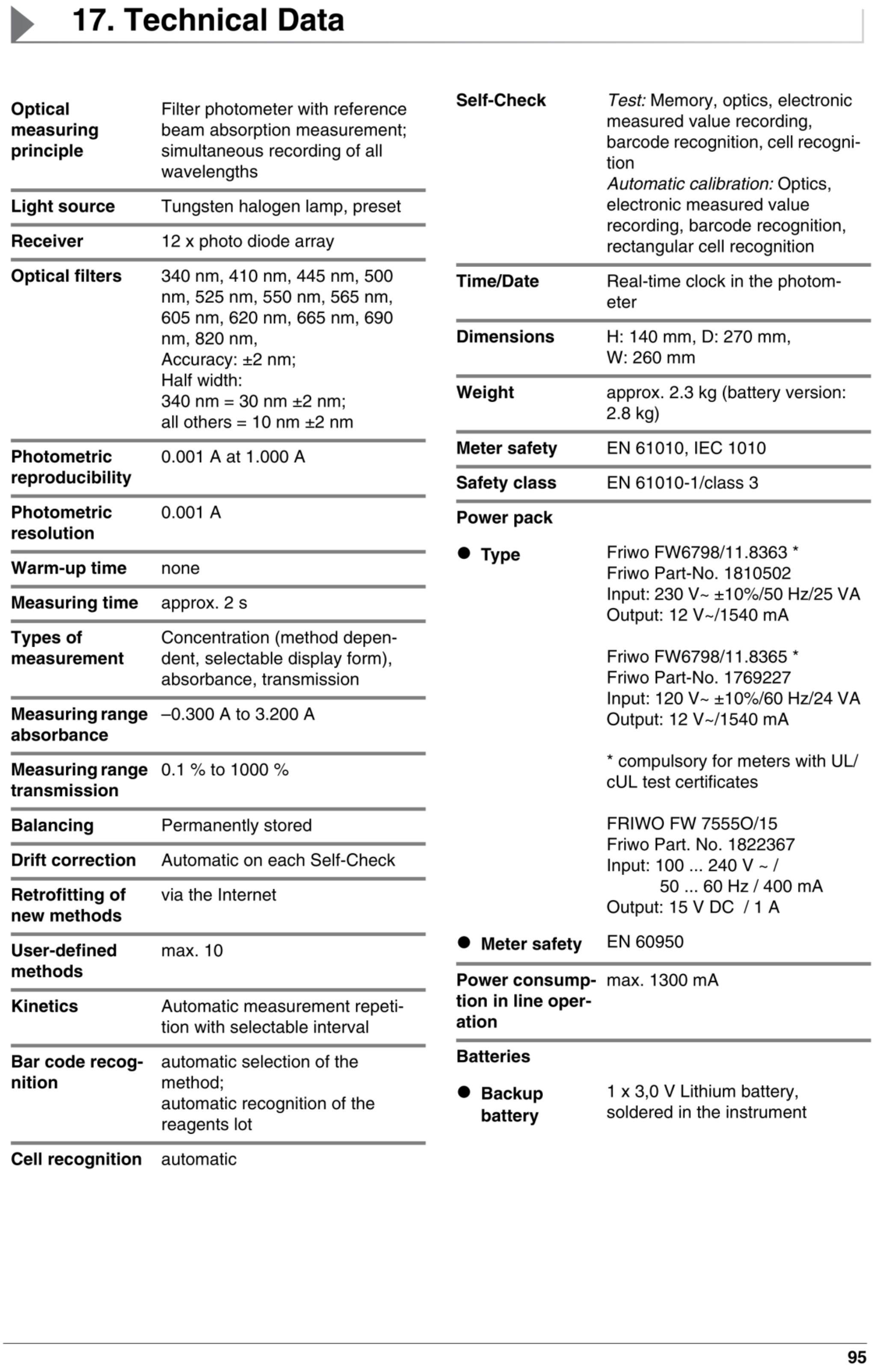


Section 1 Specifications

Specifications are subject to change without notice.

Performance Specifications	
Operating Mode	Transmittance (%), Absorbance and Concentration
Source Lamp	Gas-filled Tungsten (visible)
Wavelength Range	340–900 nm
Wavelength Accuracy	± 1.5 nm
Wavelength Reproducibility	< 0.1 nm
Wavelength Resolution	1 nm
Wavelength Calibration	Automatic
Wavelength Selection	Automatic, based on method selection
Spectral Bandwidth	5 nm
Photometric measuring range	± 3.0 Ext in Wavelength Range 340–900 nm
Photometric Accuracy	5 mAbs at 0.0–0.5 Abs 1% at 0.50–2.0 Abs
Photometric Linearity	< 0.5%–2 Abs < = 1% at > 2 Abs with neutral glass at 546 nm
Stray Light	< 0.2% T @ 340 nm with KV450/3 < 0.1% T @ 340 nm with $NaNO_2$
Data storage	500 measured values (result, date, time, sample ID, user ID)
User programs	50
Physical and Environmental Specifications	
Width	220 mm (8.6 in)
Height	135 mm (5.3 in)
Depth	330 mm (12.9 in)
Weight	4.06 kg (8.95 lbs) without battery 4.38 kg (9.66 lbs) with battery
Operating Requirements	10–40 °C (50–104 °F), max. 80% relative humidity (non-condensing)
Storage Requirements	-40–60 °C (-40–140 °F) max. 80% relative humidity (non-condensing)
Additional technical data	
Mains connection	15 V- / 30VA Plug-in power supply unit: (100–240 V/50–60 Hz)
Interfaces	Use only shielded cable with max. length of 3 m. 1 x USB type A 1 x USB type B
Enclosure Rating	IP 41 with closed lid IP 42 with Protective Cover in place
Safety class	Safety class II

F – Technical specifications for MERCK NOVA 60 SQ® photometer

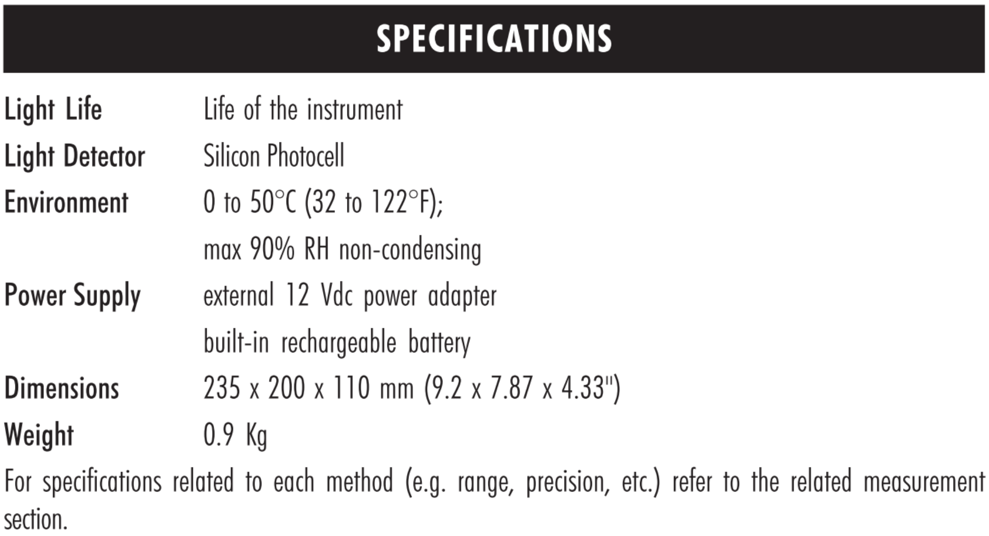


17. Technical Data

Optical measuring principle	Filter photometer with reference beam absorption measurement; simultaneous recording of all wavelengths
Light source	Tungsten halogen lamp, preset
Receiver	12 x photo diode array
Optical filters	340 nm, 410 nm, 445 nm, 500 nm, 525 nm, 550 nm, 565 nm, 605 nm, 620 nm, 665 nm, 690 nm, 820 nm, Accuracy: ±2 nm; Half width: 340 nm = 30 nm ±2 nm; all others = 10 nm ±2 nm
Photometric reproducibility	0.001 A at 1.000 A
Photometric resolution	0.001 A
Warm-up time	none
Measuring time	approx. 2 s
Types of measurement	Concentration (method dependent, selectable display form), absorbance, transmission
Measuring range absorbance	–0.300 A to 3.200 A
Measuring range transmission	0.1 % to 1000 %
Balancing	Permanently stored
Drift correction	Automatic on each Self-Check
Retrofitting of new methods	via the Internet
User-defined methods	max. 10
Kinetics	Automatic measurement repetition with selectable interval
Bar code recognition	automatic selection of the method; automatic recognition of the reagents lot
Cell recognition	automatic

Self-Check	*Test:* Memory, optics, electronic measured value recording, barcode recognition, cell recognition *Automatic calibration:* Optics, electronic measured value recording, barcode recognition, rectangular cell recognition
Time/Date	Real-time clock in the photometer
Dimensions	H: 140 mm, D: 270 mm, W: 260 mm
Weight	approx. 2.3 kg (battery version: 2.8 kg)
Meter safety	EN 61010, IEC 1010
Safety class	EN 61010-1/class 3
Power pack	
● **Type**	Friwo FW6798/11.8363 * Friwo Part-No. 1810502 Input: 230 V~ ±10%/50 Hz/25 VA Output: 12 V~/1540 mA Friwo FW6798/11.8365 * Friwo Part-No. 1769227 Input: 120 V~ ±10%/60 Hz/24 VA Output: 12 V~/1540 mA * compulsory for meters with UL/cUL test certificates FRIWO FW 7555O/15 Friwo Part. No. 1822367 Input: 100 ... 240 V ~ / 50 ... 60 Hz / 400 mA Output: 15 V DC / 1 A
● **Meter safety**	EN 60950
Power consumption in line operation	max. 1300 mA
Batteries	
● **Backup battery**	1 x 3,0 V Lithium battery, soldered in the instrument

Ga – Technical specifications for HANNA instruments HI 83203 photometer

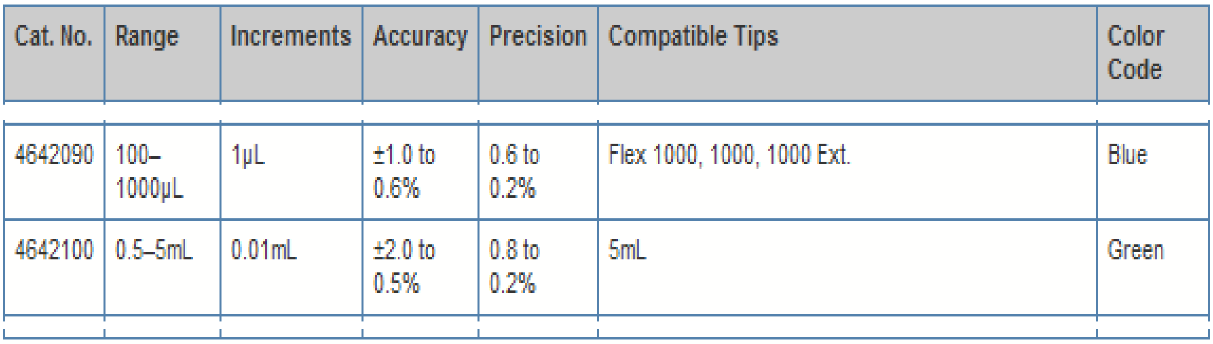


SPECIFICATIONS

Light Life	Life of the instrument
Light Detector	Silicon Photocell
Environment	0 to 50°C (32 to 122°F); max 90% RH non-condensing
Power Supply	external 12 Vdc power adapter built-in rechargeable battery
Dimensions	235 x 200 x 110 mm (9.2 x 7.87 x 4.33")
Weight	0.9 Kg

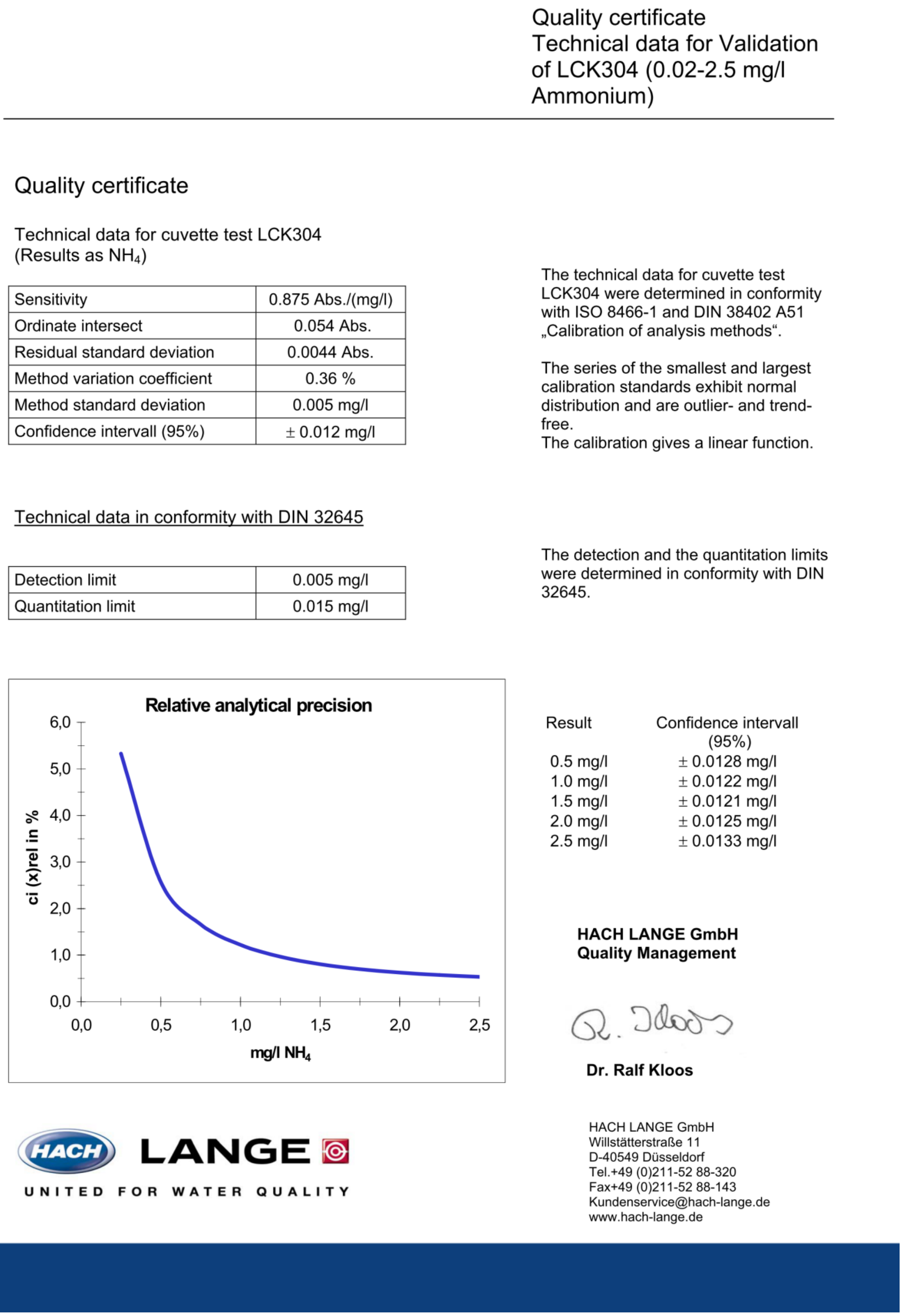
For specifications related to each method (e.g. range, precision, etc.) refer to the related measurement section.

Gb – Technical specifications for Finnpipette* F2 Adjustable-Volume Pipetters



Cat. No.	Range	Increments	Accuracy	Precision	Compatible Tips	Color Code
4642090	100–1000µL	1µL	±1.0 to 0.6%	0.6 to 0.2%	Flex 1000, 1000, 1000 Ext.	Blue
4642100	0.5–5mL	0.01mL	±2.0 to 0.5%	0.8 to 0.2%	5mL	Green

H – Water analysis cuvette, reagent and cell tests for large scale experiment



Quality certificate
Technical data for Validation
of LCK304 (0.02-2.5 mg/l
Ammonium)

Quality certificate

Technical data for cuvette test LCK304
(Results as NH_4)

Sensitivity	0.875 Abs./(mg/l)
Ordinate intersect	0.054 Abs.
Residual standard deviation	0.0044 Abs.
Method variation coefficient	0.36 %
Method standard deviation	0.005 mg/l
Confidence intervall (95%)	± 0.012 mg/l

The technical data for cuvette test LCK304 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	0.005 mg/l
Quantitation limit	0.015 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.

Result	Confidence intervall (95%)
0.5 mg/l	± 0.0128 mg/l
1.0 mg/l	± 0.0122 mg/l
1.5 mg/l	± 0.0121 mg/l
2.0 mg/l	± 0.0125 mg/l
2.5 mg/l	± 0.0133 mg/l

HACH LANGE GmbH
Quality Management

R. Kloos

Dr. Ralf Kloos

HACH LANGE LANGE
UNITED FOR WATER QUALITY

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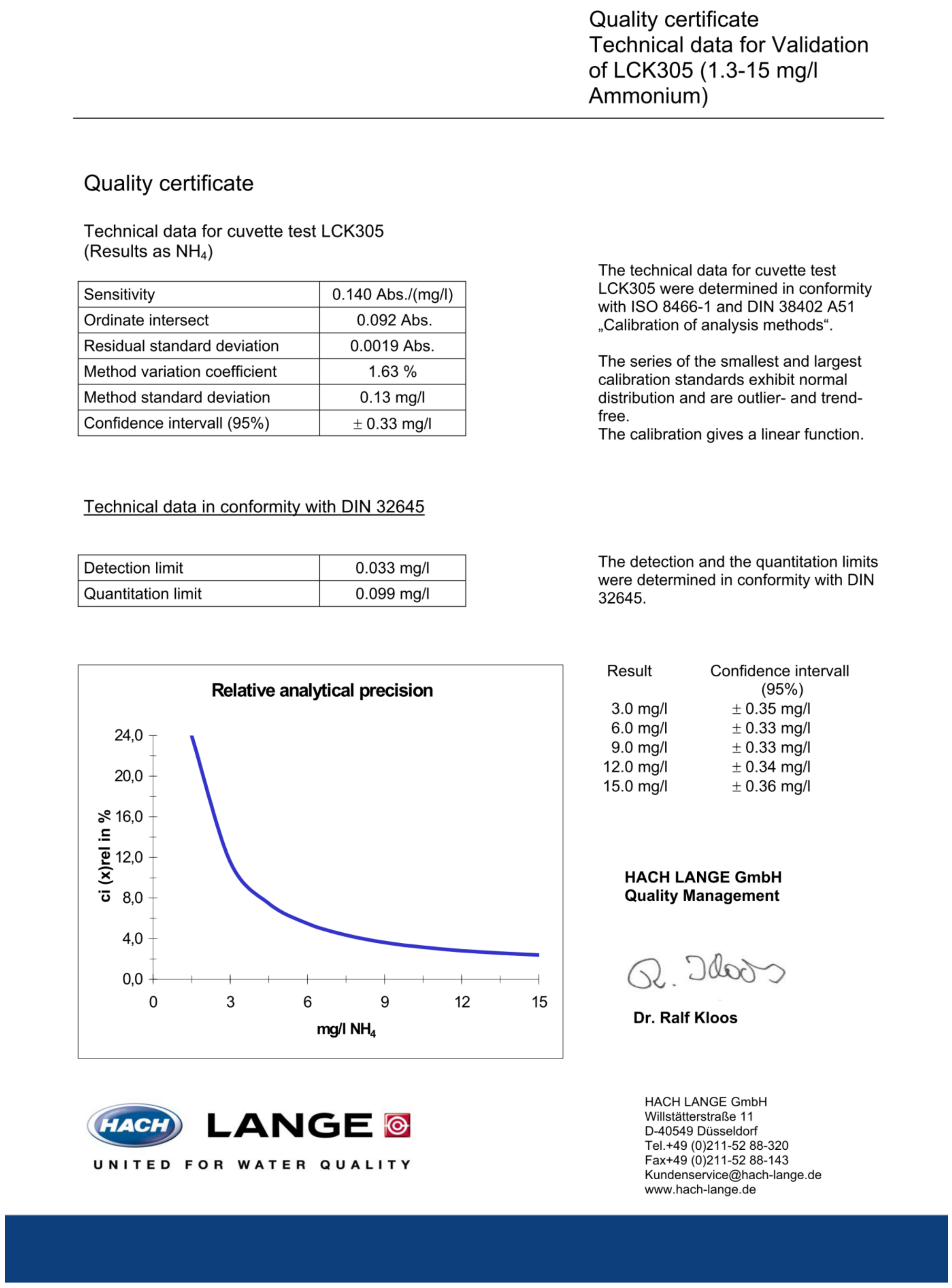
Kundenservice@hach-lange.de
www.hach-lange.de



Quality certificate
Technical data for Validation of LCK305 (1.3-15 mg/l Ammonium)

Quality certificate

Technical data for cuvette test LCK305
(Results as NH_4)

Sensitivity	0.140 Abs./(mg/l)
Ordinate intersect	0.092 Abs.
Residual standard deviation	0.0019 Abs.
Method variation coefficient	1.63 %
Method standard deviation	0.13 mg/l
Confidence intervall (95%)	± 0.33 mg/l

The technical data for cuvette test LCK305 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	0.033 mg/l
Quantitation limit	0.099 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.

Result	Confidence intervall (95%)
3.0 mg/l	± 0.35 mg/l
6.0 mg/l	± 0.33 mg/l
9.0 mg/l	± 0.33 mg/l
12.0 mg/l	± 0.34 mg/l
15.0 mg/l	± 0.36 mg/l

HACH LANGE GmbH
Quality Management

Dr. Ralf Kloos

HACH LANGE
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Quality certificate
Technical data for Validation
of LCK341 (0.05-2 mg/l
Nitrite)

Quality certificate

Technical data for cuvette test LCK341
(Results as NO_2)

Sensitivity	0.638 Abs./(mg/l)
Ordinate intersect	0.077 Abs.
Residual standard deviation	0.0093 Abs.
Method variation coefficient	1.32 %
Method standard deviation	0.015 mg/l
Confidence intervall (95%)	± 0.035 mg/l

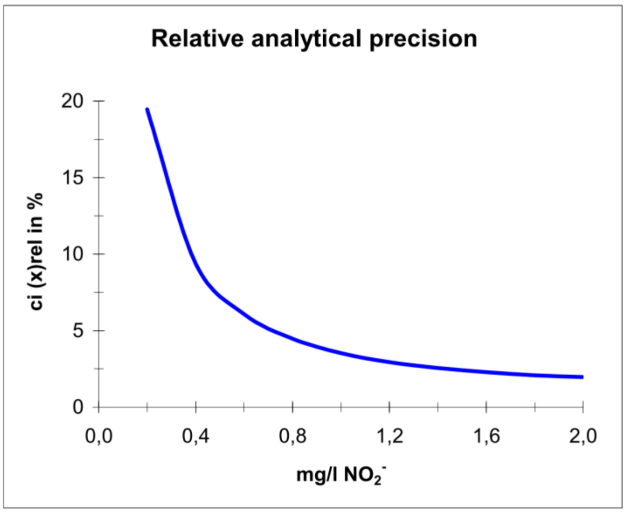
The technical data for cuvette test LCK341 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	0.012 mg/l
Quantitation limit	0.037 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.



Result	Confidence intervall (95%)
0.40 mg/l	± 0.037 mg/l
0.80 mg/l	± 0.036 mg/l
1.20 mg/l	± 0.035 mg/l
1.60 mg/l	± 0.036 mg/l
2.00 mg/l	± 0.039 mg/l

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R. Kloos

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Quality certificate
Technical data for Validation of LCK340 (22-155 mg/l Nitrate)

Quality certificate

Technical data for cuvette test LCK340
(Results as NO_3)

Sensitivity	0.0036 Abs./(mg/l)
Ordinate intersect	0.055 Abs.
Residual standard deviation	0.0045 Abs.
Method variation coefficient	1.49 %
Method standard deviation	1.2 mg/l
Confidence intervall (95%)	± 3.0 mg/l

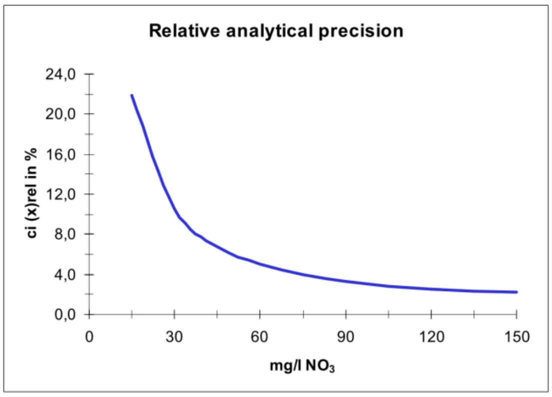
The technical data for cuvette test LCK340 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	1.0 mg/l
Quantitation limit	3.1 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.



Result	Confidence intervall (95%)
30.0 mg/l	± 3.16 mg/l
60.0 mg/l	± 3.00 mg/l
90.0 mg/l	± 2.96 mg/l
120.0 mg/l	± 3.06 mg/l
150.0 mg/l	± 3.28 mg/l

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Quality certificate
Technical data for Validation of LCK348 (0.5-5.0 mg/l Ptot, Total Phosphor)

Quality certificate

Technical data for cuvette test LCK348
(Results as PO_4-P)

Sensitivity	0.152 Abs./(mg/l)
Ordinate intersect	0.113 Abs.
Residual standard deviation	0.0028 Abs.
Method variation coefficient	0.67 %
Method standard deviation	0.018 mg/l
Confidence interval (95%)	± 0.045 mg/l

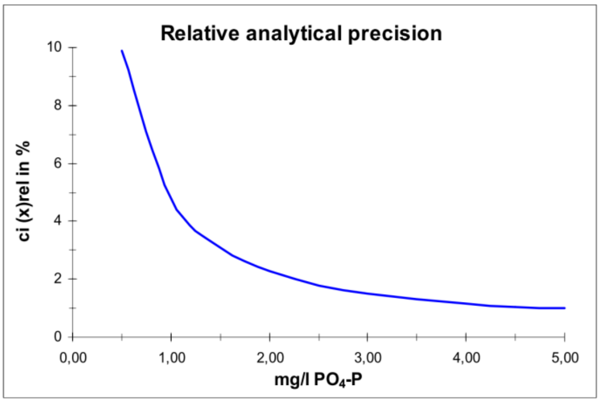
The technical data for cuvette test LCK348 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	0.041 mg/l
Quantitation limit	0.123 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.



Result	Confidence interval (95%)
1.0 mg/l	± 0.048 mg/l
2.0 mg/l	± 0.045 mg/l
3.0 mg/l	± 0.045 mg/l
4.0 mg/l	± 0.046 mg/l
5.0 mg/l	± 0.049 mg/l

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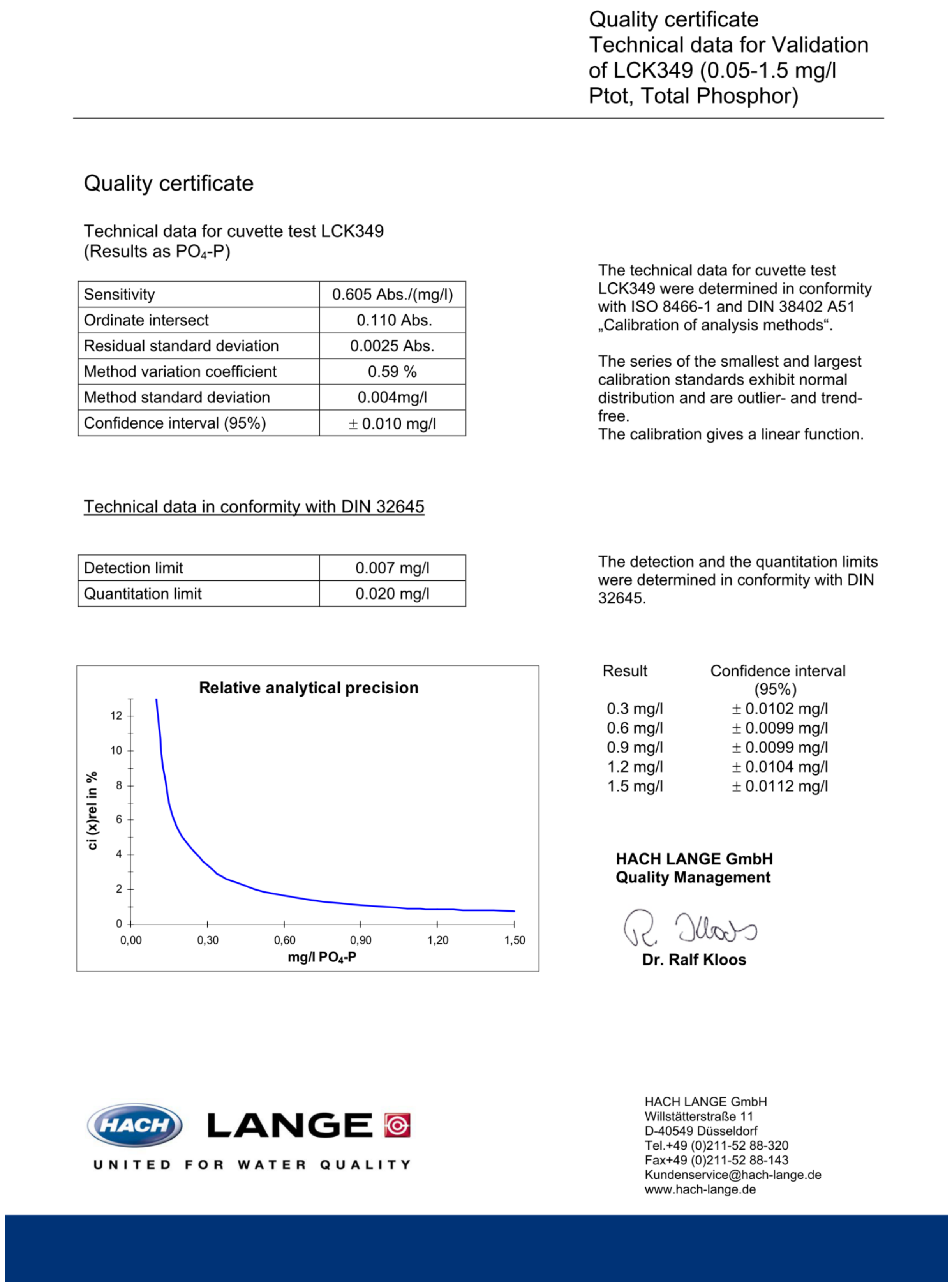

Quality certificate
Technical data for Validation
of LCK349 (0.05-1.5 mg/l
Ptot, Total Phosphor)

Quality certificate

Technical data for cuvette test LCK349
(Results as PO_4-P)

Sensitivity	0.605 Abs./(mg/l)
Ordinate intersect	0.110 Abs.
Residual standard deviation	0.0025 Abs.
Method variation coefficient	0.59 %
Method standard deviation	0.004mg/l
Confidence interval (95%)	± 0.010 mg/l

The technical data for cuvette test LCK349 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	0.007 mg/l
Quantitation limit	0.020 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.

Relative analytical precision

Result	Confidence interval (95%)
0.3 mg/l	± 0.0102 mg/l
0.6 mg/l	± 0.0099 mg/l
0.9 mg/l	± 0.0099 mg/l
1.2 mg/l	± 0.0104 mg/l
1.5 mg/l	± 0.0112 mg/l

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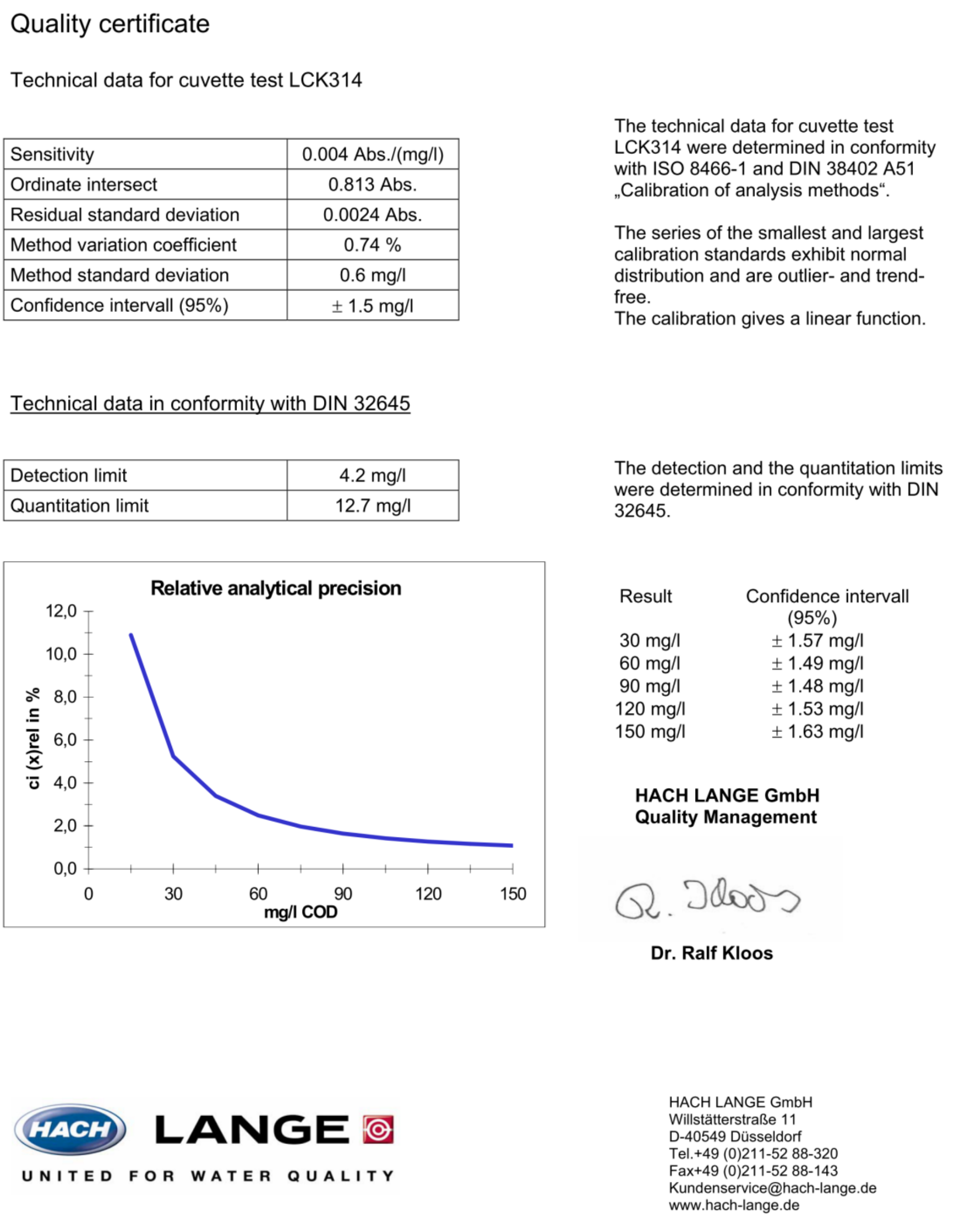
Quality certificate Technical data for Validation of LCK314 (15-150 mg/l COD)



Quality certificate

Technical data for cuvette test LCK314

Sensitivity	0.004 Abs./(mg/l)
Ordinate intersect	0.813 Abs.
Residual standard deviation	0.0024 Abs.
Method variation coefficient	0.74 %
Method standard deviation	0.6 mg/l
Confidence intervall (95%)	± 1.5 mg/l

The technical data for cuvette test LCK314 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods".

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	4.2 mg/l
Quantitation limit	12.7 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.

Result	Confidence intervall (95%)
30 mg/l	± 1.57 mg/l
60 mg/l	± 1.49 mg/l
90 mg/l	± 1.48 mg/l
120 mg/l	± 1.53 mg/l
150 mg/l	± 1.63 mg/l

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Quality certificate
Technical data for Validation of LCK114 (150-1000 mg/l COD)

Quality certificate

Technical data for cuvette test LCK114

Sensitivity	0.0005 Abs./(mg/l)
Ordinate intersect	0.048 Abs.
Residual standard deviation	0.0037 Abs.
Method variation coefficient	1.33 %
Method standard deviation	7.3 mg/l
Confidence intervall (95%)	± 17.7 mg/l

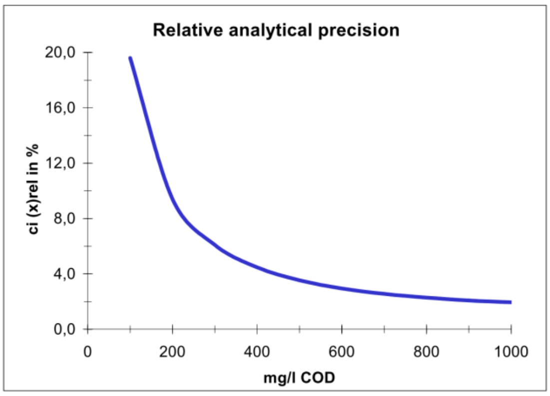
The technical data for cuvette test LCK114 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	4.4 mg/l
Quantitation limit	13.2 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.



Result	Confidence intervall (95%)
200 mg/l	± 18.8 mg/l
400 mg/l	± 17.8 mg/l
600 mg/l	± 17.7 mg/l
800 mg/l	± 18.3 mg/l
1000 mg/l	± 19.5 mg/l

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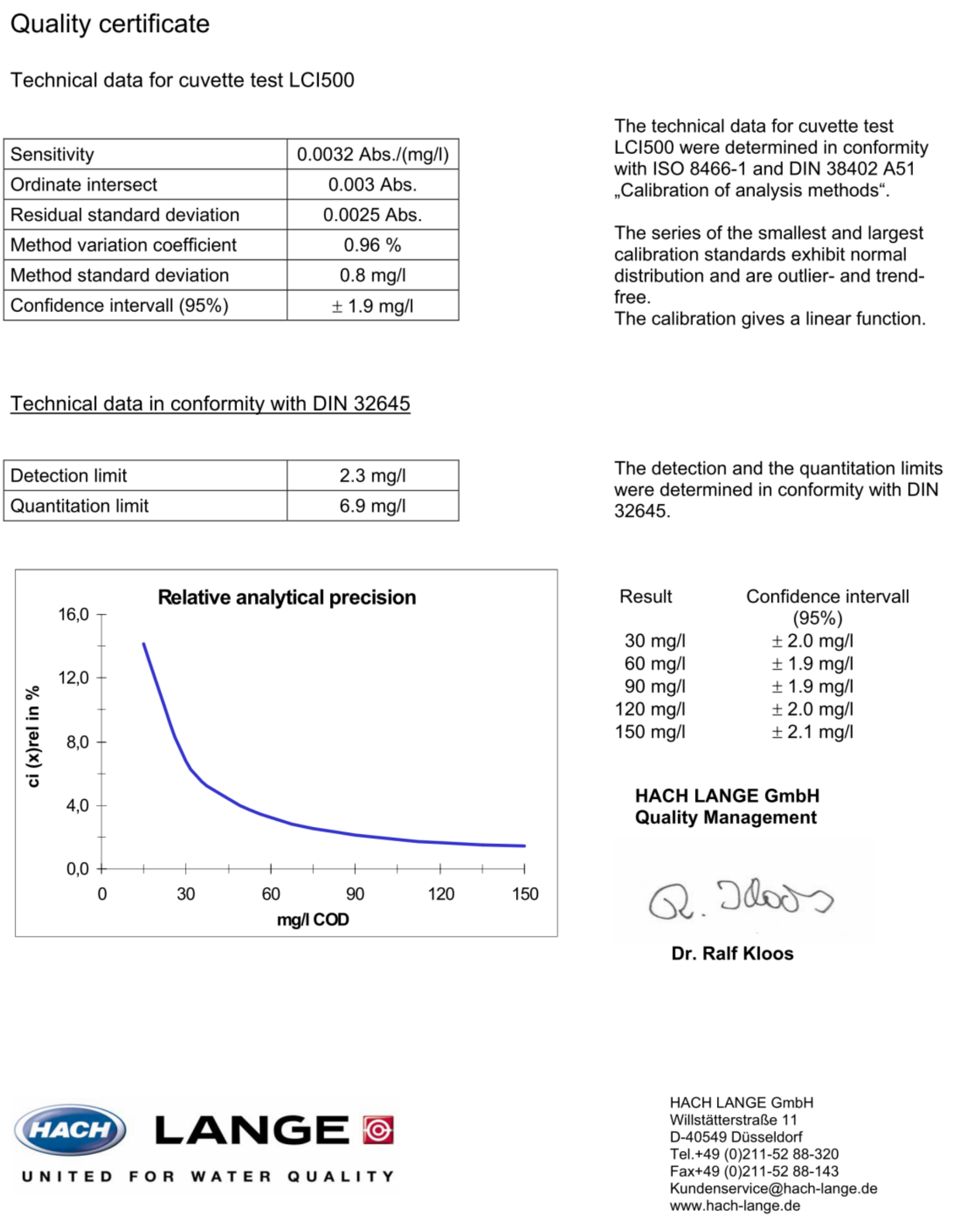
Quality certificate
Technical data for Validation of LI500 (0-150 mg/l COD in conformity with ISO 15705)



Quality certificate

Technical data for cuvette test LCI500

Sensitivity	0.0032 Abs./(mg/l)
Ordinate intersect	0.003 Abs.
Residual standard deviation	0.0025 Abs.
Method variation coefficient	0.96 %
Method standard deviation	0.8 mg/l
Confidence intervall (95%)	± 1.9 mg/l

The technical data for cuvette test LCI500 were determined in conformity with ISO 8466-1 and DIN 38402 A51 „Calibration of analysis methods“.

The series of the smallest and largest calibration standards exhibit normal distribution and are outlier- and trend-free.
The calibration gives a linear function.

Technical data in conformity with DIN 32645

Detection limit	2.3 mg/l
Quantitation limit	6.9 mg/l

The detection and the quantitation limits were determined in conformity with DIN 32645.

Result	Confidence intervall (95%)
30 mg/l	± 2.0 mg/l
60 mg/l	± 1.9 mg/l
90 mg/l	± 1.9 mg/l
120 mg/l	± 2.0 mg/l
150 mg/l	± 2.1 mg/l

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Nitrite

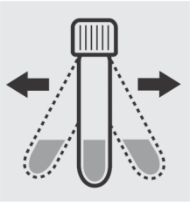
114547

Cell Test

Measuring	0.010 – 0.700 mg/l NO_2-N
range:	0.03 – 2.30 mg/l NO_2
	Expression of results also possible in mmol/l.

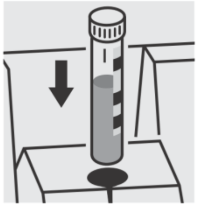
Check the pH of the sample, specified range: pH 2 – 10.
If required, add dilute sulfuric acid drop by drop to adjust the pH.

Pipette 5.0 ml of the sample into a reaction cell, close with the screw cap.



Shake the cell vigorously to dissolve the solid substance.

Reaction time: 10 minutes



Place the cell into the cell compartment. Align the mark on the cell with that on the photometer.

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) ready-for-use nitrite standard solution CertiPUR®, Cat.No. 119899, concentration 1000 mg/l NO_2^-, can be used after diluting accordingly as well as the Standard solution for photometric applications, CRM, Cat.No. 125041.

1.14547.0001

Nitrite
Cell Test

NO_2^-

May 2011

1. Method

In acidic solution nitrite ions react with sulfanilic acid to form a diazonium salt, which in turn reacts with N-(1-naphthyl)ethylenediamine dihydrochloride to form a red-violet azo dye. This dye is determined photometrically.
The method is analogous to EPA 354.1, APHA 4500-NO_2^- B, and DIN EN 26 777 D10.

2. Measuring range and number of determinations

Measuring range	Number of determinations
0.010 - 0.700 mg/l NO_2-N	25
0.03 - 2.30 mg/l NO_2^-	

For programming data for selected photometers / spectrophotometers see the website.

3. Applications

Sample material:
Groundwater, drinking water, and surface water
Seawater
Wastewater
Food after appropriate sample pretreatment
Soils after appropriate sample pretreatment

4. Influence of foreign substances

This was checked in solutions containing 0,5 and 0 mg/l NO_2-N. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %							
Ag^+	**1**	Cu^{2+}	100	Pb^{2+}	1000	EDTA	1000
Ca^{2+}	1000	F^-	100	PO_4^{3-}	1000	**Reducing agents (ascorbic acid, sulfite)**	**10**
Cd^{2+}	1000	**Fe^{3+}**	**1**	**S^{2-}**	**10**	NaCl	20 %
CN^-	1000	Hg^{2+}	100	SiO_3^{2-}	1000	$NaNO_3$	20 %
CO_3^{2-}	100	Mg^{2+}	1000	**Sn^{2+}**	**10**	Na_2SO_4	15 %
Cr^{3+}	100	Mn^{2+}	1000	Zn^{2+}	1000		
$Cr_2O_7^{2-}$	**1**	NH_4^+	1000				

5. Reagents and auxiliaries

Please note the warnings on the packaging materials!
Store the pack protected from light! The test reagents are stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
25 reaction cells
1 cell with blank (**white** screw cap); **required only when using the SQ 118 photometer**
1 sheet of round stickers for numbering the cells

Other reagents and accessories:
Merckoquant® Nitrite Test, Cat. No. 110057,
measuring range 0.5 - 10 mg/l NO_2^- (0.15 - 3.0 mg/l NO_2-N)
Universal indicator strips pH 0 - 14, Cat. No. 109535
Sulfuric acid 0.5 mol/l TitriPUR®, Cat. No. 109072
Nitrite standard solution CRM, 0.200 mg/l NO_2-N, Cat. No. 125041

Pipette for a pipetting volume of 5.0 ml

6. Preparation

- Analyze immediately after sampling.
- Check the nitrite content with the Merckoquant® Nitrite Test.
  Samples containing more than 0.700 mg/l NO_2-N must be diluted with distilled water.
- **The pH must be within the range 2 - 10.**
  Adjust, if necessary, with sulfuric acid.
- Filter turbid samples.

7. Procedure

Pretreated sample (**15 - 25 °C**)	5.0 ml	Pipette into a reaction cell, close the cell tightly, and shake **vigorously until the reagent is completely dissolved**.
Leave to stand for 10 min (reaction time), then measure the sample in the photometer.		

Notes on the measurement:

- For photometric measurement the cells must be clean.
  Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-high readings.
- The pH of the measurement solution must be within the range 2.0 - 2.5.
- The colour of the measurement solution remains stable for at least 60 min after the end of the reaction time stated above.

8. Analytical quality assurance

recommended before each measurement series
To check the photometric measurement system (test reagent, measurement device, handling) and the mode of working, the nitrite standard solution CRM, 0.200 mg/l NO_2-N, Cat. No. 125041 can be used.
Sample-dependent interferences (matrix effects) can be determined by means of standard addition.
Additional notes see under **www.merck-chemicals.com/qa**.

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51:

Standard deviation of the method (mg/l NO_2-N)	± 0.0028
Coefficient of variation of the method (%)	± 0.83
Confidence interval (mg/l NO_2-N)	± 0.008
Number of lots	44

Characteristic data of the procedure:

Sensitivity: Absorbance 0.010 A corresponds to (mg/l NO_2-N)	0.003
Accuracy of a measurement value (mg/l NO_2-N)	max. ± 0.010

For quality and batch certificates for Spectroquant® test kits see the website.

9. Note

Information on disposal can be obtained under the Quick Link "Waste Disposal Advice" at www.merck-chemicals.com/test-kits.

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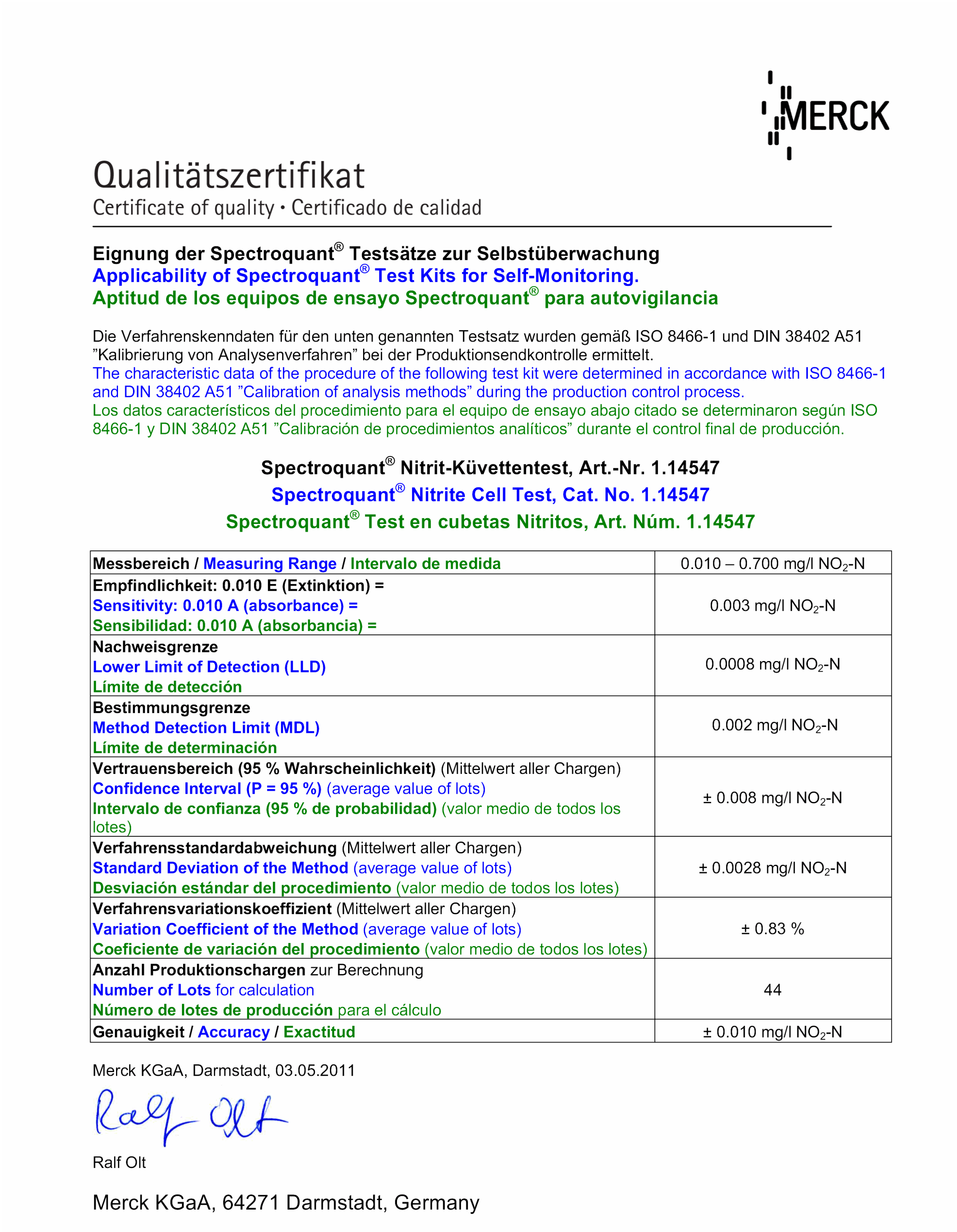
test-kits@merck-chemicals.com www.merck-chemicals.com/photometry



MERCK

Qualitätszertifikat

Certificate of quality • Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 "Kalibrierung von Analysenverfahren" bei der Produktionsendkontrolle ermittelt.

The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 "Calibration of analysis methods" during the production control process.

Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 "Calibración de procedimientos analíticos" durante el control final de producción.

Spectroquant® Nitrit-Küvettentest, Art.-Nr. 1.14547
Spectroquant® Nitrite Cell Test, Cat. No. 1.14547
Spectroquant® Test en cubetas Nitritos, Art. Núm. 1.14547

Messbereich / Measuring Range / Intervalo de medida	0.010 – 0.700 mg/l NO_2-N
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.003 mg/l NO_2-N
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	0.0008 mg/l NO_2-N
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	0.002 mg/l NO_2-N
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	± 0.008 mg/l NO_2-N
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	± 0.0028 mg/l NO_2-N
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	± 0.83 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	44
Genauigkeit / Accuracy / Exactitud	± 0.010 mg/l NO_2-N

Merck KGaA, Darmstadt, 03.05.2011

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany

Nitrate

114764

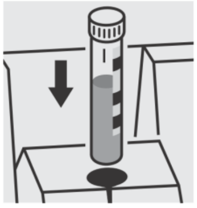
Cell Test

Measuring	1.0 – 50.0 mg/l NO_3-N
range:	4 – 221 mg/l NO_3
	Expression of results also possible in mmol/l.

Pipette 0.50 ml of the sample into a reaction cell, **do not mix**.

Add 1.0 ml of **NO_3-1K** with pipette, close the cell with the screw cap, and mix. **Caution, cell becomes hot!**

Reaction time: 10 minutes



Place the cell into the cell compartment. Align the mark on the cell with that on the photometer.

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) we recommended to use Spectroquant® CombiCheck 80, Cat.No. 114738, or the Standard solution for photometric applications, CRM, Cat. No. 125037, 125038, and 125039.

Ready-for-use nitrate standard solution CertiPUR®, Cat.No. 119811, concentration 1000 mg/l NO_3^-, can also be used after diluting accordingly.

To check for sample-dependent effects the use of addition solutions (e.g. in CombiCheck 80) is highly recommended.

1.14764.0001

Nitrate Cell Test

NO_3^-

1. Method

In sulfuric and phosphoric solution nitrate ions react with 2,6-dimethylphenol (DMP) to form 4-nitro-2,6-dimethylphenol that is determined photometrically. **The method is analogous to DIN 38405 D9.**

2. Measuring range and number of determinations

Measuring range	Number of determinations
1.0 - 50.0 mg/l NO_3-N	25
4 - 221 mg/l NO_3^-	

For programming data for selected photometers / spectrophotometers see the website.

3. Applications

This test is not suited for the determination in waters with chloride contents exceeding 2000 mg/l and COD values exceeding 1000 mg/l.

Sample material:
Groundwater, drinking water, and surface water
Spring water and well water
Mineral water
Wastewater and industrial water
Nutrient solutions for fertilization
Soils after appropriate sample pretreatment
This test is **not suited** for seawater.

4. Influence of foreign substances

This was checked in solutions containing 25 and 0 mg/l NO_3-N. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %					
Al^{3+}	1000	Mg^{2+}	1000	EDTA	1000
Ca^{2+}	1000	Mn^{2+}	1000	Surfactants [2]	1000
Cd^{2+}	500	NH_4^+	1000		
Cl^-	**2000**	Ni^{2+}	1000	**COD (K-hydrogen phthalate)**	**1000**
CN^-	100	**NO_2^-**	**10 [1]**		
Cr^{3+}	1000	Pb^{2+}	250	**Organic substances (glucose)**	**1000**
$Cr_2O_7^{2-}$	**100**	PO_4^{3-}	1000	Na-acetate	20 %
Cu^{2+}	1000	SiO_3^{2-}	500	NaCl	0.5 %
F^-	1000	SO_3^{2-}	100	Na_2SO_4	20 %
Fe^{3+}	250	Zn^{2+}	1000		
Hg^{2+}	250				

[1] In cases of higher concentrations, eliminate nitrite ions acc. to section 6.
[2] tested with nonionic, cationic, and anionic surfactants

5. Reagents and auxiliaries

Please note the warnings on the packaging materials!

The test reagents are stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
1 bottle of reagent NO_3-1K
25 reaction cells
1 cell with blank (**white** screw cap); **required only when using the SQ 118 photometer**
1 sheet of round stickers for numbering the cells

Other reagents and accessories:
Merckoquant® Chloride Test, Cat. No. 110079,
measuring range 500 - ≥3000 mg/l Cl^-
Merckoquant® Nitrite Test, Cat. No. 110007,
measuring range 2 - 80 mg/l NO_2^- (0.6 - 24 mg/l NO_2-N)
Amidosulfuric acid for analysis EMSURE®, Cat. No. 100103
Acilit® indicator strips pH 0 - 6.0, Cat. No. 109531
Sulfuric acid 25 % for analysis EMSURE®, Cat. No. 100716
Merckoquant® Nitrate Test, Cat. No. 110020,
measuring range 10 - 500 mg/l NO_3^- (2.3 - 113 mg/l NO_3-N)
Spectroquant® CombiCheck 80, Cat. No. 114738
Nitrate standard solution CRM, 2.50 mg/l NO_3-N, Cat. No. 125037
Nitrate standard solution CRM, 15.0 mg/l NO_3-N, Cat. No. 125038
Nitrate standard solution CRM, 40.0 mg/l NO_3-N, Cat. No. 125039

Pipettes for pipetting volumes of 0.50 and 1.0 ml

February 2011

6. Preparation

- Analyze immediately after sampling.
- Check the chloride content with the Merckoquant® Chloride Test. Samples containing more than 2000 mg/l Cl^- must be diluted with distilled water.
- Check the nitrite content with the Merckoquant® Nitrite Test.

  If necessary, eliminate interfering nitrite ions. The stated amounts apply for nitrite contents of up to 100 mg/l:
  To 10 ml of sample add approx. 50 mg of amidosulfuric acid and dissolve.
  The pH of this solution must be within the range 1 - 3. Adjust, if necessary, with sulfuric acid.
- Check the nitrate content with the Merckoquant® Nitrate Test. Samples containing more than 50.0 mg/l NO_3-N (221 mg/l NO_3^-) must be diluted with distilled water.
- Filter turbid samples.

7. Procedure

Pretreated sample (**5 - 25 °C**)	0.50 ml	Pipette into a reaction cell. **Do not mix contents!**
Reagent NO_3-1K	1.0 ml	Add with pipette (**Wear eye protection! The cell becomes hot!**). Close the cell **tightly** and mix. **The cell must be held only by the screw cap!**
Leave the hot cell to stand for 10 min (reaction time). **Do not cool with cold water!** Measure the sample in the photometer.		

Notes on the measurement:

- For photometric measurement the cells must be clean. Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-high readings.
- The colour of the measurement solution remains stable for 30 min after the end of the reaction time stated above. (After 60 min the measurement value would have increased by 5 %.)

8. Analytical quality assurance

it is recommended prior to each measurement series
To check the photometric measurement system (test reagents, measurement device, handling) and the mode of working, the nitrate standard solutions 125037, 125038, and 125039 or Spectroquant® CombiCheck 80 can be used. Besides a **standard solution** with 25.0 mg/l NO_3-N, CombiCheck 80 also contains an **addition solution** for determining sample-dependent interferences (matrix effects).
Additional notes see under **www.merck-chemicals.com/qa**.

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51:

Standard deviation of the method (mg/l NO_3-N)	± 0.25
Coefficient of variation of the method (%)	± 0.9
Confidence interval (mg/l NO_3-N)	± 0.6
Number of lots	22

Characteristic data of the procedure:

Sensitivity: Absorbance 0.010 A corresponds to (mg/l NO_3-N)	0.3
Accuracy of a measurement value (mg/l NO_3-N)	max. ± 1.0

For quality and batch certificates for Spectroquant® test kits see the website.

9. Notes

- Reclose the reagent bottle immediately after use.
- **For information on disposal/return for disposal please contact your local Merck organization or Merck dealer.**

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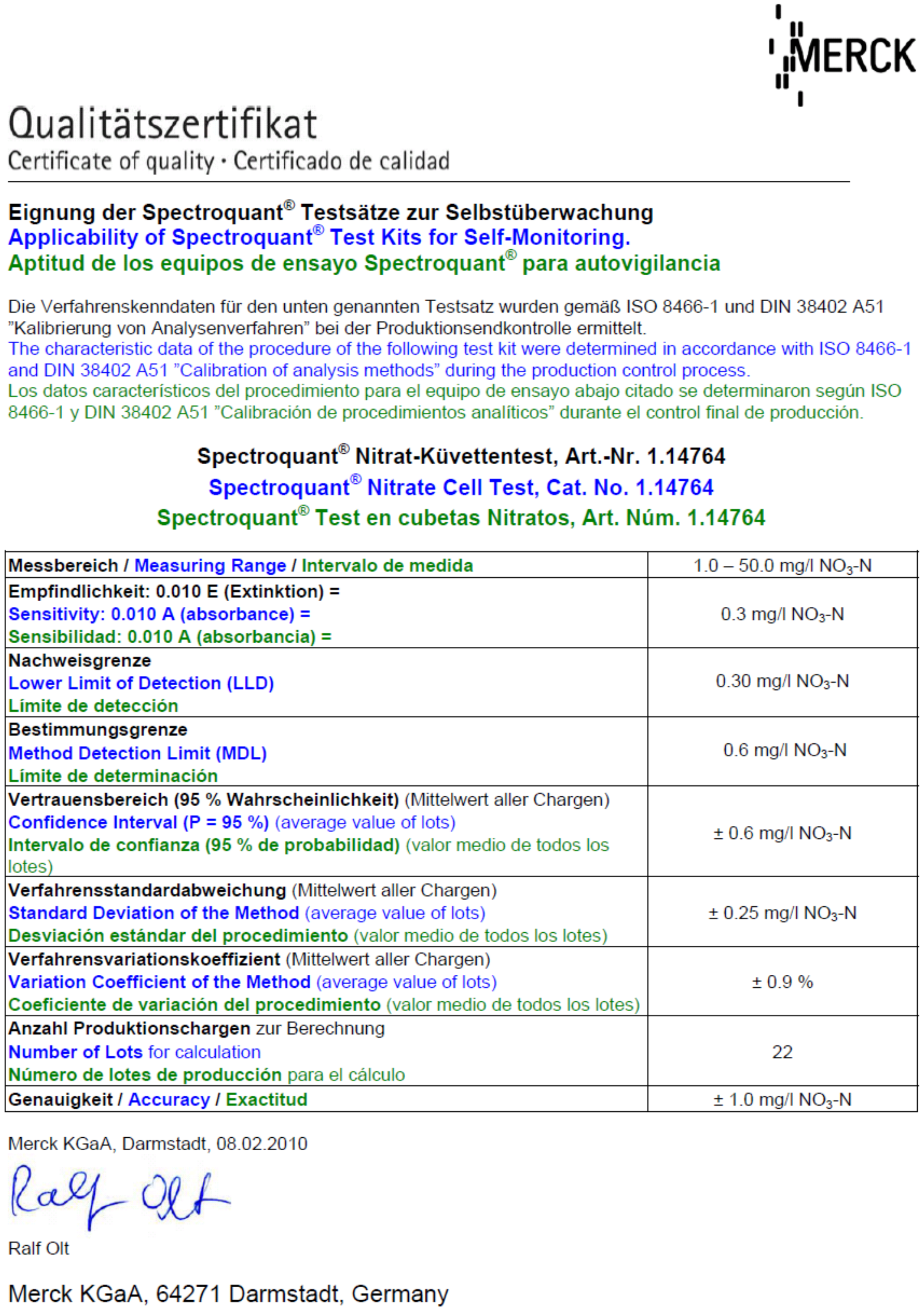
environmental.analysis@merck.de www.merck-chemicals.com/photometry



MERCK

Qualitätszertifikat

Certificate of quality • Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 ”Kalibrierung von Analysenverfahren” bei der Produktionsendkontrolle ermittelt.
The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 ”Calibration of analysis methods” during the production control process.
Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 ”Calibración de procedimientos analíticos” durante el control final de producción.

Spectroquant® Nitrat-Küvettentest, Art.-Nr. 1.14764
Spectroquant® Nitrate Cell Test, Cat. No. 1.14764
Spectroquant® Test en cubetas Nitratos, Art. Núm. 1.14764

Messbereich / Measuring Range / Intervalo de medida	1.0 – 50.0 mg/l NO_3-N
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.3 mg/l NO_3-N
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	0.30 mg/l NO_3-N
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	0.6 mg/l NO_3-N
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	± 0.6 mg/l NO_3-N
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	± 0.25 mg/l NO_3-N
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	± 0.9 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	22
Genauigkeit / Accuracy / Exactitud	± 1.0 mg/l NO_3-N

Merck KGaA, Darmstadt, 08.02.2010

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany

NITRATE

SPECIFICATIONS

Range	0.0 to 30.0 mg/L
Resolution	0.1 mg/L
Accuracy	±0.5 mg/L ±10% of reading
Typical EMC Deviation	±0.1 mg/L
Light Source	Tungsten lamp with narrow band interference filter @ 525 nm
Method	Adaptation of the cadmium reduction method. The reaction between nitrate and the reagent causes an amber tint in the sample.

REQUIRED REAGENTS

Code	Description	Quantity
HI 93728-0	Powder reagent	1 packet

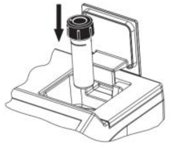
REAGENT SETS

HI 93728-01 Reagents for 100 tests
HI 93728-03 Reagents for 300 tests
For other accessories see page 46.

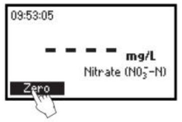
MEASUREMENT PROCEDURE

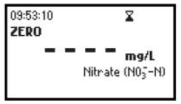
- Select the *Nitrate* method using the procedure described in the *Method Selection* section (see page 11).
- Using the pipette, fill the cuvette with 6 ml of sample, up to half of its height, and replace the cap.

- Place the cuvette into the holder and close the lid.

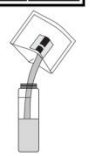


- Press ZERO key. The display will show "-0.0-" when the meter is zeroed and ready for measurement.

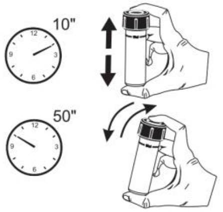




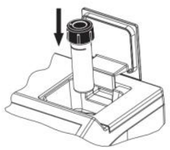
- Remove the cuvette and add the content of one packet of HI 93728-0 reagent.

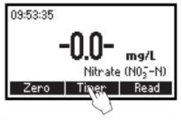


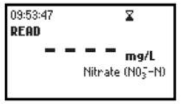
- Replace the cap and immediately shake vigorously up and down for exactly 10 seconds. Continue to mix by inverting the cuvette gently for 50 seconds, while taking care not to induce air bubbles. Powder will not completely dissolve. Time and way of shaking could sensitively affect the measurement.

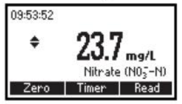


- Reinsert the cuvette into the instrument, taking care not to shake it.
- Press TIMER and the display will show the countdown prior to the measurement or, alternatively, wait for 4 minutes and 30 seconds and press READ. When the timer ends the meter will perform the reading. The instrument displays the results in mg/L of nitrate-nitrogen.

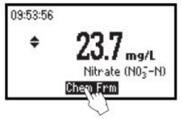


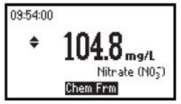






- Press the ▲ or ▼ to access the second level of functions.
- Press the **Chem Frm** functional key to convert the result in mg/L of nitrate (NO$_3^-$).



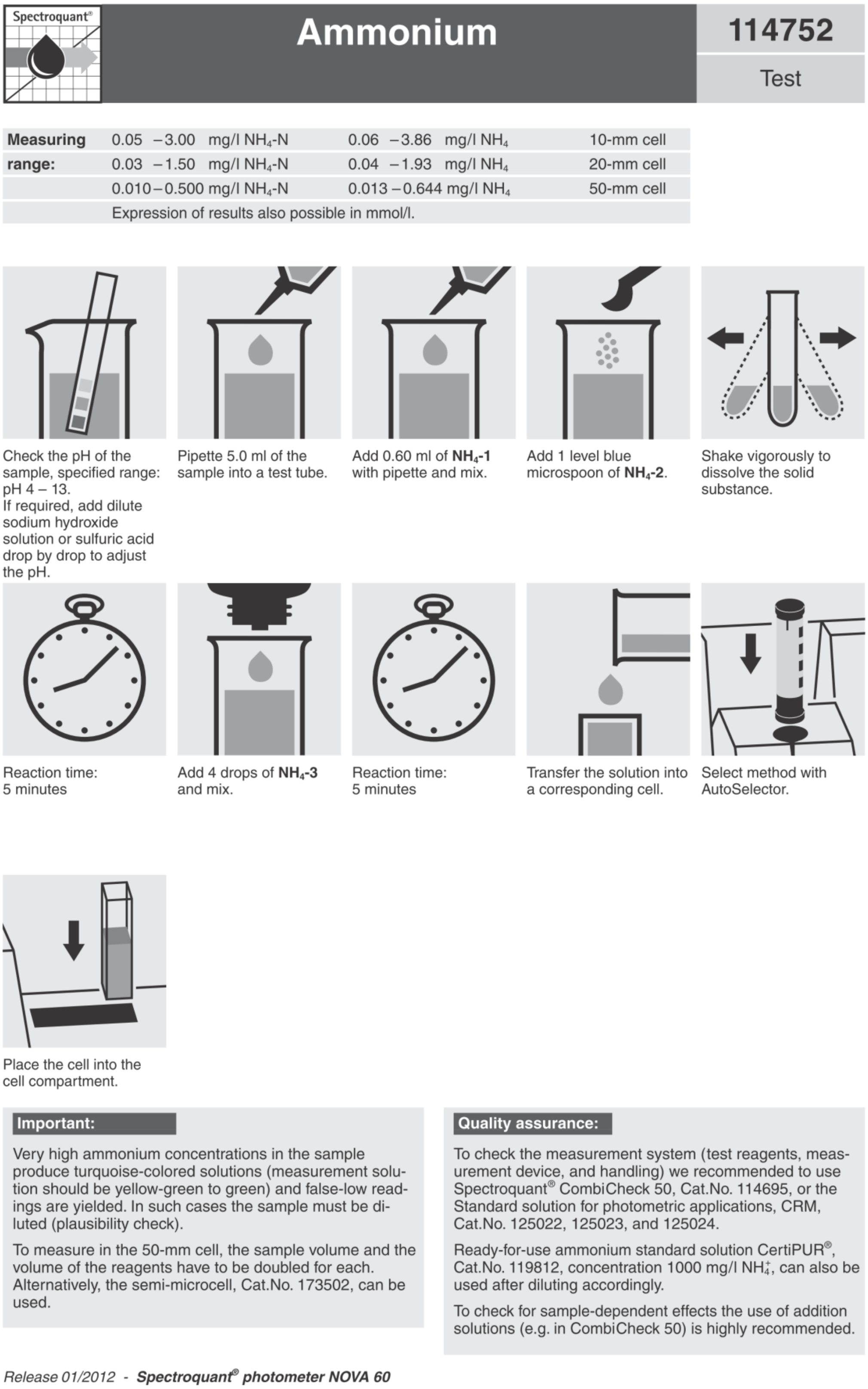


- Press the ▲ or ▼ to go back to the measurement screen.

INTERFERENCES

Interference may be caused by:
Ammonia and amines, as urea and primary aliphatic amines
Chloride above 100 ppm
Chlorine above 2 ppm
Copper
Iron(III)
Strong oxidizing and reducing substances
Sulfide must be absent

I- Water analysis tests and cell tests for small scale experiment



Ammonium

114752

Test

Measuring range:	0.05 – 3.00 mg/l NH_4-N	0.06 – 3.86 mg/l NH_4	10-mm cell
	0.03 – 1.50 mg/l NH_4-N	0.04 – 1.93 mg/l NH_4	20-mm cell
	0.010 – 0.500 mg/l NH_4-N	0.013 – 0.644 mg/l NH_4	50-mm cell
	Expression of results also possible in mmol/l.		

Check the pH of the sample, specified range: pH 4 – 13. If required, add dilute sodium hydroxide solution or sulfuric acid drop by drop to adjust the pH.

Pipette 5.0 ml of the sample into a test tube.

Add 0.60 ml of **NH_4-1** with pipette and mix.

Add 1 level blue microspoon of **NH_4-2**.

Shake vigorously to dissolve the solid substance.

Reaction time: 5 minutes

Add 4 drops of **NH_4-3** and mix.

Reaction time: 5 minutes

Transfer the solution into a corresponding cell.

Select method with AutoSelector.

Place the cell into the cell compartment.

Important:

Very high ammonium concentrations in the sample produce turquoise-colored solutions (measurement solution should be yellow-green to green) and false-low readings are yielded. In such cases the sample must be diluted (plausibility check).

To measure in the 50-mm cell, the sample volume and the volume of the reagents have to be doubled for each. Alternatively, the semi-microcell, Cat.No. 173502, can be used.

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) we recommended to use Spectroquant® CombiCheck 50, Cat.No. 114695, or the Standard solution for photometric applications, CRM, Cat.No. 125022, 125023, and 125024.

Ready-for-use ammonium standard solution CertiPUR®, Cat.No. 119812, concentration 1000 mg/l NH_4^+, can also be used after diluting accordingly.

To check for sample-dependent effects the use of addition solutions (e.g. in CombiCheck 50) is highly recommended.

*Release 01/2012 - **Spectroquant® photometer NOVA 60***

June 2011

1.14752.0001 / 1.14752.0002

Spectroquant®

Ammonium Test

NH_4^+

1. Method

Ammonium nitrogen (NH_4-**N**) occurs partly in the form of ammonium ions and partly as ammonia. A pH-dependent equilibrium exists between the two forms. In strongly alkaline solution ammonium nitrogen is present almost entirely as ammonia, which reacts with a chlorinating agent to form monochloramine. This in turn reacts with thymol to form a blue indophenol derivative that is determined photometrically.
The method is analogous to EPA 350.1, APHA 4500-NH_3 D, ISO 7150/1, and DIN 38406 E5.

2. Measuring range and number of determinations

Cell	Measuring range		Number of determinations
mm	mg/l NH_4-N	mg/l NH_4^+	
50 20 10	**0.010** - 0.500 0.03 - 1.50 0.05 - **3.00**	**0.013** - 0.644 0.04 - 1.93 0.06 - **3.86**	250 (Cat No. 1.14752.0002) or 500 (Cat. No. 1.14752.0001)

For programming data for selected photometers / spectrophotometers see the website.

3. Applications

This test measures both ammonium ions and dissolved ammonia.

Sample material:
Groundwater and surface water
Seawater[1)]
Drinking water
Wastewater
Aquarium water
Nutrient solutions for fertilization
Soils and food after appropriate sample pretreatment
(Applications see the website)

[1)] To determine the concentration of ammonium in seawater 0.1 ml of sodium hydroxide solution 5 mol/l must be added **after** the addition of reagent NH_4-1. Subsequently proceed as described in section 7 (“Procedure”).

4. Influence of foreign substances

This was checked in solutions containing 2 and 0 mg/l NH_4-N. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %					
Al^{3+}	1000	Mg^{2+}	100	EDTA	500
Ca^{2+}	1000	**Mn^{2+}**	**10**	**Primary amines**[1)]	**0**
Cd^{2+}	100	Ni^{2+}	100	**Secondary amines**[2)]	**0**
CN^-	**1**	NO_2^-	100	Surfactants[3)]	500
Cr^{3+}	100	Pb^{2+}	1000	Na-acetate	10 %
$Cr_2O_7^{2-}$	1000	PO_4^{3-}	100	NaCl	10 %
Cu^{2+}	**10**	**S^{2-}**	**1**	$NaNO_3$	20 %
F^-	**10**	SiO_3^{2-}	500	Na_2SO_4	20 %
Fe^{3+}	100	Zn^{2+}	100		
Hg^{2+}	100				

Reducing agents interfere with the determination.

[1)] tested with methylamine
[2)] tested with dimethylamine
[3)] tested with nonionic, cationic, and anionic surfactants

5. Reagents and auxiliaries

Please note the warnings on the packaging materials!
The test reagents are stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
Reagent NH_4-1: 1 bottle
Reagent NH_4-2: 2 bottles (Cat. No. 1.14752.0002) or
3 bottles (Cat. No. 1.14752.0001)
Reagent NH_4-3: 1 bottle
1 AutoSelector

Other reagents and accessories:
Sodium hydroxide solution 1.000 l Combi-Titrisol®, 5 mol/l, Cat. No. 109913
Universal indicator strips pH 0 - 14, Cat. No. 109535
Sodium hydroxide solution 1 mol/l TitriPUR®, Cat. No. 109137
Sulfuric acid 0.5 mol/l TitriPUR®, Cat. No. 109072
Spectroquant® CombiCheck 50, Cat. No. 114695
Ammonium standard solution CRM, 0.400 mg/l NH_4-N, Cat. No. 125022
Ammonium standard solution CRM, 1.00 mg/l NH_4-N, Cat. No. 125023
Ammonium standard solution CRM, 2.00 mg/l NH_4-N, Cat. No. 125024

Pipettes for pipetting volumes of 0.60 and 5.0 ml
Rectangular cells 10, 20, and 50 mm (2 of each), Cat. Nos. 114946, 114947, and 114944
Semi-microcells 50 mm (2 pcs), Cat. No. 173502

6. Preparation

- Analyze immediately after sampling.
- **The pH must be within the range 4 - 13.**
  Adjust, if necessary, with sodium hydroxide solution or sulfuric acid.
- Filter turbid samples.

7. Procedure

Pretreated sample (**20 - 30 °C**) Reagent NH_4-1 (**20 - 30 °C**) Reagent NH_4-2	5.0 ml 0.60 ml 1 level blue microspoon (in the cap of the NH_4-2 bottle)	Pipette into a test tube. Add with pipette and mix. Add and shake **vigorously until the reagent is completely dissolved**.
Leave to stand for 5 min (reaction time A).		
Reagent NH_4-3	4 drops[1)]	Add and mix.
Leave to stand for 5 min (reaction time B), then fill the sample into the cell, and measure in the photometer.		

[1)] **Hold the bottle vertically while adding the reagent!**

For measurement in the **50-mm cell** both the sample volume as well as the quantities of reagents NH_4-1, NH_4-2, and NH_4-3 must be doubled. Alternatively, the semi-microcell Cat. No. 173502 can be used.

Notes on the measurement:

- **Certain photometers may require a blank** (preparation as per measurement sample, but with distilled water instead of sample).
- For photometric measurement the cells must be clean.
  Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-high readings.
- Ammonium-free samples turn yellow on addition of reagent NH_4-3.
- The pH of the measurement solution must be approx. 12.5.
- The colour of the measurement solution remains stable for at least 60 min after the end of the reaction time B stated above.
- In the event of ammonium concentrations exceeding 100 mg/l, other reaction products are formed and false-low readings are yielded. In such cases it is advisable to conduct a plausibility check of the measurement results by diluting the sample (1:10, 1:100).

8. Analytical quality assurance

recommended before each measurement series
To check the photometric measurement system (test reagent, measurement device, handling) and the mode of working, the ammonium standard solutions CRM, 0.400 mg/l NH_4-N, Cat. No. 125022, 1.00 mg/l NH_4-N, Cat. No. 125023, and 2.00 mg/l NH_4-N, Cat. No. 125024 or Spectroquant® CombiCheck 50 can be used. Besides a **standard solution** with 1.00 mg/l NH_4-N, CombiCheck 50 also contains an **addition solution** for determining sample-dependent interferences (matrix effects).
Additional notes see under **www.merck-chemicals.com/qa**.

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51 (10-mm cell):

Standard deviation of the method (mg/l NH_4-N)	± 0.023
Coefficient of variation of the method (%)	± 1.6
Confidence interval (mg/l NH_4-N)	± 0.06
Number of lots	35

Characteristic data of the procedure:

	Measuring range mg/l NH_4-N	
	0.010 - 0.500	**0.05 - 3.00**
Sensitivity: Absorbance 0,010 A corresponds to (mg/l NH_4-N)	0.003	0.01
Accuracy of a measurement value (mg/l NH_4-N)	max. ± 0.017	max. ± 0.08

For quality and batch certificates for Spectroquant® test kits see the website.

9. Notes

- Reclose the reagent bottles immediately after use.
- Rinse glassware ammonium-free with distilled water. **Do not use detergent!**
- **Information on disposal can be obtained under the Quick Link “Waste Disposal Advice” at www.merck-chemicals.com/test-kits.**

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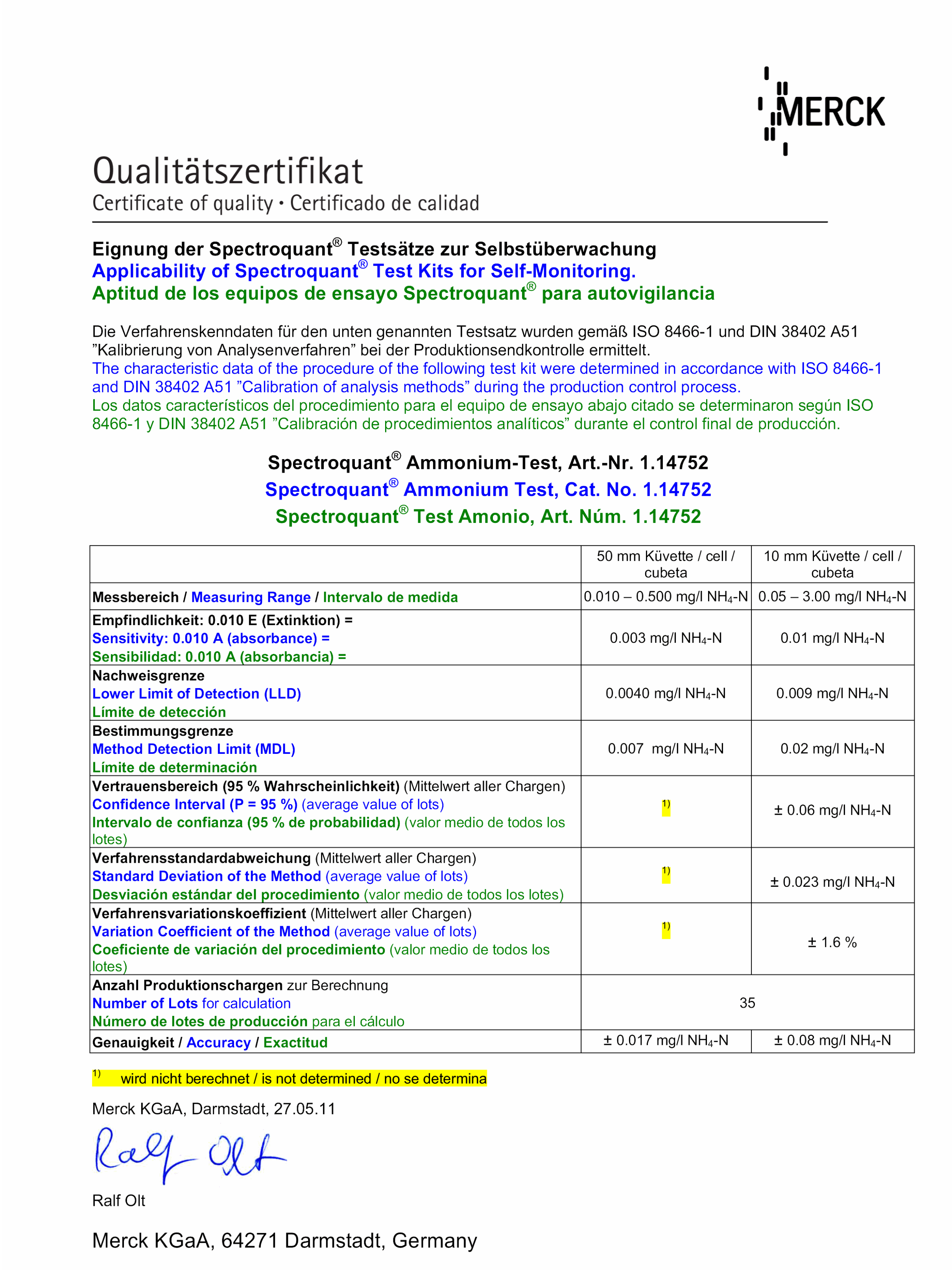
test-kits@merck-chemicals.com www.merck-chemicals.com/photometry



MERCK

Qualitätszertifikat

Certificate of quality • Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 ”Kalibrierung von Analysenverfahren” bei der Produktionsendkontrolle ermittelt.
The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 ”Calibration of analysis methods” during the production control process.
Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 ”Calibración de procedimientos analíticos” durante el control final de producción.

Spectroquant® Ammonium-Test, Art.-Nr. 1.14752
Spectroquant® Ammonium Test, Cat. No. 1.14752
Spectroquant® Test Amonio, Art. Núm. 1.14752

	50 mm Küvette / cell / cubeta	10 mm Küvette / cell / cubeta
Messbereich / **Measuring Range** / **Intervalo de medida**	0.010 – 0.500 mg/l NH_4-N	0.05 – 3.00 mg/l NH_4-N
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.003 mg/l NH_4-N	0.01 mg/l NH_4-N
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	0.0040 mg/l NH_4-N	0.009 mg/l NH_4-N
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	0.007 mg/l NH_4-N	0.02 mg/l NH_4-N
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	1)	± 0.06 mg/l NH_4-N
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	1)	± 0.023 mg/l NH_4-N
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	1)	± 1.6 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	35	
Genauigkeit / **Accuracy** / **Exactitud**	± 0.017 mg/l NH_4-N	± 0.08 mg/l NH_4-N

1) wird nicht berechnet / is not determined / no se determina

Merck KGaA, Darmstadt, 27.05.11

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany

Spectroquant®

COD

Chemical oxygen demand

114560

Cell Test

Measuring range:	4.0 – 40.0 mg/l COD or O_2 Expression of results also possible in mmol/l.

Suspend the bottom sediment in the cell by swirling.

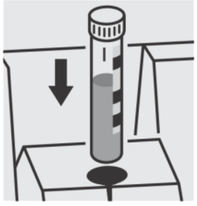
Carefully pipette 3.0 ml of the sample into a reaction cell, close tightly with the screw cap, and mix vigorously. **Caution, the cell becomes hot!**

Heat the reaction cell in the thermoreactor at 148 °C for 2 hours.

Remove the cell from the thermoreactor and place in a test-tube rack to cool.

Swirl the cell after 10 minutes.

Replace the cell in the rack for complete cooling to room temperature. **Very important!**



Place the cell into the cell compartment. Align the mark on the cell with that on the photometer.

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) we recommended to use Spectroquant® CombiCheck 50, Cat.No. 114695, or the Standard solution for photometric applications, CRM, Cat.No. 125028.

To check for sample-dependent effects the use of addition solutions (e.g. in CombiCheck 50) is highly recommended.

*Release 01/2012 - **Spectroquant® photometer NOVA 60***

1.14560.0001

COD
Cell Test

COD

USEPA approved for wastewater

1. Definition

The COD (chemical oxygen demand) expresses the amount of oxygen originating from potassium dichromate that reacts with the oxidizable substances contained in 1 l of water under the working conditions of the specified procedure.

1 mol $K_2Cr_2O_7$ is equivalent to 1.5 mol O_2
Results are expressed as mg/l COD (= mg/l O_2)

2. Method

The water sample is oxidized with a hot sulfuric solution of potassium dichromate, with silver sulfate as the catalyst. Chloride is masked with mercury sulfate. The concentration of unconsumed yellow $Cr_2O_7^{2-}$ ions is then determined photometrically.
The method corresponds to ISO 15705 and is analogous to EPA 410.4 and APHA 5220 D.

3. Measuring range and number of determinations

Measuring range	Number of determinations
4.0 - 40.0 mg/l COD	25

For programming data for selected photometers see the website.

4. Applications

This test measures organic and inorganic compounds oxidizable by dichromate. Exceptions: some heterocyclic compounds (e. g. pyridine), quaternary nitrogen compounds, and readily volatile hydrocarbons.

Sample material:
Groundwater and surface water
In-process controls
Wastewater

5. Influence of foreign substances

This was checked in solutions with a COD of 20 mg/l. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %					
Cl^-	2000	SO_3^{2-}	25	H_2O_2	10
Cr^{3+}	75			$NaNO_3$	10 %
CrO_4^{2-}	**5**			Na_2SO_4	10 %
NO_2^-	**10**			Na_3PO_4	10 %

6. Reagents and auxiliaries

Please note the warnings on the packaging materials!

Store the pack protected from light!
The test reagents are stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
25 reaction cells
1 sheet of round stickers for numbering the cells

Other reagents and accessories:
Merckoquant® Chloride Test, Cat. No. 110079,
measuring range 500 - ≥3000 mg/l Cl^-
Spectroquant® CombiCheck 50, Cat. No. 114695
COD standard solution CRM, 20.0 mg/l COD, Cat. No. 125028

Pipette for a pipetting volume of 3.0 ml
Thermoreactor

7. Preparation

- Analyze immediately after sampling.
- Homogenize the samples.
- Check the chloride content with the Merckoquant® Chloride Test. Samples containing more than 2000 mg/l Cl^- must be diluted with distilled water **prior to** determining the COD.

September 2011

8. Procedure

Suspend the bottom sediment in the reaction cell by swirling.		
Pretreated sample	3.0 ml	**Carefully** allow to run from the pipette down the inside of the tilted reaction cell onto the reagent (**Wear eye protection! The cell becomes hot!**).
Tightly attach the screw cap to the cell. **In all subsequent steps the cell must be held only by the screw cap!** **Vigorously** mix the contents of the cell. Heat the cell at 148 °C in the preheated thermoreactor for 120 min. Remove the hot cell from the thermoreactor and allow to cool in a test-tube rack. **Do not cool with cold water!** Wait 10 min, swirl the cell, and return to the rack for complete cooling to room temperature (cooling time at least 30 min). Measure in the photometer.		

Notes on the measurement:

- For photometric measurement the cells must be clean.
  Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-low readings.
- The measurement value remains stable over a long term.
- When using the SQ 118 photometer, a blank must be prepared for each test package according to the procedure described above (as per measurement sample, but with distilled water instead of sample).

9. Analytical quality assurance

recommended before each measurement series
To check the photometric measurement system (test reagent, measurement device, handling) and the mode of working, the COD standard solution CRM, 20.0 mg/l COD (Cat. No. 125028) or Spectroquant® CombiCheck 50 can be used. Besides a **standard solution** with 20.0 mg/l COD, CombiCheck 50 also contains an **addition solution** for determining sample-dependent interferences (matrix effects).
Additional notes see under **www.merck-chemicals.com/qa**.

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51:

Standard deviation of the method (mg/l COD)	± 0.30
Coefficient of variation of the method (%)	± 1.4
Confidence interval (mg/l COD)	± 0.7
Number of lots	46

Characteristic data of the procedure:

Sensitivity: Absorbance 0.010 A corresponds to (mg/l COD)	0.4
Accuracy of a measurement value (mg/l COD)	max. ± 1.5

For quality and batch certificates for test kits see the website.

10. Note

The test reagents must not be run off with the wastewater!
Information on disposal can be obtained under the Quick Link "Waste Disposal Advice" at www.merck-chemicals.com/test-kits.

Merck KGaA, 64271 Darmstadt, Germany, Tel. +49(0)6151 72-2440, Fax +49(0)6151 72-7780
test-kits@merck-chemicals.com www.merck-chemicals.com/photometry

Qualitätszertifikat

Certificate of quality · Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 "Kalibrierung von Analysenverfahren" bei der Produktionsendkontrolle ermittelt.
The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 "Calibration of analysis methods" during the production control process.
Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 "Calibración de procedimientos analíticos" durante el control final de producción.

Spectroquant® CSB-Küvettentest, Art.-Nr. 1.14560
Spectroquant® COD Cell Test, Cat. No. 1.14560
Spectroquant® Test en cubetas DQO, Art. Núm. 1.14560

Messbereich / Measuring Range / Intervalo de medida	4.0 – 40.0 mg/l CSB / COD / DQO
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.4 mg/l CSB / COD / DQO
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	2.50 mg/l CSB / COD / DQO
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	4.0 mg/l CSB / COD / DQO
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	± 0.7 mg/l CSB / COD / DQO
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	± 0.30 mg/l CSB / COD / DQO
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	± 1.4 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	46
Genauigkeit / Accuracy / Exactitud	± 1.5 mg/l CSB / COD / DQO

Merck KGaA, Darmstadt, 19.09.2011

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany

Nitrite

114776

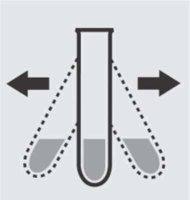
Test

Measuring	0.02 – 1.00 mg/l NO_2-N	0.07 – 3.28 mg/l NO_2	10-mm cell
range:	0.010 – 0.500 mg/l NO_2-N	0.03 – 1.64 mg/l NO_2	20-mm cell
	0.002 – 0.200 mg/l NO_2-N	0.007 – 0.657 mg/l NO_2	50-mm cell
	Expression of results also possible in mmol/l.		


Check the pH of the sample, specified range: pH 2 – 10.
If required, add dilute sulfuric acid drop by drop to adjust the pH.


Pipette 5.0 ml of the sample into a test tube.

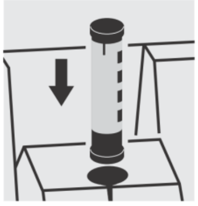

Add 1 level blue micro-spoon of **NO_2-1**.


Shake vigorously to dissolve the solid substance.


Check the pH, specified range: pH 2.0 – 2.5.
If required, add dilute sodium hydroxide solution or sulfuric acid drop by drop to adjust the pH.


Reaction time:
10 minutes


Transfer the solution into a corresponding cell.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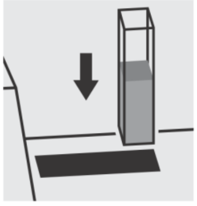

Place the cell into the cell compartment.

Important:

To measure in the 50-mm cell, the sample volume and the volume of the reagents have to be doubled for each. Alternatively, the semi-microcell, Cat.No. 173502, can be used.

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) ready-for-use nitrite standard solution CertiPUR®, Cat.No. 119899, concentration 1000 mg/l NO_2^-, can be used after diluting accordingly as well as the Standard solution for photometric applications, CRM, Cat.No. 125041.

1.14776.0001 / 1.14776.0002

Nitrite Test

NO_2^-

1. Method

In acidic solution nitrite ions react with sulfanilic acid to form a diazonium salt, which in turn reacts with N-(1-naphthyl)ethylenediamine dihydrochloride to form a red-violet azo dye. This dye is determined photometrically.
The method is analogous to EPA 354.1, APHA 4500-NO_2^- B, and DIN EN 26 777 D10.

2. Measuring range and number of determinations

Cell mm	Measuring range mg/l NO_2-N	 mg/l NO_2^-	Number of determinations
50 20 10	**0.002** - 0.200 0.010 - 0.500 0.02 - **1.00**	**0.007** - 0.657 0.03 - 1.64 0.07 - **3.28**	335 (Cat. No. 1.14776.0002) or 1000 (Cat. No. 1.14776.0001)

For programming data for selected photometers / spectrophotometers see the website.

3. Applications

Sample material:
Groundwater, drinking water, and surface water
Seawater
Wastewater
Food after appropriate sample pretreatment
Soils after appropriate sample pretreatment

4. Influence of foreign substances

This was checked in solutions containing 0,5 and 0 mg/l NO_2-N. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %							
Ca^{2+}	1000	Hg^{2+}	100	SiO_3^{2-}	1000	EDTA	1000
Cd^{2+}	1000	Mg^{2+}	1000	Zn^{2+}	1000	**Reducing agents (ascorbic acid, sulfite)**	**10**
CN^-	1000	Mn^{2+}	1000				
Cr^{3+}	100	NH_4^+	1000				
$Cr_2O_7^{2-}$	**1**	Pb^{2+}	1000			NaCl	20 %
Cu^{2+}	100	PO_4^{3-}	1000			$NaNO_3$	20 %
Fe^{3+}	**1**	**S^{2-}**	**10**			Na_2SO_4	15 %

5. Reagents and auxiliaries

Please note the warnings on the packaging materials!

The test reagent is stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
Reagent NO_2-1: 2 bottles (Cat. No. 1.14776.0002) or
6 bottles (Cat. No. 1.14776.0001)
1 AutoSelector

Other reagents and accessories:
Merckoquant® Nitrite Test, Cat. No. 110057,
measuring range 0.5 - 10 mg/l NO_2^- (0.15 - 3.0 mg/l NO_2-N)
Universal indicator strips pH 0 - 14, Cat. No. 109535
Acilit® indicator strips pH 0 - 6.0, Cat. No. 109531
Sulfuric acid 0.5 mol/l TitriPUR®, Cat. No. 109072
Sodium hydroxide solution 1 mol/l TitriPUR®, Cat. No. 109137
Nitrite standard solution CRM, 0.200 mg/l NO_2-N, Cat. No. 125041

Pipette for a pipetting volume of 5.0 ml
Rectangular cells 10, 20, and 50 mm (2 of each), Cat. Nos. 114946, 114947, and 114944
Semi-microcells 50 mm (2 pcs), Cat. No. 173502

6. Preparation

- Analyze immediately after sampling.
- Check the nitrite content with the Merckoquant® Nitrite Test.
  Samples containing more than 1.00 mg/l NO_2-N must be diluted with distilled water.
- **The pH must be within the range 2 - 10.**
  Adjust, if necessary, with sulfuric acid.
- Filter turbid samples.

April 2011

7. Procedure

Pretreated sample (**15 - 25 °C**)	5.0 ml	Pipette into a test tube.
Reagent NO_2-1	1 level blue microspoon (in the cap of the NO_2-1 bottle)	Add and shake **vigorously until the reagent is completely dissolved**. **The pH must be within the range 2.0 - 2.5.** Check with Acilit® indicator strips. Adjust the pH, if necessary, with sodium hydroxide solution or sulfuric acid.
Leave to stand for 10 min (reaction time), then fill the sample into the cell, and measure in the photometer.		

For measurement in the **50-mm cell** both the sample volume as well as the quantity of reagent NO_2-1 must be doubled. Alternatively, the semi-microcell Cat. No. 173502 can be used.

Notes on the measurement:

- **Certain photometers may require a blank** (preparation as per measurement sample, but with distilled water instead of sample).
- For photometric measurement the cells must be clean.
  Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-high readings.
- The pH of the measurement solution must be within the range 2.0 - 2.5.
- The colour of the measurement solution remains stable for at least 60 min after the end of the reaction time stated above.

8. Analytical quality assurance

recommended before each measurement series
To check the photometric measurement system (test reagent, measurement device, handling) and the mode of working, the nitrite standard solution CRM, 0.200 mg/l NO_2-N, Cat. No. 125041 can be used.
Sample-dependent interferences (matrix effects) can be determined by means of standard addition.
Additional notes see under **www.merck-chemicals.com/qa**.

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51 (10-mm cell):

Standard deviation of the method (mg/l NO_2-N)	± 0.008
Coefficient of variation of the method (%)	± 1.5
Confidence interval (mg/l NO_2-N)	± 0.02
Number of lots	37

Characteristic data of the procedure:

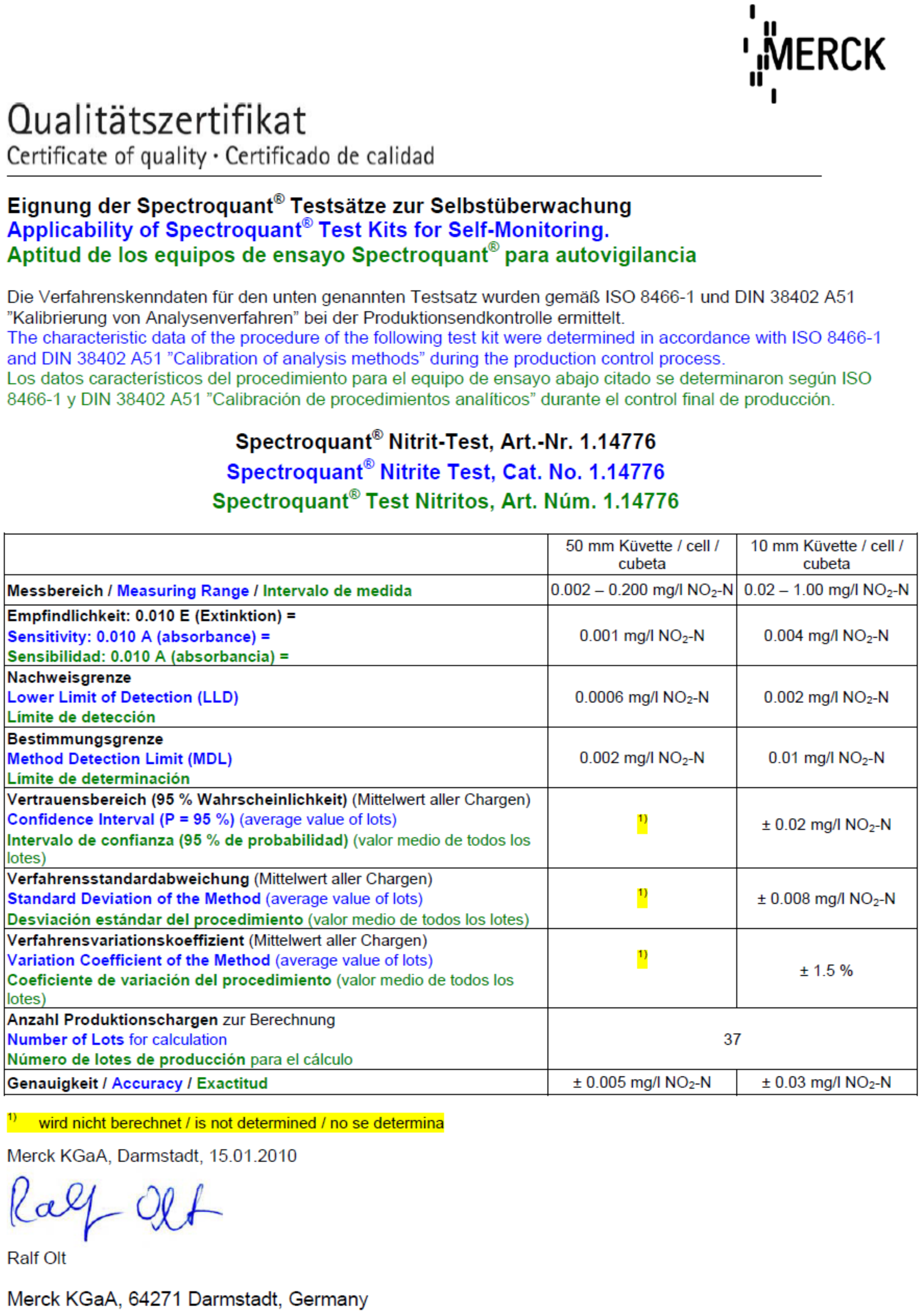
	Measuring range mg/l NO_2-N	
	0.002 - 0.200	**0.02 - 1.00**
Sensitivity: Absorbance 0,010 A corresponds to (mg/l NO_2-N)	0.001	0.004
Accuracy of a measurement value (mg/l NO_2-N)	max. ± 0.005	max. ± 0.03

For quality and batch certificates for Spectroquant® test kits see the website.

9. Notes

- Reclose the reagent bottles immediately after use.
- **Information on disposal can be obtained under the Quick Link "Waste Disposal Advice" at www.merck-chemicals.com/test-kits.**

Merck KGaA, 64271 Darmstadt, R. F. A., tel. +49(0)6151 72-2440, fax +49(0)6151 72-7780
environmental.analysis@merck.de www.merck-chemicals.com/photometry



MERCK

Qualitätszertifikat

Certificate of quality · Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 "Kalibrierung von Analysenverfahren" bei der Produktionsendkontrolle ermittelt.

The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 "Calibration of analysis methods" during the production control process.

Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 "Calibración de procedimientos analíticos" durante el control final de producción.

Spectroquant® Nitrit-Test, Art.-Nr. 1.14776
Spectroquant® Nitrite Test, Cat. No. 1.14776
Spectroquant® Test Nitritos, Art. Núm. 1.14776

	50 mm Küvette / cell / cubeta	10 mm Küvette / cell / cubeta
Messbereich / **Measuring Range** / **Intervalo de medida**	0.002 – 0.200 mg/l NO_2-N	0.02 – 1.00 mg/l NO_2-N
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.001 mg/l NO_2-N	0.004 mg/l NO_2-N
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	0.0006 mg/l NO_2-N	0.002 mg/l NO_2-N
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	0.002 mg/l NO_2-N	0.01 mg/l NO_2-N
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	1)	± 0.02 mg/l NO_2-N
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	1)	± 0.008 mg/l NO_2-N
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	1)	± 1.5 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	37	
Genauigkeit / **Accuracy** / **Exactitud**	± 0.005 mg/l NO_2-N	± 0.03 mg/l NO_2-N

1) wird nicht berechnet / is not determined / no se determina

Merck KGaA, Darmstadt, 15.01.2010

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany

Spectroquant®

Nitrate

109713

Test

Measuring	1.0 – 25.0	mg/l NO_3-N	4.4 – 110.7 mg/l NO_3	10-mm cell
range:	0.5 – 12.5	mg/l NO_3-N	2.2 – 55.3 mg/l NO_3	20-mm cell
	0.10 – 5.00	mg/l NO_3-N	0.4 – 22.1 mg/l NO_3	50-mm cell
	Expression of results also possible in mmol/l.			

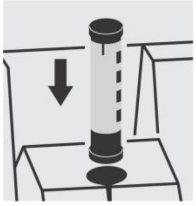
Pipette 4.0 ml of **NO_3-1** into a dry empty round cell (Empty cells, Cat. No. 114724).

Add 0.50 ml of the sample with pipette, **do not mix.**

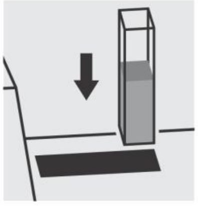
Add 0.50 ml of **NO_3-2** with pipette, close the cell with the screw cap, and mix. **Caution, cell becomes hot!**

Reaction time: 10 minutes

Transfer the solution into a corresponding rectangular cell.



Select method with AutoSelector.



Place the cell into the cell compartment.

Important:

To measure in the 50-mm cell, the sample volume and the volume of the reagents have to be doubled for each. Alternatively, the semi-microcell, Cat.No. 173502, can be used.

Note:

Empty cells with screw caps, Cat.No. 114724 are recommended for the preparation. These cells can be sealed with the screw caps, thus enabling a hazard-free mixing of the sample.

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) we recommended to use Spectroquant® CombiCheck 10 and 20, Cat.No. 114676 and 114675, or the Standard solution for photometric applications, CRM, Cat.No. 125036, 125037, and 125038.

Ready-for-use nitrate standard solution CertiPUR®, Cat.No. 119811, concentration 1000 mg/l NO_3^-, can also be used after diluting accordingly.

To check for sample-dependent effects the use of addition solutions (e.g. in CombiCheck) is highly recommended.

1.09713.0001 / 1.09713.0002

Nitrate Test

NO_3^-

1. Method

In sulfuric and phosphoric solution nitrate ions react with 2,6-dimethylphenol (DMP) to form 4-nitro-2,6-dimethylphenol that is determined photometrically.
The method is analogous to DIN 38405 D9.

2. Measuring range and number of determinations

Cell	Measuring range		Number of determinations
mm	mg/l NO_3-N	mg/l NO_3^-	
50 20 10	**0.10** - 5.00 0.5 - 12.5 1.0 - **25.0**	**0.4** - 22.1 2.2 - 55.3 4.4 - **110.7**	100 (Cat. No. 1.09713.0001) or 250 (Cat. No. 1.09713.0002)

For programming data for selected photometers / spectrophotometers see the website.

3. Applications

This test is not suited for the determination in waters with chloride contents exceeding 1000 mg/l and COD values exceeding 500 mg/l.

Sample material:
Groundwater, drinking water, and surface water
Spring water and well water
Mineral water
Wastewater and industrial water
Soils and fertilizers after appropriate sample pretreatment
This test is **not suited** for seawater.

4. Influence of foreign substances

This was checked in solutions containing 10 and 0 mg/l NO_3-N. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %					
Al^{3+}	1000	Hg^{2+}	100	Surfactants [2]	1000
Ca^{2+}	500	Mg^{2+}	1000	**COD (K-hydrogen phthalate)**	**500**
Cd^{2+}	250	Mn^{2+}	1000	**Organic substances (glucose)**	**500**
Cl^-	**1000**	NH_4^+	1000	Na-acetate	25 %
CN^-	100	Ni^{2+}	500	NaCl	0.2 %
Cr^{3+}	500	**NO_2^-**	**5** [1]	Na_2SO_4	25 %
$Cr_2O_7^{2-}$	**50**	Pb^{2+}	100		
Cu^{2+}	500	PO_4^{3-}	1000		
F^-	1000	SiO_3^{2-}	500		
Fe^{3+}	100	Zn^{2+}	1000		

[1] In cases of higher concentrations, eliminate nitrite ions acc. to section 6.
[2] tested with nonionic, cationic, and anionic surfactants

5. Reagents and auxiliaries

Please note the warnings on the packaging materials!
The test reagents are stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
1 bottle of reagent NO_3-1
1 bottle of reagent NO_3-2
1 AutoSelector

Other reagents and accessories:
Merckoquant® Chloride Test, Cat. No. 110079,
measuring range 500 - ≥3000 mg/l Cl^-
Merckoquant® Nitrite Test, Cat. No. 110007,
measuring range 2 - 80 mg/l NO_2^- (0.6 - 24 mg/l NO_2-N)
Amidosulfuric acid for analysis EMSURE®, Cat. No. 100103
Acilit® indicator strips pH 0 - 6.0, Cat. No. 109531
Sulfuric acid 25 % for analysis EMSURE®, Cat. No. 100716
Merckoquant® Nitrate Test, Cat. No. 110020,
measuring range 10 - 500 mg/l NO_3^- (2.3 - 113 mg/l NO_3-N)
Spectroquant® CombiCheck 20, Cat. No. 114675
Nitrate standard solution CRM, 0.500 mg/l NO_3-N, Cat. No. 125036
Nitrate standard solution CRM, 2.50 mg/l NO_3-N, Cat. No. 125037
Nitrate standard solution CRM, 15.0 mg/l NO_3-N, Cat. No. 125038

Empty cells 16 mm with screw caps (25 pcs), Cat. No. 114724
Pipettes for pipetting volumes of 0.50 and 4.0 ml
Rectangular cells 10, 20, and 50 mm (2 of each), Cat. Nos. 114946, 114947, and 114944
Semi-microcells 50 mm (2 pcs), Cat. No. 173502

April 2011

6. Preparation

- Analyze immediately after sampling.
- Check the chloride content with the Merckoquant® Chloride Test. Samples containing more than 1000 mg/l Cl^- must be diluted with distilled water.
- Check the nitrite content with the Merckoquant® Nitrite Test.
  If necessary, eliminate interfering nitrite ions (stated amounts apply for nitrite contents of up to 50 mg/l):
  To 10 ml of sample add approx. 50 mg of amidosulfuric acid and dissolve.
  The pH of this solution must be within the range 1 - 3. Adjust, if necessary, with sulfuric acid.
- Check the nitrate content with the Merckoquant® Nitrate Test. Samples containing more than 25.0 mg/l NO_3-N (110.7 mg/l NO_3^-) must be diluted with distilled water.
- Filter turbid samples.

7. Procedure

Reagent NO_3-1	4.0 ml	Pipette into a dry test tube[1].
Pretreated sample (**5 - 25 °C**)	0.50 ml	Add with pipette, **do not mix!**
Reagent NO_3-2	0.50 ml	Add with pipette (**Wear eye protection! The mixture becomes hot!**) and mix, holding **only the upper part** of the tube!
Leave the hot reaction solution to stand for 10 min (reaction time). **Do not cool with cold water!** Fill the sample into the rectangular cell and measure in the photometer.		

[1] Empty cells Cat. No. 114724 are recommended that can be sealed with screw caps, thus enabling the sample to be mixed safely.

For measurement in the **50-mm cell** both the sample volume as well as the quantities of reagents NO_3-1 and NO_3-2 must be doubled. Alternatively, the semi-microcell Cat. No. 173502 can be used.

Notes on the measurement:

- **Certain photometers may require a blank** (preparation as per measurement sample, but with distilled water instead of sample).
- For photometric measurement the cells must be clean. Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-high readings.
- The colour of the measurement solution remains stable for 30 min after the end of the reaction time stated above. (After 60 min the measurement value would have increased by 5 %.)

8. Analytical quality assurance

recommended before each measurement series
To check the photometric measurement system (test reagent, measurement device, handling) and the mode of working, the nitrate standard solutions CRM, 0.500 mg/l NO_3-N, Cat. No. 125036, 2.50 mg/l NO_3-N, Cat. No. 125037, and 15.0 mg/l NO_3-N, Cat. No. 125038 or Spectroquant® CombiCheck 20 can be used.
Besides a **standard solution** with 9.0 mg/l NO_3-N, CombiCheck 20 also contains an **addition solution** for determining sample-dependent interferences (matrix effects).
Additional notes see under **www.merck-chemicals.com/qa**.

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51 (10-mm cell):

Standard deviation of the method (mg/l NO_3-N)	± 0.11
Coefficient of variation of the method (%)	± 0.85
Confidence interval (mg/l NO_3-N)	± 0.3
Number of lots	20

Characteristic data of the procedure:

	Measuring range mg/l NO_3-N	
	0.10 - 5.00	**1.0 - 25.0**
Sensitivity: Absorbance 0.010 A corresponds to (mg/l NO_3-N)	0.04	0.2
Accuracy of a measurement value (mg/l NO_3-N)	max. ± 0.10	max. ± 0.5

For quality and batch certificates for Spectroquant® test kits see the website.

9. Notes

- Reclose the reagent bottles immediately after use.
- **Information on disposal can be obtained under the Quick Link “Waste Disposal Advice” at www.merck-chemicals.com/test-kits.**

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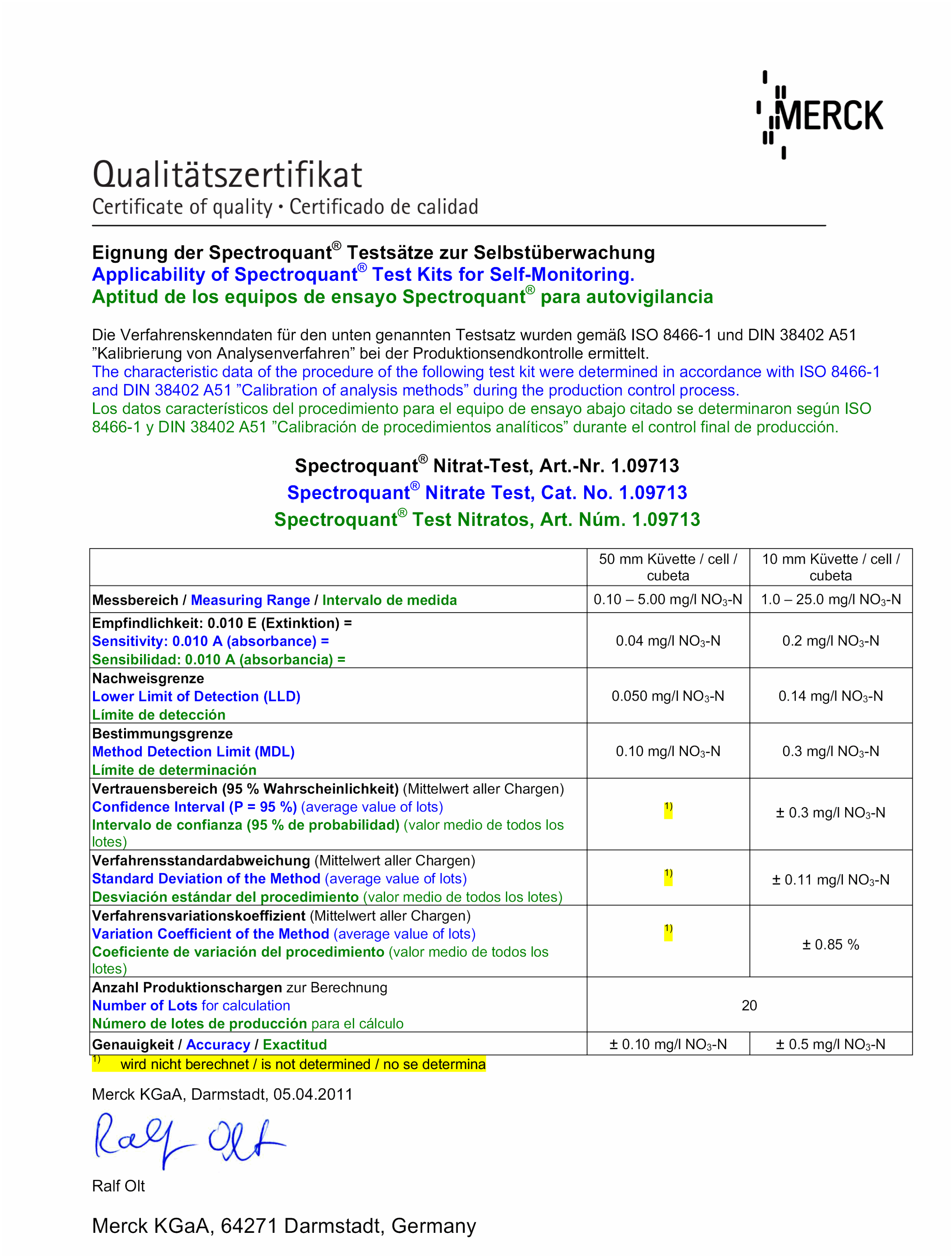
environmental.analysis@merck.de www.merck-chemicals.com/photometry



Qualitätszertifikat

Certificate of quality • Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 ”Kalibrierung von Analysenverfahren” bei der Produktionsendkontrolle ermittelt.

The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 ”Calibration of analysis methods” during the production control process.

Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 ”Calibración de procedimientos analíticos” durante el control final de producción.

Spectroquant® Nitrat-Test, Art.-Nr. 1.09713
Spectroquant® Nitrate Test, Cat. No. 1.09713
Spectroquant® Test Nitratos, Art. Núm. 1.09713

	50 mm Küvette / cell / cubeta	10 mm Küvette / cell / cubeta
Messbereich / **Measuring Range** / **Intervalo de medida**	0.10 – 5.00 mg/l NO_3-N	1.0 – 25.0 mg/l NO_3-N
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.04 mg/l NO_3-N	0.2 mg/l NO_3-N
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	0.050 mg/l NO_3-N	0.14 mg/l NO_3-N
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	0.10 mg/l NO_3-N	0.3 mg/l NO_3-N
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	[1]	± 0.3 mg/l NO_3-N
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	[1]	± 0.11 mg/l NO_3-N
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	[1]	± 0.85 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	20	
Genauigkeit / **Accuracy** / **Exactitud**	± 0.10 mg/l NO_3-N	± 0.5 mg/l NO_3-N

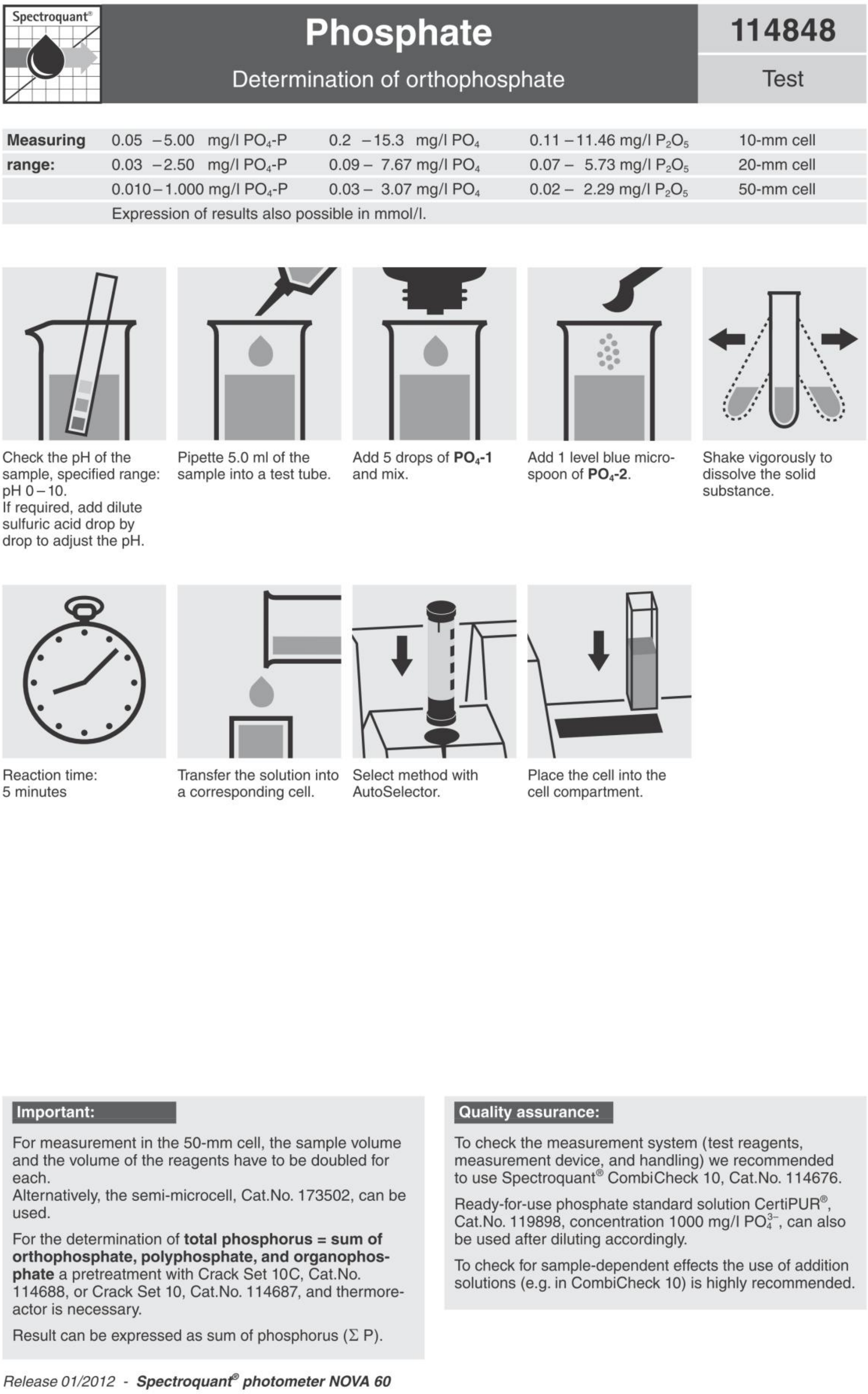
[1] wird nicht berechnet / is not determined / no se determina

Merck KGaA, Darmstadt, 05.04.2011

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany



Spectroquant®

Phosphate

Determination of orthophosphate

114848

Test

Measuring range:	0.05 – 5.00 mg/l PO_4-P	0.2 – 15.3 mg/l PO_4	0.11 – 11.46 mg/l P_2O_5	10-mm cell
	0.03 – 2.50 mg/l PO_4-P	0.09 – 7.67 mg/l PO_4	0.07 – 5.73 mg/l P_2O_5	20-mm cell
	0.010 – 1.000 mg/l PO_4-P	0.03 – 3.07 mg/l PO_4	0.02 – 2.29 mg/l P_2O_5	50-mm cell
	Expression of results also possible in mmol/l.			

Check the pH of the sample, specified range: pH 0 – 10.
If required, add dilute sulfuric acid drop by drop to adjust the pH.

Pipette 5.0 ml of the sample into a test tube.

Add 5 drops of **PO_4-1** and mix.

Add 1 level blue micro-spoon of **PO_4-2**.

Shake vigorously to dissolve the solid substance.

Reaction time: 5 minutes

Transfer the solution into a corresponding cell.

Select method with AutoSelector.

Place the cell into the cell compartment.

Important:

For measurement in the 50-mm cell, the sample volume and the volume of the reagents have to be doubled for each.
Alternatively, the semi-microcell, Cat.No. 173502, can be used.

For the determination of **total phosphorus = sum of orthophosphate, polyphosphate, and organophosphate** a pretreatment with Crack Set 10C, Cat.No. 114688, or Crack Set 10, Cat.No. 114687, and thermoreactor is necessary.

Result can be expressed as sum of phosphorus (Σ P).

Quality assurance:

To check the measurement system (test reagents, measurement device, and handling) we recommended to use Spectroquant® CombiCheck 10, Cat.No. 114676.

Ready-for-use phosphate standard solution CertiPUR®, Cat.No. 119898, concentration 1000 mg/l PO_4^{3-}, can also be used after diluting accordingly.

To check for sample-dependent effects the use of addition solutions (e.g. in CombiCheck 10) is highly recommended.

*Release 01/2012 - **Spectroquant® photometer NOVA 60***

November 2010

Spectroquant®

Phosphate Test

1.14848.0001
1.14848.0002

P

for the determination of orthophosphate

1. Method

In sulfuric solution orthophosphate ions react with molybdate ions to form molybdophosphoric acid. Ascorbic acid reduces this to phosphomolybdenum blue (PMB) that is determined photometrically.
The method is analogous to EPA 365.2+3, APHA 4500-P E, and DIN EN ISO 6878.

2. Measuring range and number of determinations

Cell	Measuring range			Number of determinations
mm	mg/l PO_4-P	mg/l PO_4^{3-}	mg/l P_2O_5	
50	**0.010** - 1.000	**0.03** - 3.07	**0.02** - 2.29	220 (Cat. No. 1.14848.0002) or 420 (Cat. No. 1.14848.0001)
20	0.03 - 2.50	0.09 - 7.67	0.07 - 5.73	
10	0.05 - **5.00**	0.2 -**15.3**	0.11 -**11.46**	

For programming data for selected photometers / spectrophotometers see the website.

3. Applications

This test measures only orthophosphate. Samples must be decomposed by digestion before total phosphorus can be measured (see section 6).

Sample material:
Groundwater and surface water, seawater
Drinking water
Wastewater
Nutrient solutions for fertilization
Soils after appropriate sample pretreatment
Food after appropriate sample pretreatment

4. Influence of foreign substances

This was checked in solutions containing 2 and 0 mg/l PO_4-P. The determination is not yet interfered with up to the concentrations of foreign substances given in the table.

Concentrations of foreign substances in mg/l or %							
Ag^+	1000	F^-	50	Pb^{2+}	25	EDTA	1000
AsO_4^{3-}	**0.2**	Fe^{3+}	1000	**S^{2-}**	**2.5**	Surfactants[1]	100
Ca^{2+}	1000	**Hg^{2+}**	**10**	SiO_3^{2-}	1000	COD (K-hydrogen phthalate)	150
Cd^{2+}	1000	Mg^{2+}	1000	SO_3^{2-}	1000	Na-acetate	1 %
CN^-	1000	Mn^{2+}	1000	Zn^{2+}	1000	NaCl	5 %
Cr^{3+}	1000	NH_4^+	1000			$NaNO_3$	10 %
$Cr_2O_7^{2-}$	**5**	Ni^{2+}	500			Na_2SO_4	10 %
Cu^{2+}	250	NO_2^-	1000				

Reducing agents interfere with the determination.

[1] tested with nonionic, cationic, and anionic surfactants

5. Reagents and auxiliaries

Please note the warnings on the packaging materials!

The test reagents are stable up to the date stated on the pack when stored closed at +15 to +25 °C.

Package contents:
Reagent PO_4-1: 1 bottle (Cat. No. 1.14848.0002) or
2 bottles (Cat. No. 1.14848.0001)
Reagent PO_4-2: 1 bottle (Cat. No. 1.14848.0002) or
2 bottles (Cat. No. 1.14848.0001)
1 AutoSelector

Other reagents and accessories:
Spectroquant® Crack Set 10C, Cat. No. 114688
+ thermoreactor
or
Spectroquant® Crack Set 10, Cat. No. 114687
+ empty cells 16 mm with screw caps (25 pcs), Cat. No. 114724
+ thermoreactor
Merckoquant® Phosphate Test, Cat. No. 110428,
measuring range 10 - 500 mg/l PO_4^{3-} (3.3 - 163 mg/l PO_4-P)
Universal indicator strips pH 0 - 14, Cat. No. 109535
Sulfuric acid 0.5 mol/l TitriPUR®, Cat. No. 109072
Spectroquant® CombiCheck 10, Cat. No. 114676
Hydrochloric acid 25 % for analysis EMSURE®, Cat. No. 100316
Sodium hydroxide solution 1 mol/l (approx. 4 %) TitriPUR®, Cat. No. 109137

Pipette for a pipetting volume of 5.0 ml
Rectangular cells 10, 20, and 50 mm (2 of each), Cat. Nos. 114946, 114947, and 114944
Semi-microcells 50 mm (2 pcs), Cat. No. 173502

6. Preparation

- Analyze immediately after sampling.
- Total phosphorus can be determined after pretreatment of the sample using one of the Spectroquant® Crack Sets.
- Check the phosphate content with the Merckoquant® Phosphate Test. Samples containing more than 5.00 mg/l PO_4-P must be diluted with distilled water **prior to** digestion.
- **The pH must be within the range 0 - 10.** Adjust, if necessary, with sulfuric acid.
- Filter turbid samples.

7. Procedure

Pretreated sample (**10 - 35 °C**)	5.0 ml	Pipette into a test tube.
Reagent PO_4-1	5 drops[1]	Add and mix.
Reagent PO_4-2	1 level blue microspoon (in the cap of the PO_4-2 bottle)	Add and shake **vigorously until the reagent is completely dissolved**.
Leave to stand for 5 min (reaction time), then fill the sample into the cell, and measure in the photometer.		

[1] **Hold the bottle vertically while adding the reagent!**

For measurement in the **50-mm cell** both the sample volume as well as the quantities of reagents PO_4-1 and PO_4-2 must be doubled. Alternatively, the semi-microcell Cat. No. 173502 can be used.

Notes on the measurement:

- **Certain photometers may require a blank** (preparation as per measurement sample, but with distilled water instead of sample). The blank is slightly yellow.
- For photometric measurement the cells must be clean. Wipe, if necessary, with a clean dry cloth.
- Measurement of turbid solutions yields false-high readings.
- The pH of the measurement solution must be within the range 0.80 - 0.95.
- The colour of the measurement solution remains stable for at least 60 min after the end of the reaction time stated above.

8. Analytical quality assurance

To check the photometric measurement system (test reagents, measurement device, handling) and the mode of working, Spectroquant® CombiCheck 10 can be used. Besides a **standard solution** with 0.80 mg/l PO_4-P, this article also contains an **addition solution** for determining sample-dependent interferences (matrix effects).

Characteristic quality data:

In the production control, the following data were determined in accordance with ISO 8466-1 and DIN 38402 A51 (10-mm cell):

Standard deviation of the method (mg/l PO_4-P)	± 0.031
Coefficient of variation of the method (%)	± 1.3
Confidence interval (mg/l PO_4-P)	± 0.06
Number of lots	35

Characteristic data of the procedure:

	Measuring range mg/l PO_4-P	
	0.010 - 1.000	**0.05 - 5.00**
Sensitivity: Absorbance 0,010 A corresponds to (mg/l PO_4-P)	0.004	0.02
Accuracy of a measurement value (mg/l PO_4-P)	max. ± 0.016	max. ± 0.08

For quality and batch certificates for Spectroquant® test kits see the website.

9. Notes

- Reclose the reagent bottles immediately after use.
- Use only phosphate-free detergents to rinse glassware. Otherwise fill with hydrochloric acid (approx. 10 %) and leave to stand for several hours.
- All glass surfaces coming into contact with the blue complex must be cleansed from time to time as follows:
  Fill the test tubes and the cells with sodium hydroxyde solution (approx. 0.4 %) and leave to stand for max. 1 hour.

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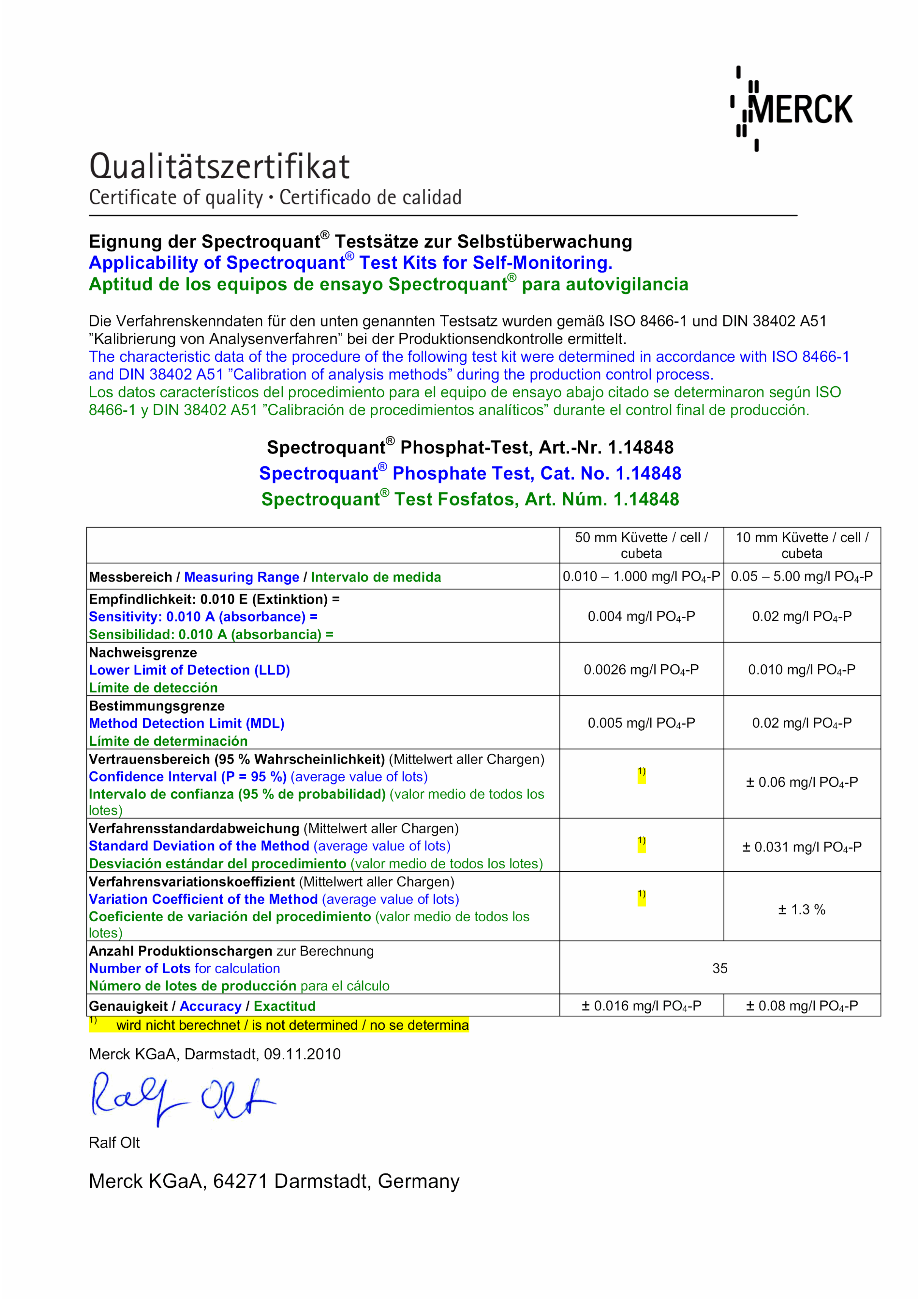
environmental.analysis@merck.de http://photometry.merck.de



Qualitätszertifikat

Certificate of quality • Certificado de calidad

Eignung der Spectroquant® Testsätze zur Selbstüberwachung
Applicability of Spectroquant® Test Kits for Self-Monitoring.
Aptitud de los equipos de ensayo Spectroquant® para autovigilancia

Die Verfahrenskenndaten für den unten genannten Testsatz wurden gemäß ISO 8466-1 und DIN 38402 A51 "Kalibrierung von Analysenverfahren" bei der Produktionsendkontrolle ermittelt.
The characteristic data of the procedure of the following test kit were determined in accordance with ISO 8466-1 and DIN 38402 A51 "Calibration of analysis methods" during the production control process.
Los datos característicos del procedimiento para el equipo de ensayo abajo citado se determinaron según ISO 8466-1 y DIN 38402 A51 "Calibración de procedimientos analíticos" durante el control final de producción.

Spectroquant® Phosphat-Test, Art.-Nr. 1.14848
Spectroquant® Phosphate Test, Cat. No. 1.14848
Spectroquant® Test Fosfatos, Art. Núm. 1.14848

	50 mm Küvette / cell / cubeta	10 mm Küvette / cell / cubeta
Messbereich / Measuring Range / Intervalo de medida	0.010 – 1.000 mg/l PO_4-P	0.05 – 5.00 mg/l PO_4-P
Empfindlichkeit: 0.010 E (Extinktion) = **Sensitivity: 0.010 A (absorbance) =** **Sensibilidad: 0.010 A (absorbancia) =**	0.004 mg/l PO_4-P	0.02 mg/l PO_4-P
Nachweisgrenze **Lower Limit of Detection (LLD)** **Límite de detección**	0.0026 mg/l PO_4-P	0.010 mg/l PO_4-P
Bestimmungsgrenze **Method Detection Limit (MDL)** **Límite de determinación**	0.005 mg/l PO_4-P	0.02 mg/l PO_4-P
Vertrauensbereich (95 % Wahrscheinlichkeit) (Mittelwert aller Chargen) **Confidence Interval (P = 95 %)** (average value of lots) **Intervalo de confianza (95 % de probabilidad)** (valor medio de todos los lotes)	1)	± 0.06 mg/l PO_4-P
Verfahrensstandardabweichung (Mittelwert aller Chargen) **Standard Deviation of the Method** (average value of lots) **Desviación estándar del procedimiento** (valor medio de todos los lotes)	1)	± 0.031 mg/l PO_4-P
Verfahrensvariationskoeffizient (Mittelwert aller Chargen) **Variation Coefficient of the Method** (average value of lots) **Coeficiente de variación del procedimiento** (valor medio de todos los lotes)	1)	± 1.3 %
Anzahl Produktionschargen zur Berechnung **Number of Lots** for calculation **Número de lotes de producción** para el cálculo	35	
Genauigkeit / Accuracy / Exactitud	± 0.016 mg/l PO_4-P	± 0.08 mg/l PO_4-P

1) wird nicht berechnet / is not determined / no se determina

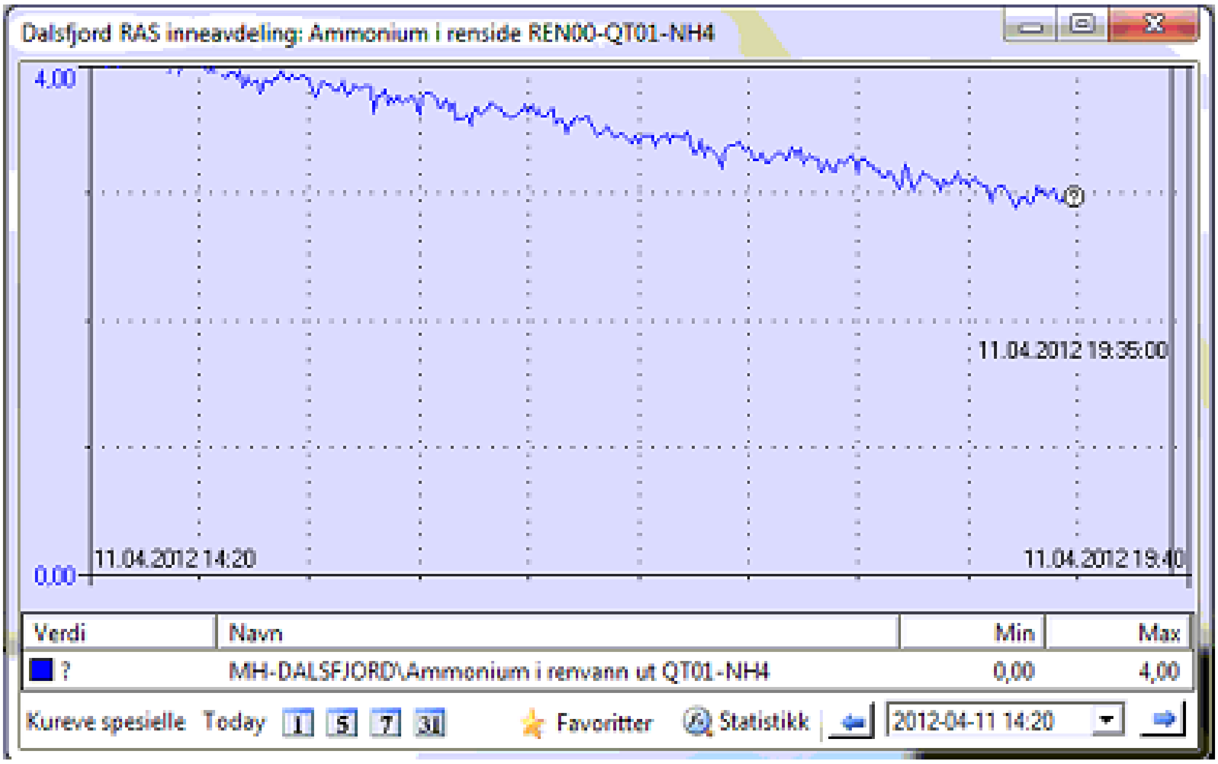
Merck KGaA, Darmstadt, 09.11.2010

Ralf Olt

Ralf Olt

Merck KGaA, 64271 Darmstadt, Germany

J – Data logs from large scale experiment

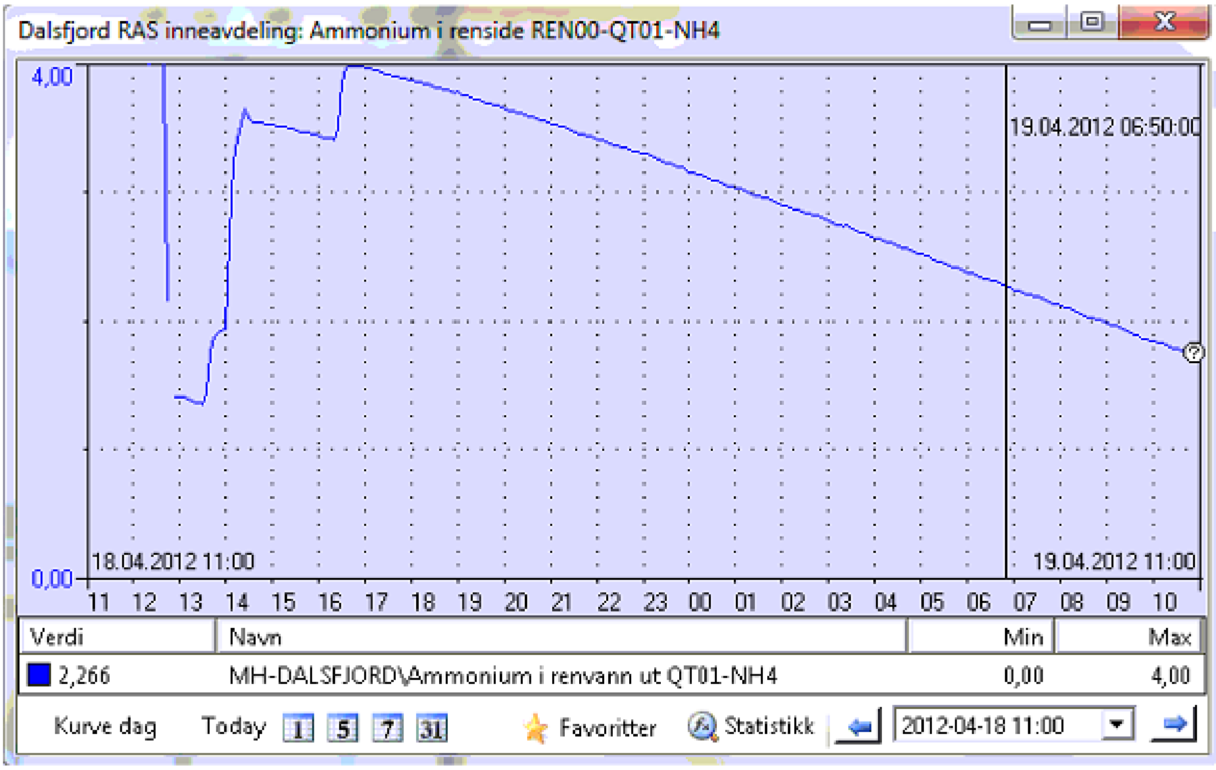


Dalsfjord RAS inneavdeling: Ammonium i renside REN00-QT01-NH4

Verdi	Navn	Min	Max
🟦 ?	MH-DALSFJORD\Ammonium i renvann ut QT01-NH4	0,00	4,00

2012-04-11 14:20

Figure b: Data log from monitoring instrument placed in MBBR for Marine Harvest Norway AS Avd. Dalsfjord, for NH_4-N (mg L^{-1}) from 11.04.2012 14:20 until 19:35, where: x-axis is time and y-axis is NH_4-N (mg L^{-1}).

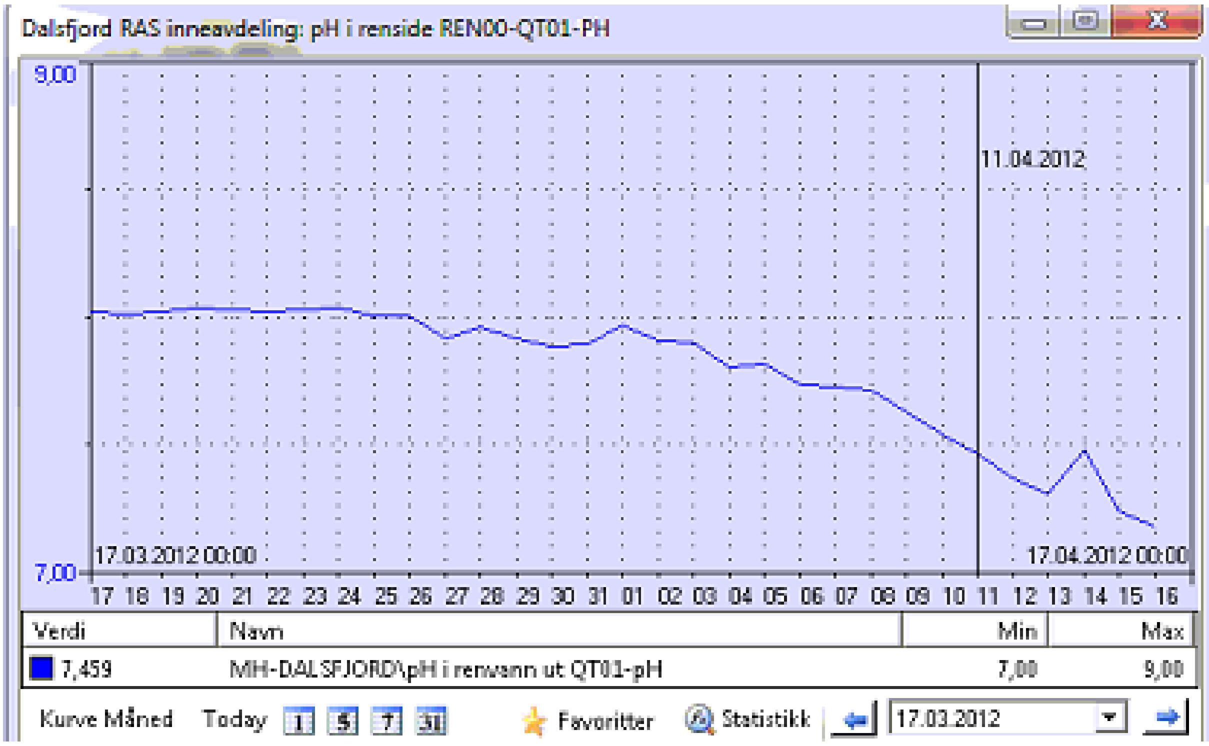


Dalsfjord RAS inneavdeling: Ammonium i renside REN00-QT01-NH4

Verdi	Navn	Min	Max
🟦 2,266	MH-DALSFJORD\Ammonium i renvann ut QT01-NH4	0,00	4,00

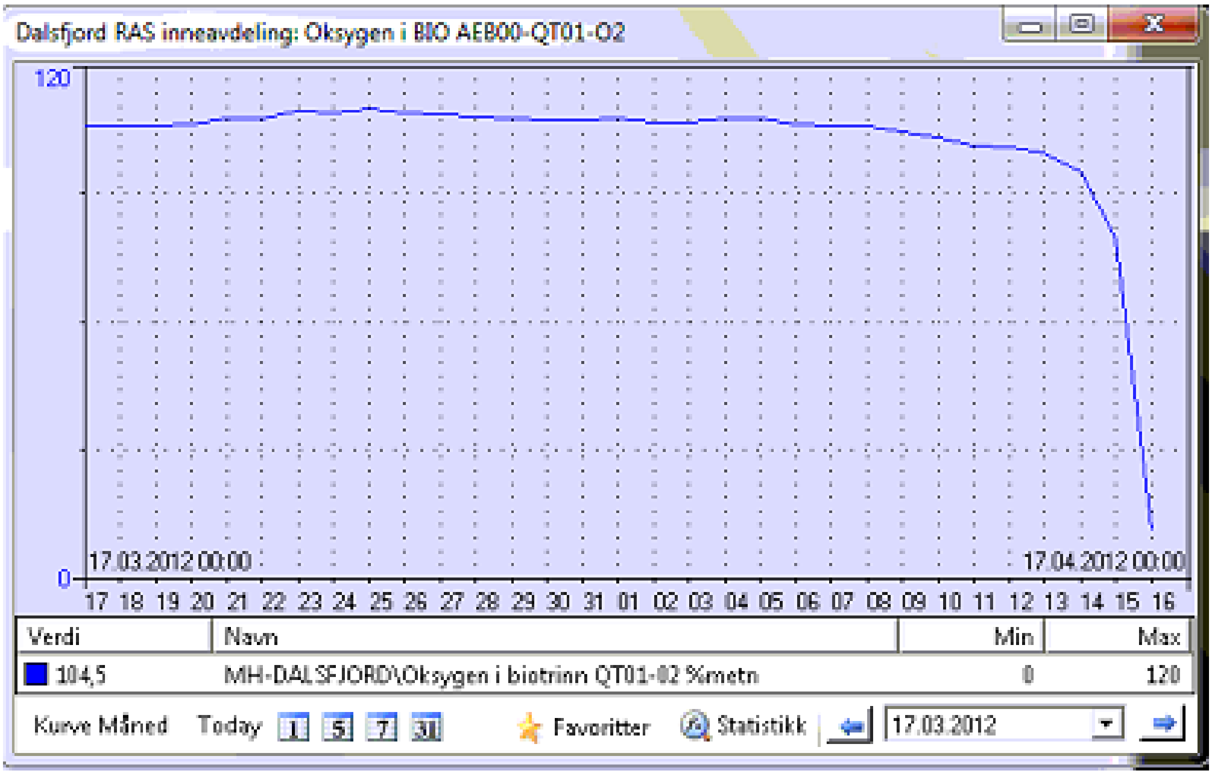
2012-04-18 11:00

Figure c: Data log from monitoring instrument placed in MBBR for Marine Harvest Norway AS Avd. Dalsfjord, for NH_4-N (mg L^{-1}) from 18.04.2012 13:00 until 19.04.2012 11:00, where: x-axis is time as hours and y-axis is: (y) x 7,444 = mg NH_4-N L^{-1}.



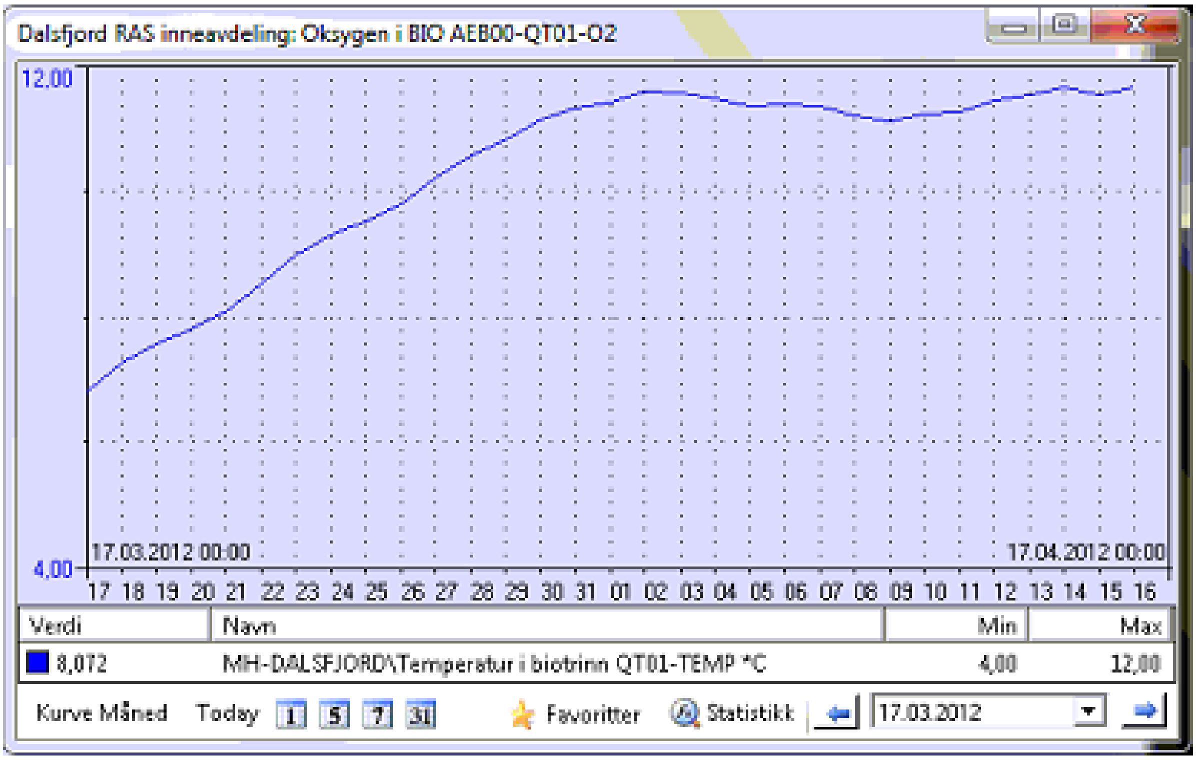
Verdi	Navn	Min	Max
🟦 7,459	MH-DALSFJORD\pH i renvann ut QT01-pH	7,00	9,00

Figure d: Data log from monitoring instrument placed in MBBR for Marine Harvest Norway AS Avd. Dalsfjord, for pH from 17.03.2012 00:00 until 16.04.2012 00:00, where: x-axis is time as dates of the month and y-axis is pH.



Verdi	Navn	Min	Max
🟦 104,5	MH-DALSFJORD\Oksygen i biotrinn QT01-02 %metn	0	120

Figure e: Data log from monitoring instrument placed in MBBR for Marine Harvest Norway AS Avd. Dalsfjord, for O_2 (%Sat.) from 17.03.2012 00:00 until 16.04.2012 00:00, where: x-axis is time as dates of the month and y-axis is O_2 (%Sat.).



Verdi	Navn	Min	Max
■ 8,072	MH-DALSFJORD\Temperatur i biotrinn QT01-TEMP °C	4,00	12,00

Figure f: Data log from monitoring instrument placed in MBBR for Marine Harvest Norway AS Avd. Dalsfjord, for temperature (°C) from 17.03.2012 00:00 until 16.04.2012 00:00, where: x-axis is time as dates of the month and y-axis is temperature (°C).

K – Raw data from large scale experiment

Table b: Temperature, oxygen saturation and pH measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes). Note: Temp. (°C), O2 (mg/l) and pH were analysed with stationed monitoring equipment. pH (R2), pH(FrR1) and pH(FrR2) were analysed with HACH LANGE HQ11D Portable pH meter. Fr = Frozen sample. <u>Rejections:</u> All frozen values

Day	Temp (°C)	O2 (%Sat.)	pH (Avg.)	pH (Stas.)	pH (R2)	pH (FrR1)	pH (FrR2)
1	5.2	111	7.90	7.90		~~7.85~~	~~7.81~~
2	5.2		7.90	7.90		~~7.49~~	~~7.56~~
3	5.5		7.90	7.90		~~7.58~~	~~7.61~~
4	6.2	106	7.90	7.90		~~7.71~~	~~7.71~~
7			7.95	7.95	7.95		
10	8.4	107	8.02	8.03	8.00		
11	8.8	109	7.87	8.03	7.70		
12	9.1	108	8.05	8.03	8.07		~~7.88~~
13	9.4	108	8.05	8.02	8.07		
14	9.7	109	7.98	8.01	7.95		
15			7.90	7.90			~~7.69~~
16			7.95	7.95			~~8.40~~
17			7.90	7.90			~~7.56~~
18			7.85	7.85			~~8.25~~
19			7.85	7.85			~~7.57~~
20			7.95	7.95			~~8.23~~
21	11.2	107	7.87	7.91	7.82		~~7.64~~
22	11.5	108	7.91	7.83	7.98		
23	11.0	108	7.88	7.77	7.99		
24	11.0	107	7.86	7.77	7.94		
25	11.0	106	7.77	7.67	7.87		
26	10.9	106	7.79	7.72	7.86		
27			7.70	7.70			
29			7.48	7.48			
30	11.4	101	7.40	7.40			
31			7.39	7.39			
32		100	7.17	7.17			
33		95	7.60	7.60			
34		80	7.20	7.20			
35		10	7.15	7.15			
37			7.27	7.27			
38	12.0		6.98	6.98			
39			6.85	6.85			
45	9.6	103	6.81	6.81			
46	9.2		6.79	6.79			

Table c: NH_4-N measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. Stas. = Stationed monitoring equipment, ^{1} = 304, ^{2} = 305, ^{3} = Merck 10mm, ^{4} = Merck 50mm, * = Under Measuring Range, Fr = Frozen sample, x = sample dilution, -1/-2 = first and second analysis. Rejections: Day16/18(1st/2nd)/20(1st/2nd): Major error in sampling method, Day33: Evening sample (20:50), Day34(1st)/35/36/37: Major error in analysis, Day34(2nd)/38/39: Error in time of sampling.

Day	Avg.	Stas.	R1	R1x	R2	R2x	FrR1	FrR1x	FrR2-1	FrR2-1x	FrR2-2	FrR2-2x
1	0.02	0.013					0.017^4	0	0.018^4	0		
2	6.42	5.60					6.95^3	5	6.70^3	5		
3	7.85	7.00					8.45^3	5	8.10^3	5		
4	9.50	8.60					9.80^3	5	10.10^3	5		
7	12.00	12.50			11.50^1							
10	11.15	11.90			10.40^1	5						
11	10.78	11.70			9.85^1	5						
12	10.17	11.60			9.45^1	5			9.45^1	5		
13	10.58	11.50			9.65^1	5						
14	10.13	11.40	9.55^1	5	9.45^1	5						
15	10.90								10.90^1	10		
16									~~6.68^1~~	10		
17	10.40								10.40^1	10		
18									~~4.78^1~~	10	~~4.84^2~~	0
19	10.00								10.00^1	10		
20									~~6.49^1~~	10	~~6.43^2~~	0
21	10.11	11.70			10.10^2	0			9.28^1	10	9.35^2	0
22	9.76	11.00			8.52^2	0						
23	8.91	10.00			7.82^2	0						
24	7.84	8.90			6.78^2	0						
25	9.50	10.50			8.50^2	0						
26	8.12	9.50			7.32^2	0			7.55^2	0		
27	9.66								9.66^2	0		
28	7.71								7.71^2	0		
29	6.84								6.84^2	0		
30	5.99	3.26							8.71^2	0		
31	8.07								8.07^2	0		
32	2.14	1.70							2.57^2	0		
33	7.01	~~2.40~~							6.86^2	0	7.15^1	50
34	14.90	14.90							~~107.80^2~~	7	~~33.00^1~~	50
35	20.73	20.00							~~72.80^2~~	7	21.45^1	50
36	29.28	27.00							~~109.20^2~~	7	31.55^1	50
37	12.83	10.00			10.10^2				~~62.23^2~~	7	18.40^1	50
38	12.00	12.00							~~18.36^2~~	4		
39	6.00	6.00							~~16.44^2~~	4		
40	1.48								1.48^2*	4		
41	0.40								0.40^2*	4		
42	3.42								3.42^2*	4		
45	5.46	5.00			5.92^2	0						
46	6.77	6.60			6.94^2	0						

Table d: NO_2-N measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. ^{1} = 341, ^{2} = Merck Cell tube, ^{3} = Merck 50mm, ^{4} = Merck 10mm, $*^o$ = Over Measuring Range, $*^u$ = Under Measuring Range, Fr = Frozen sample, x = sample dilution. Rejections: Day16/18/20: Major error in sampling method.

Day	Avg.	R1	R1x	R2	R2x	FrR1	FrR1x	FrR2	FrR2x
1	0.00					0.000^{3*u}	0	0.004^3	0
2	0.01					0.004^3	0	0.006^3	0
3	0.01					0.005^3	0	0.006^3	0
4	0.01					0.011^3	0	0.014^3	0
10	0.06			0.061^2	0				
11	0.08			0.081^2	0				
12	0.11			0.106^2	0			0.108^2	0
13	0.15			0.145^2	0				
14	0.18	0.175^2	0	0.183^2	0				
15	0.23							0.23^1	2
16								~~0.21^1~~	2
17	0.50							0.50^1	2
18								~~0.31^1~~	2
19	0.93							0.93^1	2
20								~~0.85^1~~	2
21	1.64			1.56^1	0			1.73^1	2
22	2.46			2.46^1	4				
23	3.35			3.35^1	10				
24	4.23			4.23^1	10				
25	5.13			5.13^1	10				
26	5.63			5.73^1	10			5.53^1	10
27	6.26							6.26^1	10
28	6.62							6.62^1	10
29	6.80							6.80^1	10
30	5.69							5.69^1	10
31	4.59							4.59^1	10
32	2.47							2.47^1	10
33	1.50							1.50^1	10
34	2.01							2.01^1	10
35	2.32							2.32^1	10
36	2.12							2.12^1	10
37	2.19			2.10^1	2			2.28^1	10
38	4.08							4.08^1	20
39	8.18							8.18^1	20
40	15.26							15.26^1	20
41	17.64							17.64^1	20
42	30.60							30.60^1	20
46	26.40			26.40^{1*o}	20				

Table e: NO_3-N measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. [1] = 340, [2] = Merck 50mm, [3] =Merck Cell tube, [4] = Hanna, * = Under Measuring Range, Fr = Frozen sample, x = sample dilution. <u>Rejections:</u> Day37: Major error in analysis.

Day	Avg.	R2-1	R2-1x	R2-2	R2-2x	FrR1	FrR1x	FrR2	FrR2x
1	0.47					0.64[2]	0	0.29[2]	0
2	0.46					0.46[2]	0	0.0[2]*	0
3	0.14					0.16[2]	0	0.12[2]	0
4	0.24					0.0[2]*	0	0.24[2]	0
10	-			0.0[4]*	0				
11	-			0.0[4]*	0				
12	-	0.0[3]*	0	0.0[4]*	0			0.0[4]*	0
13	-	0.0[3]*	0	0.0[4]*	0				
14	-			0.0[4]*	0				
21	0.90	0.90[3]	0						
22	1.00	1.00[3]	0						
23	1.50	1.50[3]	0						
24	2.10	2.10[3]	0						
25	2.60	2.60[3]	0						
26	3.24	3.60[3]	0					2.87[1]	0
27	3.92							3.92[1]	0
28	6.20							6.20[1]	0
29	7.12							7.12[1]	0
30	13.10							13.10[1]	0
31	17.50							17.50[1]	0
32	24.72							24.72[1]	3.125
33	34.69							34.69[1]	3.125
34	44.06							44.06[1]	3.125
35	57.81							57.81[1]	3.125
36	67.50							67.50[1]	3.125
37	95.94	~~521[3]~~	100					95.94[1]	3.125
38	115.63							115.63[1]	6.25
39	145.00							145.00[1]	6.25
40	168.75							168.75[1]	6.25
41	208.44							208.44[1]	3.125
42	245.00							245.00[1]	6.25
46	68.63	68.63[1]	9.375						

Table f: COD measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. [1] = 314, [2] = Merck Cell tube, [3] = 500, [4] = 114, * = Under Measuring Range, Fr = Frozen sample, x = sample dilution. <u>Rejections:</u> Day 15/19/21: Negative reading.

Day	Avg.	R2	R2x	FrR1	FrR1x	FrR2	FrR2x
1	7			4.5[2]	0	10.0[2]	0
2	11			11.9[2]	0	10.2[2]	0
3	13			10.7[2]	0	16.1[2]	0
4	13			12.7[2]	0	12.7[2]	0
11	21	21.0[1]	0				
15						Negativ[3]	0
19						Negativ[3]	0
21	39	39.2[1]	0			Negativ[3]	0
24	80	79.9[1]	0				
25	91	91.3[4]*	0				
45	126	126.0[1]	0				

Table g: SS measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. Fr = Frozen sample. <u>Rejections:</u> Day 40: Unknown error.

Day	Avg.	R2	R2mg	R2ml	FrR1	FrR1mg	FrR1ml	FrR2	FrR2mg	FrR2ml
1	25				10.00	1	100	40.00	4	100
2	50				20.00	2	100	80.00	8	100
3	55				40.00	4	100	70.00	7	100
4	35				30.00	3	100	40.00	4	100
38	207	207	54	261						
39	240	240	48	200						
40		8	2	238						
41	460	460	46	100						
42	390	390	39	100						
46	130	130	26	200						

Table h: PO$_4^{3-}$-P measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. [1] = 349, [2] = 348, * = Under Measuring Range, [f] = filtered sample, Fr = Frozen sample, x = sample dilution.

Day	Avg.	R1	R1x	R2	R2x	FrR2	FrR2x
11	0.126			0.126[1]	0		
12	0.116			0.087[1]	0	0.145[1]	0
13	0.096			0.096[1]	0		
14	0.098	0.115[1]	0	0.081[1]	0		
21	0.183	1.810[1]	0	0.183[2]	0		
22	0.200	1.280[1]	0	0.200[2]	0		
23	0.216			0.216[1]	0		
24	0.094			0.094[1]	0		
25	0.150			0.150[2f*]	0		
26	0.080			0.080[2f*]	0		
45	0.300			0.300[2f*]	0		
46	0.266			0.266[2f*]	0		

Table i: TP measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as mg L-1 unless specified. ^{1} = 349, ^{2} = 348, $*^u$ = Under Measuring Range, $*^o$ = Over Measuring Range, Fr = Frozen sample, x = sample dilution.

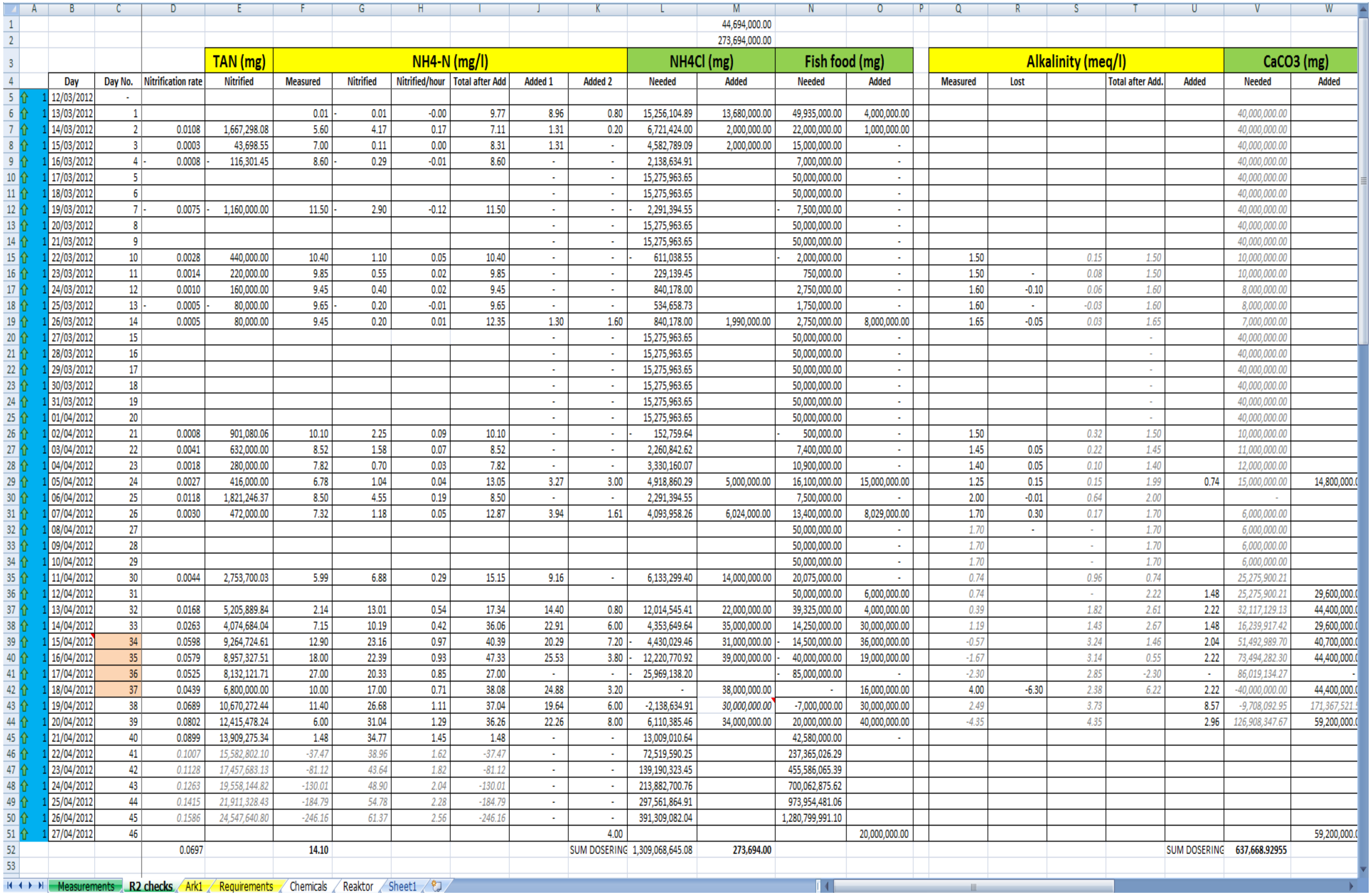
Day	Avg.	R2	R2x	FrR2	FrR2x
11	0.143	0.143^1	0		
15	0.145			0.145^1	0
19	0.134			0.134^1	0
21	0.206	0.206^2	0	0.135^1	0
24	0.164	0.164^2	0		
25	5.270	5.270^{2*o}	0		
26	1.000			1.000^2	0
27	1.170			1.170^2	0
28	0.363			0.363^2	0
29	0.750			0.750^2	0
30	3.890			3.890^2	0
31	0.628			0.628^2	0
32	0.533			0.533^2	0
33	1.280			1.280^2	0
34	0.882			0.882^2	0
35	1.540			1.540^2	0
36	1.610			1.610^2	0
37	1.470			1.470^2	0
38	1.390			1.390^2	0
39	1.710			1.710^2	0
40	0.418			0.418^2	0
41	2.320			2.320^2	0
42	3.570			3.570^2	0
45	1.575	1.575^{2*u}	5		
46	1.290	1.290^2	0		

Table j: Alkalinity measurements throughout the experimental period (Activation of a large scale MBBR from Krüger Kaldnes), values are given as meq L-1 unless specified. Fr = Frozen sample.

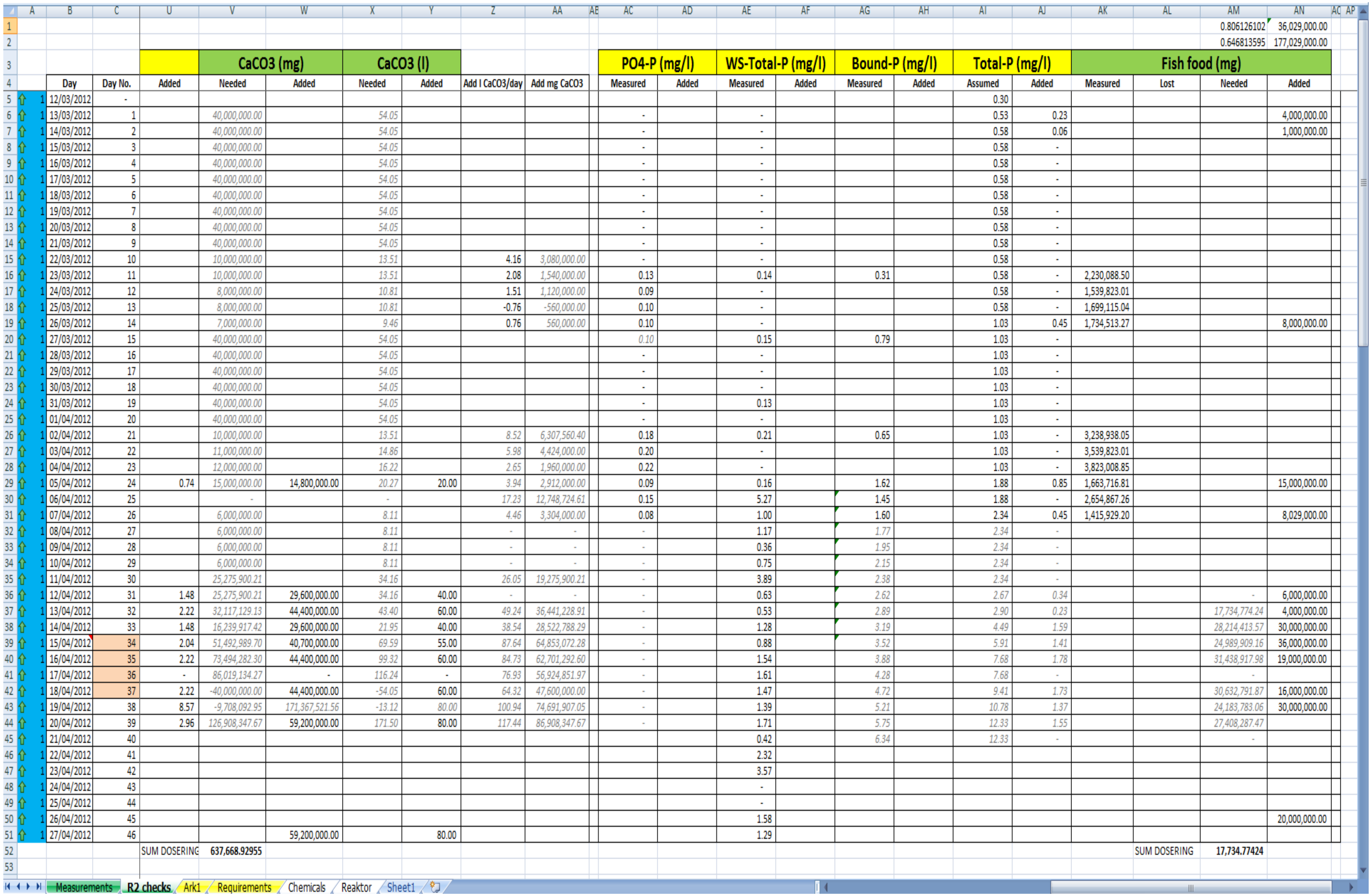
Day	Avg.	R1	R2	FrR1	FrR2
1	1.06			1.02	1.10
2	1.07			1.04	1.10
3	1.11			1.11	1.10
4	1.24			1.25	1.23
10	1.55	1.60	1.50		
11	1.50		1.50		
12	1.58		1.60		1.55
13	1.60		1.60		
14	1.63	1.60	1.65		
21	1.50		1.50		
22	1.45		1.45		
23	1.40		1.40		
24	1.25		1.25		
25	2.00		2.00		
26	1.70		1.70		
37	4.00		4.00		

Figure g: See next page. Calculation sheet Part 1 used to record and predict additives, concentrations and nitrification rates. For more information please contact author.

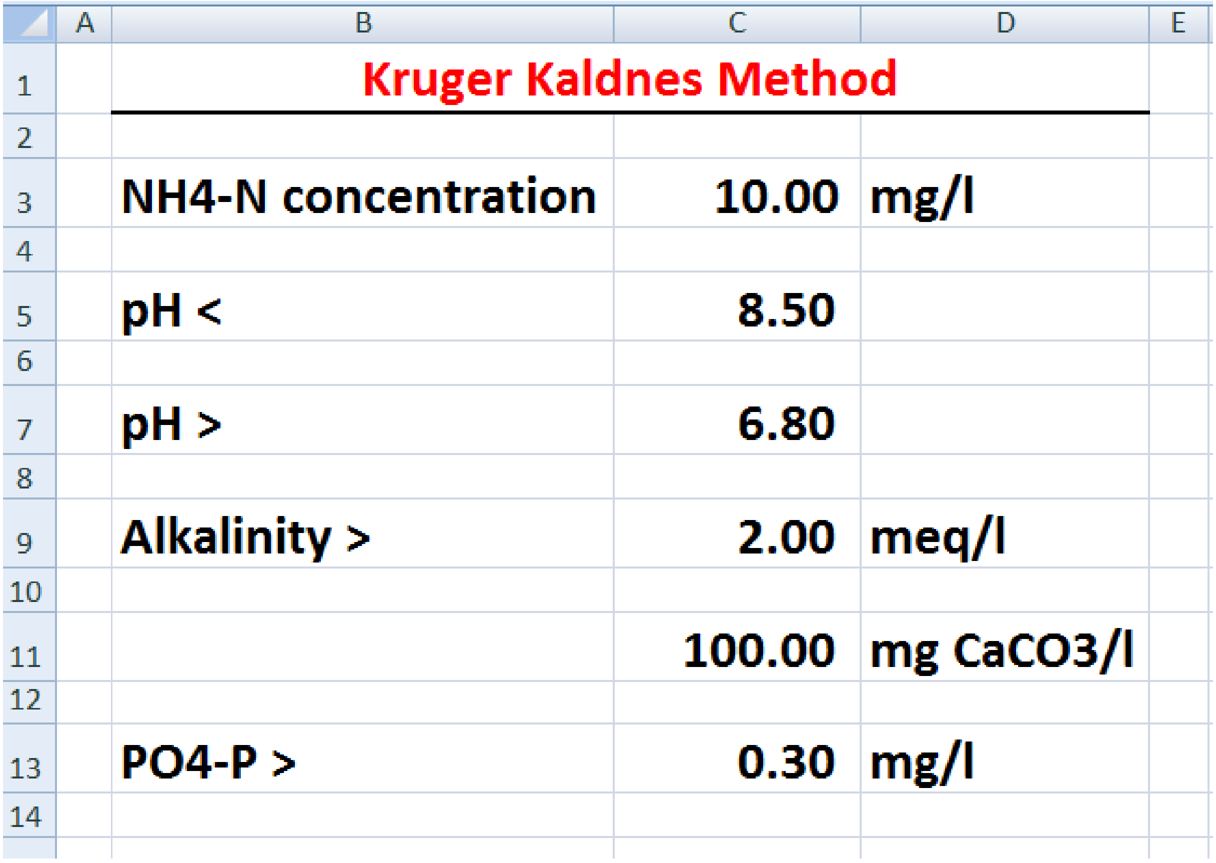
Figure h: See two pages below. Calculation sheet Part 2 used to record and predict additives, concentrations and nitrification rates. For more information please contact author.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1													44,694,000.00										
2													273,694,000.00										
3					TAN (mg)	NH4-N (mg/l)						NH4Cl (mg)		Fish food (mg)			Alkalinity (meq/l)					CaCO3 (mg)	
4		Day	Day No.	Nitrification rate	Nitrified	Measured	Nitrified	Nitrified/hour	Total after Add	Added 1	Added 2	Needed	Added	Needed	Added		Measured	Lost		Total after Add.	Added	Needed	Added
5	⇧ 1	12/03/2012	-																				
6	⇧ 1	13/03/2012	1			0.01	- 0.01	-0.00	9.77	8.96	0.80	15,256,104.89	13,680,000.00	49,935,000.00	4,000,000.00							40,000,000.00	
7	⇧ 1	14/03/2012	2	0.0108	1,667,298.08	5.60	4.17	0.17	7.11	1.31	0.20	6,721,424.00	2,000,000.00	22,000,000.00	1,000,000.00							40,000,000.00	
8	⇧ 1	15/03/2012	3	0.0003	43,698.55	7.00	0.11	0.00	8.31	1.31	-	4,582,789.09	2,000,000.00	15,000,000.00	-							40,000,000.00	
9	⇧ 1	16/03/2012	4	- 0.0008	- 116,301.45	8.60	- 0.29	-0.01	8.60	-	-	2,138,634.91		7,000,000.00	-							40,000,000.00	
10	⇧ 1	17/03/2012	5							-	-	15,275,963.65		50,000,000.00	-							40,000,000.00	
11	⇧ 1	18/03/2012	6							-	-	15,275,963.65		50,000,000.00	-							40,000,000.00	
12	⇧ 1	19/03/2012	7	- 0.0075	- 1,160,000.00	11.50	- 2.90	-0.12	11.50	-	-	- 2,291,394.55		- 7,500,000.00	-							40,000,000.00	
13	⇧ 1	20/03/2012	8							-	-	15,275,963.65		50,000,000.00	-							40,000,000.00	
14	⇧ 1	21/03/2012	9							-	-	15,275,963.65		50,000,000.00	-							40,000,000.00	
15	⇧ 1	22/03/2012	10	0.0028	440,000.00	10.40	1.10	0.05	10.40	-	-	- 611,038.55		- 2,000,000.00	-		1.50		0.15	1.50		10,000,000.00	
16	⇧ 1	23/03/2012	11	0.0014	220,000.00	9.85	0.55	0.02	9.85	-	-	229,139.45		750,000.00	-		1.50	-	0.08	1.50		10,000,000.00	
17	⇧ 1	24/03/2012	12	0.0010	160,000.00	9.45	0.40	0.02	9.45	-	-	840,178.00		2,750,000.00	-		1.60	-0.10	0.06	1.60		8,000,000.00	
18	⇧ 1	25/03/2012	13	- 0.0005	- 80,000.00	9.65	- 0.20	-0.01	9.65	-	-	534,658.73		1,750,000.00	-		1.60	-	-0.03	1.60		8,000,000.00	
19	⇧ 1	26/03/2012	14	0.0005	80,000.00	9.45	0.20	0.01	12.35	1.30	1.60	840,178.00	1,990,000.00	2,750,000.00	8,000,000.00		1.65	-0.05	0.03	1.65		7,000,000.00	
20	⇧ 1	27/03/2012	15							-	-	15,275,963.65		50,000,000.00	-					-		40,000,000.00	
21	⇧ 1	28/03/2012	16							-	-	15,275,963.65		50,000,000.00	-					-		40,000,000.00	
22	⇧ 1	29/03/2012	17							-	-	15,275,963.65		50,000,000.00	-					-		40,000,000.00	
23	⇧ 1	30/03/2012	18							-	-	15,275,963.65		50,000,000.00	-					-		40,000,000.00	
24	⇧ 1	31/03/2012	19							-	-	15,275,963.65		50,000,000.00	-					-		40,000,000.00	
25	⇧ 1	01/04/2012	20							-	-	15,275,963.65		50,000,000.00	-					-		40,000,000.00	
26	⇧ 1	02/04/2012	21	0.0008	901,080.06	10.10	2.25	0.09	10.10	-	-	- 152,759.64		- 500,000.00	-		1.50		0.32	1.50		10,000,000.00	
27	⇧ 1	03/04/2012	22	0.0041	632,000.00	8.52	1.58	0.07	8.52	-	-	2,260,842.62		7,400,000.00	-		1.45	0.05	0.22	1.45		11,000,000.00	
28	⇧ 1	04/04/2012	23	0.0018	280,000.00	7.82	0.70	0.03	7.82	-	-	3,330,160.07		10,900,000.00	-		1.40	0.05	0.10	1.40		12,000,000.00	
29	⇧ 1	05/04/2012	24	0.0027	416,000.00	6.78	1.04	0.04	13.05	3.27	3.00	4,918,860.29	5,000,000.00	16,100,000.00	15,000,000.00		1.25	0.15	0.15	1.99	0.74	15,000,000.00	14,800,000.
30	⇧ 1	06/04/2012	25	0.0118	1,821,246.37	8.50	4.55	0.19	8.50	-	-	2,291,394.55		7,500,000.00	-		2.00	-0.01	0.64	2.00		-	
31	⇧ 1	07/04/2012	26	0.0030	472,000.00	7.32	1.18	0.05	12.87	3.94	1.61	4,093,958.26	6,024,000.00	13,400,000.00	8,029,000.00		1.70	0.30	0.17	1.70		6,000,000.00	
32	⇧ 1	08/04/2012	27											50,000,000.00	-		1.70	-	-	1.70		6,000,000.00	
33	⇧ 1	09/04/2012	28											50,000,000.00	-		1.70		-	1.70		6,000,000.00	
34	⇧ 1	10/04/2012	29											50,000,000.00	-		1.70		-	1.70		6,000,000.00	
35	⇧ 1	11/04/2012	30	0.0044	2,753,700.03	5.99	6.88	0.29	15.15	9.16	-	6,133,299.40	14,000,000.00	20,075,000.00	-		0.74		0.96	0.74		25,275,900.21	
36	⇧ 1	12/04/2012	31											50,000,000.00	6,000,000.00		0.74		-	2.22	1.48	25,275,900.21	29,600,000.
37	⇧ 1	13/04/2012	32	0.0168	5,205,889.84	2.14	13.01	0.54	17.34	14.40	0.80	12,014,545.41	22,000,000.00	39,325,000.00	4,000,000.00		0.39		1.82	2.61	2.22	32,117,129.13	44,400,000.
38	⇧ 1	14/04/2012	33	0.0263	4,074,684.04	7.15	10.19	0.42	36.06	22.91	6.00	4,353,649.64	35,000,000.00	14,250,000.00	30,000,000.00		1.19		1.43	2.67	1.48	16,239,917.42	29,600,000.
39	⇧ 1	15/04/2012	34	0.0598	9,264,724.61	12.90	23.16	0.97	40.39	20.29	7.20	- 4,430,029.46	31,000,000.00	- 14,500,000.00	36,000,000.00		-0.57		3.24	1.46	2.04	51,492,989.70	40,700,000.
40	⇧ 1	16/04/2012	35	0.0579	8,957,327.51	18.00	22.39	0.93	47.33	25.53	3.80	- 12,220,770.92	39,000,000.00	- 40,000,000.00	19,000,000.00		-1.67		3.14	0.55	2.22	73,494,282.30	44,400,000.
41	⇧ 1	17/04/2012	36	0.0525	8,132,121.71	27.00	20.33	0.85	27.00	-	-	- 25,969,138.20		- 85,000,000.00	-		-2.30		2.85	-2.30	-	86,019,134.27	-
42	⇧ 1	18/04/2012	37	0.0439	6,800,000.00	10.00	17.00	0.71	38.08	24.88	3.20	-	38,000,000.00	-	16,000,000.00		4.00	-6.30	2.38	6.22	2.22	-40,000,000.00	44,400,000.
43	⇧ 1	19/04/2012	38	0.0689	10,670,272.44	11.40	26.68	1.11	37.04	19.64	6.00	-2,138,634.91	30,000,000.00	-7,000,000.00	30,000,000.00		2.49		3.73		8.57	-9,708,092.95	171,367,521.
44	⇧ 1	20/04/2012	39	0.0802	12,415,478.24	6.00	31.04	1.29	36.26	22.26	8.00	6,110,385.46	34,000,000.00	20,000,000.00	40,000,000.00		-4.35		4.35		2.96	126,908,347.67	59,200,000.
45	⇧ 1	21/04/2012	40	0.0899	13,909,275.34	1.48	34.77	1.45	1.48	-	-	13,009,010.64		42,580,000.00	-								
46	⇧ 1	22/04/2012	41	0.1007	15,582,802.10	-37.47	38.96	1.62	-37.47	-	-	72,519,590.25		237,365,026.29									
47	⇧ 1	23/04/2012	42	0.1128	17,457,683.13	-81.12	43.64	1.82	-81.12	-	-	139,190,323.45		455,586,065.39									
48	⇧ 1	24/04/2012	43	0.1263	19,558,144.82	-130.01	48.90	2.04	-130.01	-	-	213,882,700.76		700,062,875.62									
49	⇧ 1	25/04/2012	44	0.1415	21,911,328.43	-184.79	54.78	2.28	-184.79	-	-	297,561,864.91		973,954,481.06									
50	⇧ 1	26/04/2012	45	0.1586	24,547,640.80	-246.16	61.37	2.56	-246.16	-	-	391,309,082.04		1,280,799,991.10									
51	⇧ 1	27/04/2012	46								4.00				20,000,000.00								59,200,000.
52				0.0697		14.10					SUM DOSERING	1,309,068,645.08	273,694.00								SUM DOSERING	637,668.92955	
53																							



	A	B	C	U	V	W	X	Y	Z	AA	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1																					0.806126102	36,029,000.00
2																					0.646813595	177,029,000.00
3					CaCO3 (mg)		CaCO3 (l)				PO4-P (mg/l)		WS-Total-P (mg/l)		Bound-P (mg/l)		Total-P (mg/l)		Fish food (mg)			
4		Day	Day No.	Added	Needed	Added	Needed	Added	Add l CaCO3/day	Add mg CaCO3	Measured	Added	Measured	Added	Measured	Added	Assumed	Added	Measured	Lost	Needed	Added
5	1	12/03/2012	-														0.30					
6	1	13/03/2012	1		40,000,000.00		54.05				-		-				0.53	0.23				4,000,000.00
7	1	14/03/2012	2		40,000,000.00		54.05				-		-				0.58	0.06				1,000,000.00
8	1	15/03/2012	3		40,000,000.00		54.05				-		-				0.58	-				
9	1	16/03/2012	4		40,000,000.00		54.05				-		-				0.58	-				
10	1	17/03/2012	5		40,000,000.00		54.05				-		-				0.58	-				
11	1	18/03/2012	6		40,000,000.00		54.05				-		-				0.58	-				
12	1	19/03/2012	7		40,000,000.00		54.05				-		-				0.58	-				
13	1	20/03/2012	8		40,000,000.00		54.05				-		-				0.58	-				
14	1	21/03/2012	9		40,000,000.00		54.05				-		-				0.58	-				
15	1	22/03/2012	10		10,000,000.00		13.51		4.16	3,080,000.00	-		-				0.58	-				
16	1	23/03/2012	11		10,000,000.00		13.51		2.08	1,540,000.00	0.13		0.14		0.31		0.58	-	2,230,088.50			
17	1	24/03/2012	12		8,000,000.00		10.81		1.51	1,120,000.00	0.09		-				0.58	-	1,539,823.01			
18	1	25/03/2012	13		8,000,000.00		10.81		-0.76	-560,000.00	0.10		-				0.58	-	1,699,115.04			
19	1	26/03/2012	14		7,000,000.00		9.46		0.76	560,000.00	0.10		-				1.03	0.45	1,734,513.27			8,000,000.00
20	1	27/03/2012	15		40,000,000.00		54.05				0.10		0.15		0.79		1.03	-				
21	1	28/03/2012	16		40,000,000.00		54.05				-		-				1.03	-				
22	1	29/03/2012	17		40,000,000.00		54.05				-		-				1.03	-				
23	1	30/03/2012	18		40,000,000.00		54.05				-		-				1.03	-				
24	1	31/03/2012	19		40,000,000.00		54.05				-		0.13				1.03	-				
25	1	01/04/2012	20		40,000,000.00		54.05				-		-				1.03	-				
26	1	02/04/2012	21		10,000,000.00		13.51		8.52	6,307,560.40	0.18		0.21		0.65		1.03	-	3,238,938.05			
27	1	03/04/2012	22		11,000,000.00		14.86		5.98	4,424,000.00	0.20		-				1.03	-	3,539,823.01			
28	1	04/04/2012	23		12,000,000.00		16.22		2.65	1,960,000.00	0.22		-				1.03	-	3,823,008.85			
29	1	05/04/2012	24	0.74	15,000,000.00	14,800,000.00	20.27	20.00	3.94	2,912,000.00	0.09		0.16		1.62		1.88	0.85	1,663,716.81			15,000,000.00
30	1	06/04/2012	25		-		-		17.23	12,748,724.61	0.15		5.27		1.45		1.88	-	2,654,867.26			
31	1	07/04/2012	26		6,000,000.00		8.11		4.46	3,304,000.00	0.08		1.00		1.60		2.34	0.45	1,415,929.20			8,029,000.00
32	1	08/04/2012	27		6,000,000.00		8.11		-	-	-		1.17		1.77		2.34	-				
33	1	09/04/2012	28		6,000,000.00		8.11		-	-	-		0.36		1.95		2.34	-				
34	1	10/04/2012	29		6,000,000.00		8.11		-	-	-		0.75		2.15		2.34	-				
35	1	11/04/2012	30		25,275,900.21		34.16		26.05	19,275,900.21	-		3.89		2.38		2.34	-				
36	1	12/04/2012	31	1.48	25,275,900.21	29,600,000.00	34.16	40.00	-	-	-		0.63		2.62		2.67	0.34			-	6,000,000.00
37	1	13/04/2012	32	2.22	32,117,129.13	44,400,000.00	43.40	60.00	49.24	36,441,228.91	-		0.53		2.89		2.90	0.23			17,734,774.24	4,000,000.00
38	1	14/04/2012	33	1.48	16,239,917.42	29,600,000.00	21.95	40.00	38.54	28,522,788.29	-		1.28		3.19		4.49	1.59			28,214,413.57	30,000,000.00
39	1	15/04/2012	34	2.04	51,492,989.70	40,700,000.00	69.59	55.00	87.64	64,853,072.28	-		0.88		3.52		5.91	1.41			24,989,909.16	36,000,000.00
40	1	16/04/2012	35	2.22	73,494,282.30	44,400,000.00	99.32	60.00	84.73	62,701,292.60	-		1.54		3.88		7.68	1.78			31,438,917.98	19,000,000.00
41	1	17/04/2012	36	-	86,019,134.27	-	116.24	-	76.93	56,924,851.97	-		1.61		4.28		7.68	-			-	
42	1	18/04/2012	37	2.22	-40,000,000.00	44,400,000.00	-54.05	60.00	64.32	47,600,000.00	-		1.47		4.72		9.41	1.73			30,632,791.87	16,000,000.00
43	1	19/04/2012	38	8.57	-9,708,092.95	171,367,521.56	-13.12	80.00	100.94	74,691,907.05	-		1.39		5.21		10.78	1.37			24,183,783.06	30,000,000.00
44	1	20/04/2012	39	2.96	126,908,347.67	59,200,000.00	171.50	80.00	117.44	86,908,347.67	-		1.71		5.75		12.33	1.55			27,408,287.47	
45	1	21/04/2012	40										0.42		6.34		12.33	-			-	
46	1	22/04/2012	41										2.32									
47	1	23/04/2012	42										3.57									
48	1	24/04/2012	43										-									
49	1	25/04/2012	44										-									
50	1	26/04/2012	45										1.58									20,000,000.00
51	1	27/04/2012	46			59,200,000.00		80.00					1.29									
52				SUM DOSERING	637,668.92955															SUM DOSERING	17,734.77424	
53																						

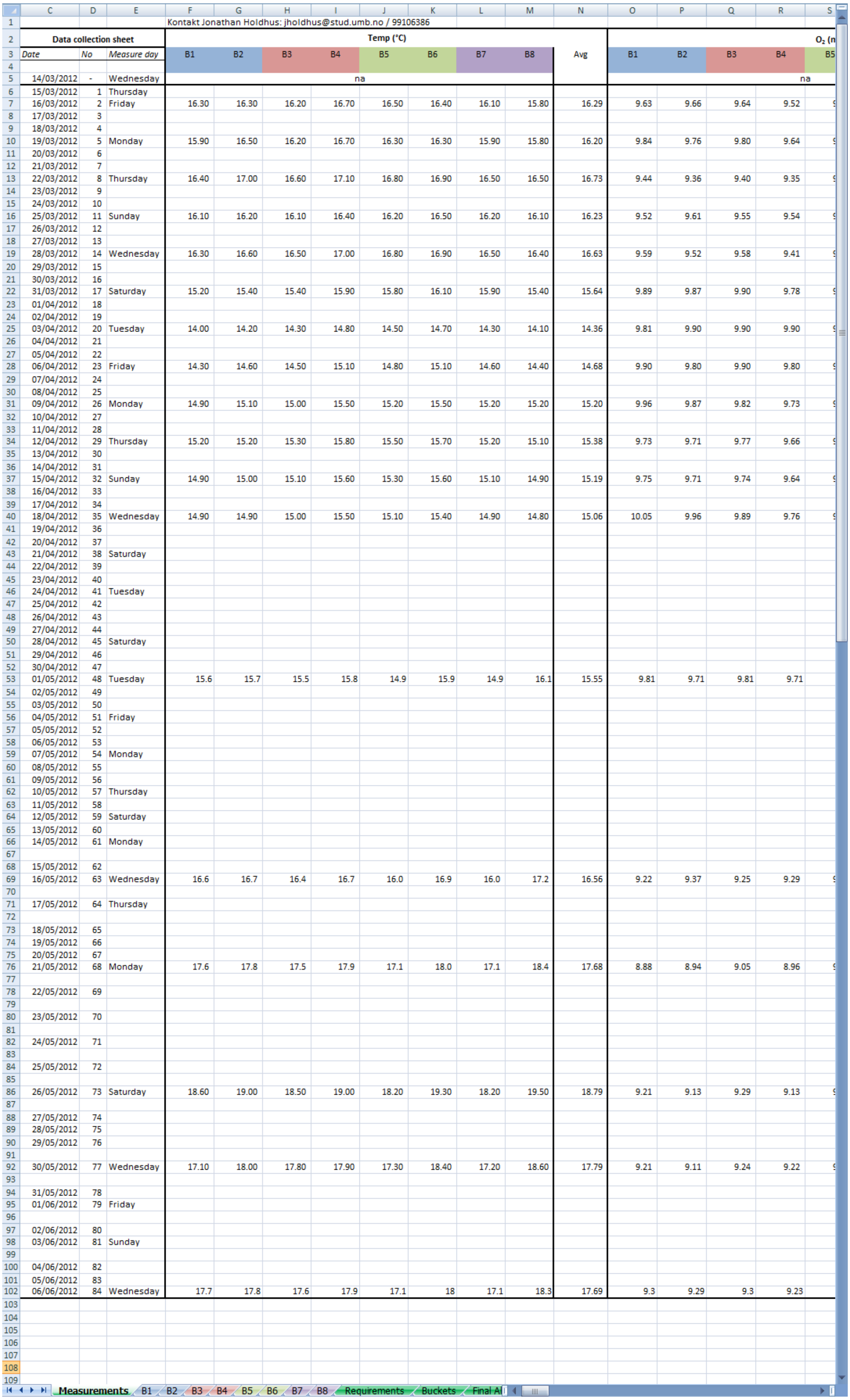


Kruger Kaldnes Method

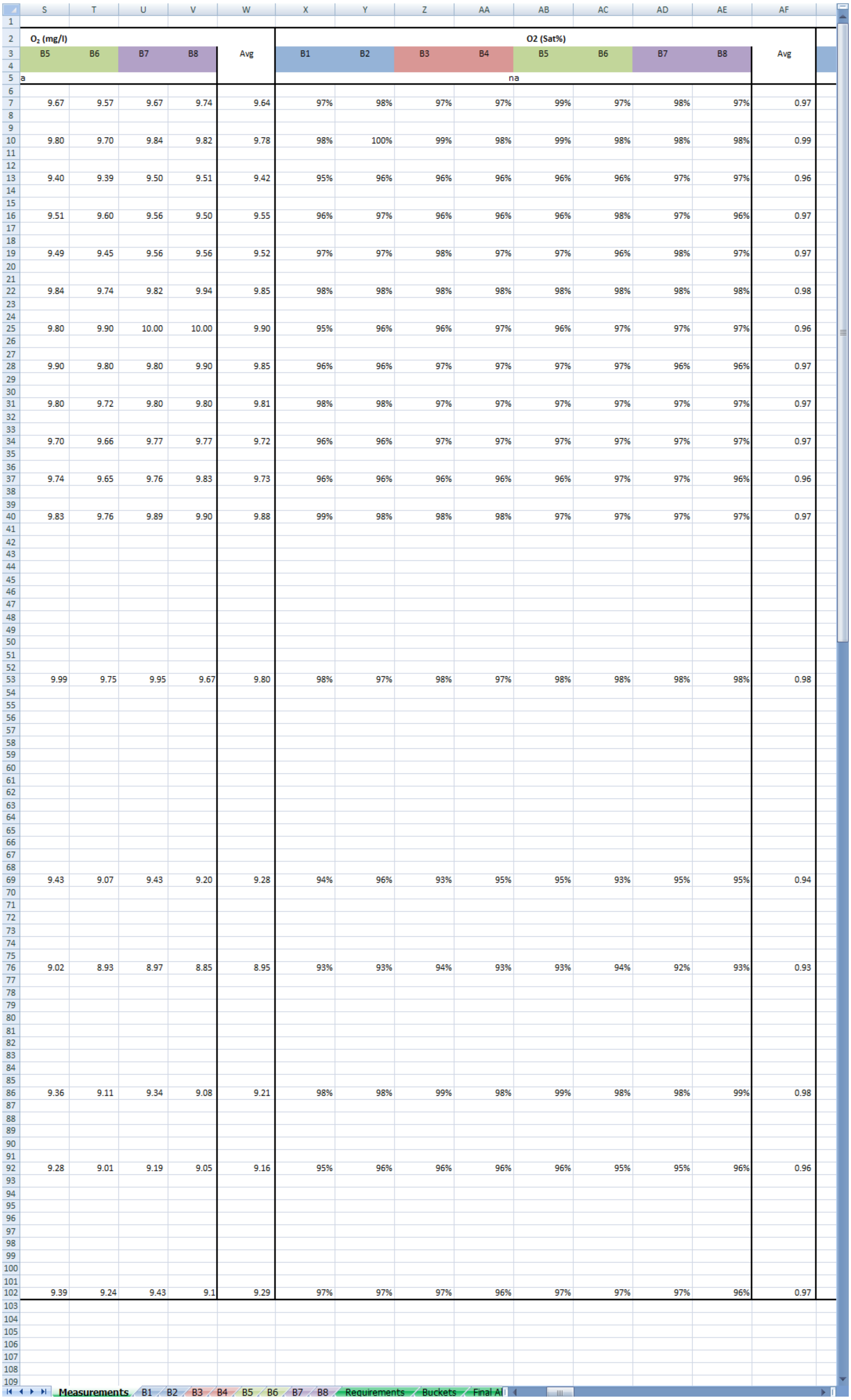
NH4-N concentration	10.00	mg/l
pH <	8.50	
pH >	6.80	
Alkalinity >	2.00	meq/l
	100.00	mg CaCO3/l
PO4-P >	0.30	mg/l

Figure i: Requirement used in the above mentioned calculation sheets.

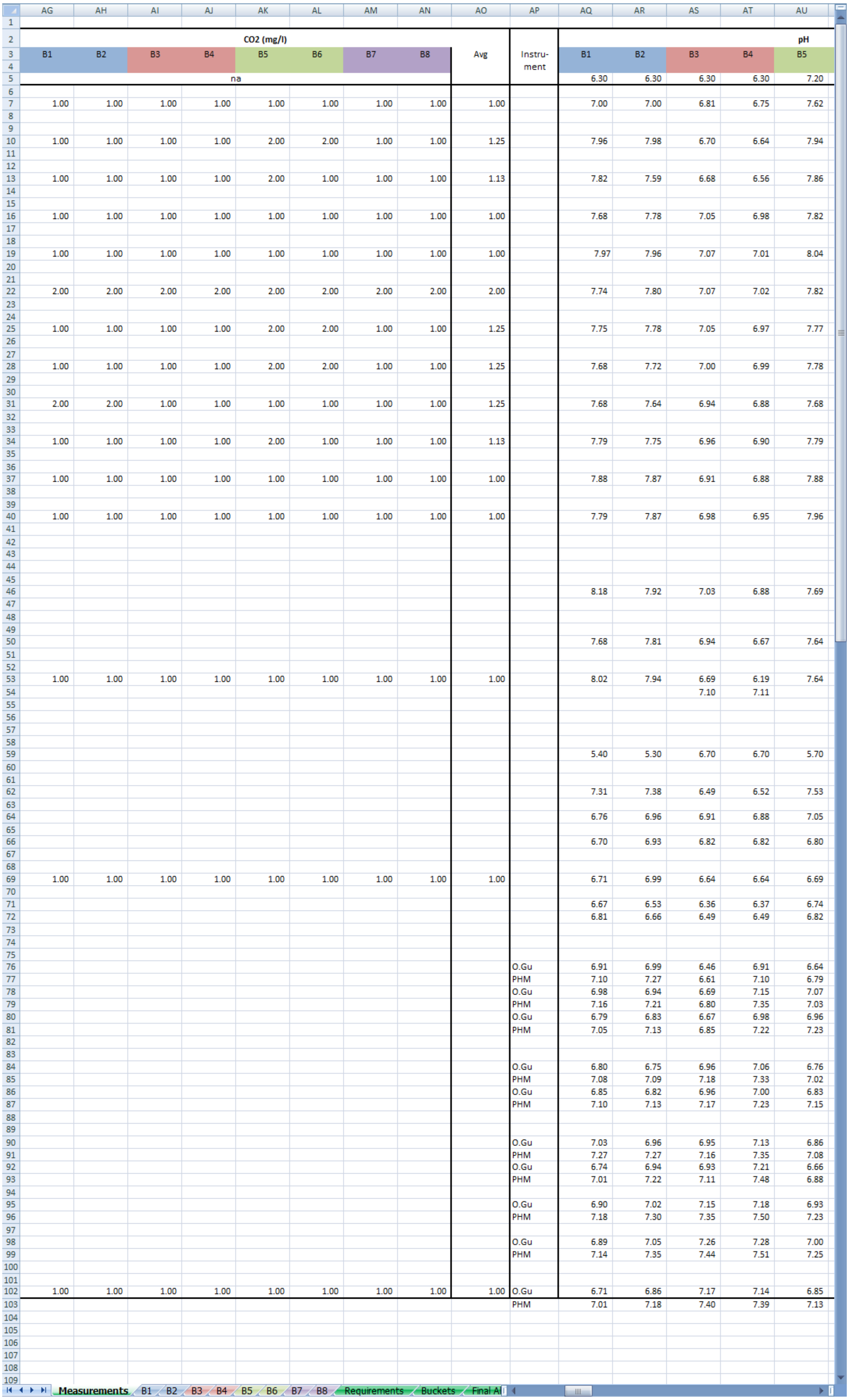
L – Raw data from small scale experiment



	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				Kontakt Jonathan Holdhus: jholdhus@stud.umb.no / 99106386													
2	**Data collection sheet**			**Temp (°C)**									**O_2 (n**				
3	*Date*	*No*	*Measure day*	B1	B2	B3	B4	B5	B6	B7	B8	Avg	B1	B2	B3	B4	B5
4																	
5	14/03/2012	-	Wednesday	na									na				
6	15/03/2012	1	Thursday														
7	16/03/2012	2	Friday	16.30	16.30	16.20	16.70	16.50	16.40	16.10	15.80	16.29	9.63	9.66	9.64	9.52	
8	17/03/2012	3															
9	18/03/2012	4															
10	19/03/2012	5	Monday	15.90	16.50	16.20	16.70	16.30	16.30	15.90	15.80	16.20	9.84	9.76	9.80	9.64	
11	20/03/2012	6															
12	21/03/2012	7															
13	22/03/2012	8	Thursday	16.40	17.00	16.60	17.10	16.80	16.90	16.50	16.50	16.73	9.44	9.36	9.40	9.35	
14	23/03/2012	9															
15	24/03/2012	10															
16	25/03/2012	11	Sunday	16.10	16.20	16.10	16.40	16.20	16.50	16.20	16.10	16.23	9.52	9.61	9.55	9.54	
17	26/03/2012	12															
18	27/03/2012	13															
19	28/03/2012	14	Wednesday	16.30	16.60	16.50	17.00	16.80	16.90	16.50	16.40	16.63	9.59	9.52	9.58	9.41	
20	29/03/2012	15															
21	30/03/2012	16															
22	31/03/2012	17	Saturday	15.20	15.40	15.40	15.90	15.80	16.10	15.90	15.40	15.64	9.89	9.87	9.90	9.78	
23	01/04/2012	18															
24	02/04/2012	19															
25	03/04/2012	20	Tuesday	14.00	14.20	14.30	14.80	14.50	14.70	14.30	14.10	14.36	9.81	9.90	9.90	9.90	
26	04/04/2012	21															
27	05/04/2012	22															
28	06/04/2012	23	Friday	14.30	14.60	14.50	15.10	14.80	15.10	14.60	14.40	14.68	9.90	9.80	9.90	9.80	
29	07/04/2012	24															
30	08/04/2012	25															
31	09/04/2012	26	Monday	14.90	15.10	15.00	15.50	15.20	15.50	15.20	15.20	15.20	9.96	9.87	9.82	9.73	
32	10/04/2012	27															
33	11/04/2012	28															
34	12/04/2012	29	Thursday	15.20	15.20	15.30	15.80	15.50	15.70	15.20	15.10	15.38	9.73	9.71	9.77	9.66	
35	13/04/2012	30															
36	14/04/2012	31															
37	15/04/2012	32	Sunday	14.90	15.00	15.10	15.60	15.30	15.60	15.10	14.90	15.19	9.75	9.71	9.74	9.64	
38	16/04/2012	33															
39	17/04/2012	34															
40	18/04/2012	35	Wednesday	14.90	14.90	15.00	15.50	15.10	15.40	14.90	14.80	15.06	10.05	9.96	9.89	9.76	
41	19/04/2012	36															
42	20/04/2012	37															
43	21/04/2012	38	Saturday														
44	22/04/2012	39															
45	23/04/2012	40															
46	24/04/2012	41	Tuesday														
47	25/04/2012	42															
48	26/04/2012	43															
49	27/04/2012	44															
50	28/04/2012	45	Saturday														
51	29/04/2012	46															
52	30/04/2012	47															
53	01/05/2012	48	Tuesday	15.6	15.7	15.5	15.8	14.9	15.9	14.9	16.1	15.55	9.81	9.71	9.81	9.71	
54	02/05/2012	49															
55	03/05/2012	50															
56	04/05/2012	51	Friday														
57	05/05/2012	52															
58	06/05/2012	53															
59	07/05/2012	54	Monday														
60	08/05/2012	55															
61	09/05/2012	56															
62	10/05/2012	57	Thursday														
63	11/05/2012	58															
64	12/05/2012	59	Saturday														
65	13/05/2012	60															
66	14/05/2012	61	Monday														
67																	
68	15/05/2012	62															
69	16/05/2012	63	Wednesday	16.6	16.7	16.4	16.7	16.0	16.9	16.0	17.2	16.56	9.22	9.37	9.25	9.29	
70																	
71	17/05/2012	64	Thursday														
72																	
73	18/05/2012	65															
74	19/05/2012	66															
75	20/05/2012	67															
76	21/05/2012	68	Monday	17.6	17.8	17.5	17.9	17.1	18.0	17.1	18.4	17.68	8.88	8.94	9.05	8.96	
77																	
78	22/05/2012	69															
79																	
80	23/05/2012	70															
81																	
82	24/05/2012	71															
83																	
84	25/05/2012	72															
85																	
86	26/05/2012	73	Saturday	18.60	19.00	18.50	19.00	18.20	19.30	18.20	19.50	18.79	9.21	9.13	9.29	9.13	
87																	
88	27/05/2012	74															
89	28/05/2012	75															
90	29/05/2012	76															
91																	
92	30/05/2012	77	Wednesday	17.10	18.00	17.80	17.90	17.30	18.40	17.20	18.60	17.79	9.21	9.11	9.24	9.22	
93																	
94	31/05/2012	78															
95	01/06/2012	79	Friday														
96																	
97	02/06/2012	80															
98	03/06/2012	81	Sunday														
99																	
100	04/06/2012	82															
101	05/06/2012	83															
102	06/06/2012	84	Wednesday	17.7	17.8	17.6	17.9	17.1	18	17.1	18.3	17.69	9.3	9.29	9.3	9.23	
103																	
104																	
105																	
106																	
107																	
108																	
109																	



	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
2	O_2 (mg/l)									O2 (Sat%)				
3	B5	B6	B7	B8	Avg	B1	B2	B3	B4	B5	B6	B7	B8	Avg
5	a								na					
7	9.67	9.57	9.67	9.74	9.64	97%	98%	97%	97%	99%	97%	98%	97%	0.97
10	9.80	9.70	9.84	9.82	9.78	98%	100%	99%	98%	99%	98%	98%	98%	0.99
13	9.40	9.39	9.50	9.51	9.42	95%	96%	96%	96%	96%	96%	97%	97%	0.96
16	9.51	9.60	9.56	9.50	9.55	96%	97%	96%	96%	96%	98%	97%	96%	0.97
19	9.49	9.45	9.56	9.56	9.52	97%	97%	98%	97%	97%	96%	98%	97%	0.97
22	9.84	9.74	9.82	9.94	9.85	98%	98%	98%	98%	98%	98%	98%	98%	0.98
25	9.80	9.90	10.00	10.00	9.90	95%	96%	96%	97%	96%	97%	97%	97%	0.96
28	9.90	9.80	9.80	9.90	9.85	96%	96%	97%	97%	97%	97%	96%	96%	0.97
31	9.80	9.72	9.80	9.80	9.81	98%	98%	97%	97%	97%	97%	97%	97%	0.97
34	9.70	9.66	9.77	9.77	9.72	96%	96%	97%	97%	97%	97%	97%	97%	0.97
37	9.74	9.65	9.76	9.83	9.73	96%	96%	96%	96%	96%	97%	97%	96%	0.96
40	9.83	9.76	9.89	9.90	9.88	99%	98%	98%	98%	97%	97%	97%	97%	0.97
53	9.99	9.75	9.95	9.67	9.80	98%	97%	98%	97%	98%	98%	98%	98%	0.98
69	9.43	9.07	9.43	9.20	9.28	94%	96%	93%	95%	95%	93%	95%	95%	0.94
76	9.02	8.93	8.97	8.85	8.95	93%	93%	94%	93%	93%	94%	92%	93%	0.93
86	9.36	9.11	9.34	9.08	9.21	98%	98%	99%	98%	99%	98%	98%	99%	0.98
92	9.28	9.01	9.19	9.05	9.16	95%	96%	96%	96%	96%	95%	95%	96%	0.96
102	9.39	9.24	9.43	9.1	9.29	97%	97%	97%	96%	97%	97%	97%	96%	0.97



	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1															
2					CO2 (mg/l)										pH
3	B1	B2	B3	B4	B5	B6	B7	B8	Avg	Instru-ment	B1	B2	B3	B4	B5
4															
5				na							6.30	6.30	6.30	6.30	7.20
6															
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		7.00	7.00	6.81	6.75	7.62
8															
9															
10	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.25		7.96	7.98	6.70	6.64	7.94
11															
12															
13	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.13		7.82	7.59	6.68	6.56	7.86
14															
15															
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		7.68	7.78	7.05	6.98	7.82
17															
18															
19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		7.97	7.96	7.07	7.01	8.04
20															
21															
22	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00		7.74	7.80	7.07	7.02	7.82
23															
24															
25	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.25		7.75	7.78	7.05	6.97	7.77
26															
27															
28	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.25		7.68	7.72	7.00	6.99	7.78
29															
30															
31	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.25		7.68	7.64	6.94	6.88	7.68
32															
33															
34	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.13		7.79	7.75	6.96	6.90	7.79
35															
36															
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		7.88	7.87	6.91	6.88	7.88
38															
39															
40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		7.79	7.87	6.98	6.95	7.96
41															
42															
43															
44															
45															
46											8.18	7.92	7.03	6.88	7.69
47															
48															
49															
50											7.68	7.81	6.94	6.67	7.64
51															
52															
53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		8.02	7.94	6.69	6.19	7.64
54													7.10	7.11	
55															
56															
57															
58															
59											5.40	5.30	6.70	6.70	5.70
60															
61															
62											7.31	7.38	6.49	6.52	7.53
63															
64											6.76	6.96	6.91	6.88	7.05
65															
66											6.70	6.93	6.82	6.82	6.80
67															
68															
69	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		6.71	6.99	6.64	6.64	6.69
70															
71											6.67	6.53	6.36	6.37	6.74
72											6.81	6.66	6.49	6.49	6.82
73															
74															
75															
76										O.Gu	6.91	6.99	6.46	6.91	6.64
77										PHM	7.10	7.27	6.61	7.10	6.79
78										O.Gu	6.98	6.94	6.69	7.15	7.07
79										PHM	7.16	7.21	6.80	7.35	7.03
80										O.Gu	6.79	6.83	6.67	6.98	6.96
81										PHM	7.05	7.13	6.85	7.22	7.23
82															
83															
84										O.Gu	6.80	6.75	6.96	7.06	6.76
85										PHM	7.08	7.09	7.18	7.33	7.02
86										O.Gu	6.85	6.82	6.96	7.00	6.83
87										PHM	7.10	7.13	7.17	7.23	7.15
88															
89															
90										O.Gu	7.03	6.96	6.95	7.13	6.86
91										PHM	7.27	7.27	7.16	7.35	7.08
92										O.Gu	6.74	6.94	6.93	7.21	6.66
93										PHM	7.01	7.22	7.11	7.48	6.88
94															
95										O.Gu	6.90	7.02	7.15	7.18	6.93
96										PHM	7.18	7.30	7.35	7.50	7.23
97															
98										O.Gu	6.89	7.05	7.26	7.28	7.00
99										PHM	7.14	7.35	7.44	7.51	7.25
100															
101															
102	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	O.Gu	6.71	6.86	7.17	7.14	6.85
103										PHM	7.01	7.18	7.40	7.39	7.13
104															
105															
106															
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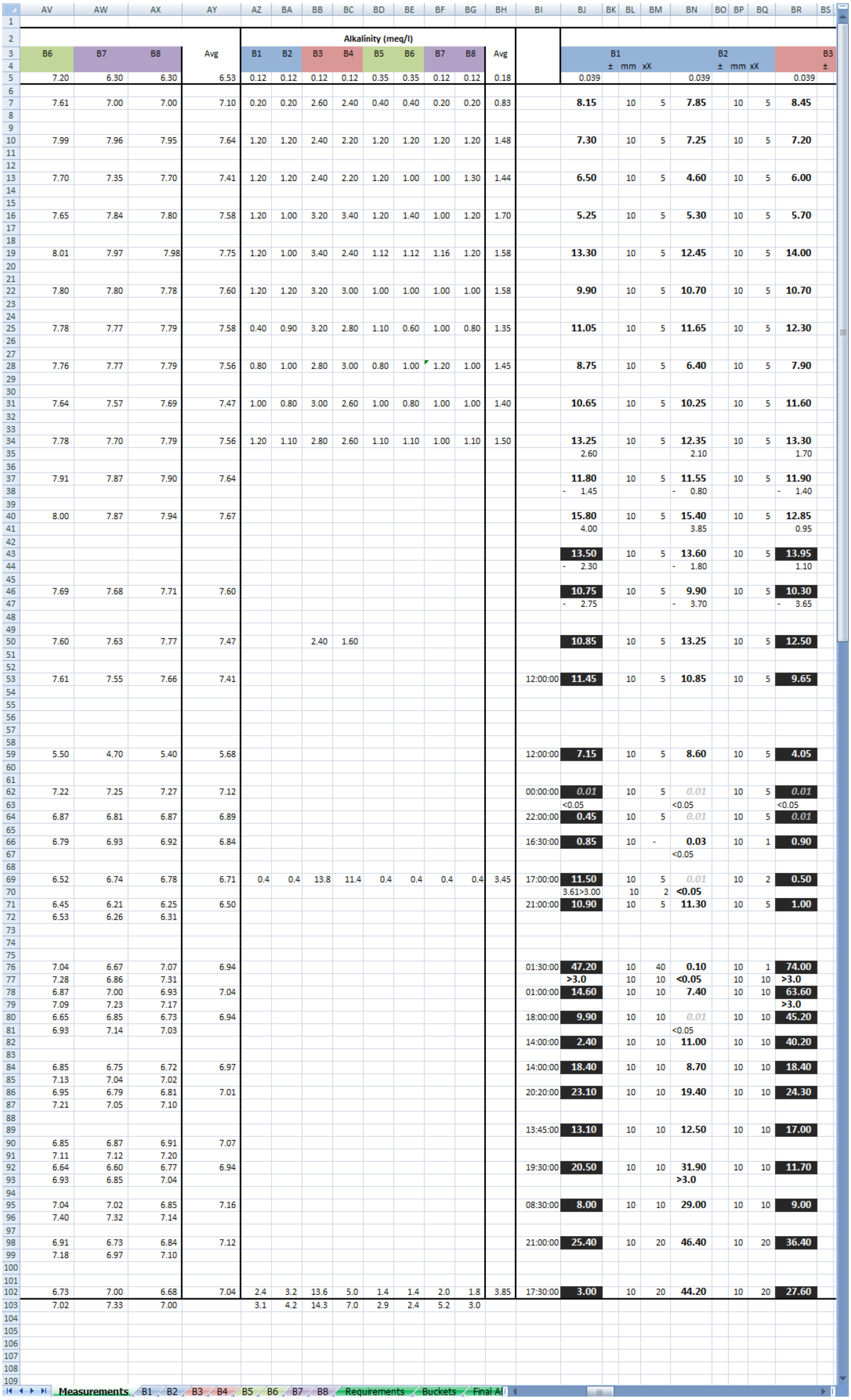

	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS
1																								
2					Alkalinity (meq/l)																			
3	B6	B7	B8	Avg	B1	B2	B3	B4	B5	B6	B7	B8	Avg			B1				B2				B3
4																±	mm	xX		±	mm	xX		±
5	7.20	6.30	6.30	6.53	0.12	0.12	0.12	0.12	0.35	0.35	0.12	0.12	0.18		0.039				0.039				0.039	
6																								
7	7.61	7.00	7.00	7.10	0.20	0.20	2.60	2.40	0.40	0.40	0.20	0.20	0.83		**8.15**		10	5	**7.85**		10	5	**8.45**	
8																								
9																								
10	7.99	7.96	7.95	7.64	1.20	1.20	2.40	2.20	1.20	1.20	1.20	1.20	1.48		**7.30**		10	5	**7.25**		10	5	**7.20**	
11																								
12																								
13	7.70	7.35	7.70	7.41	1.20	1.20	2.40	2.20	1.20	1.00	1.00	1.30	1.44		**6.50**		10	5	**4.60**		10	5	**6.00**	
14																								
15																								
16	7.65	7.84	7.80	7.58	1.20	1.00	3.20	3.40	1.20	1.40	1.00	1.20	1.70		**5.25**		10	5	**5.30**		10	5	**5.70**	
17																								
18																								
19	8.01	7.97	7.98	7.75	1.20	1.00	3.40	2.40	1.12	1.12	1.16	1.20	1.58		**13.30**		10	5	**12.45**		10	5	**14.00**	
20																								
21																								
22	7.80	7.80	7.78	7.60	1.20	1.20	3.20	3.00	1.00	1.00	1.00	1.00	1.58		**9.90**		10	5	**10.70**		10	5	**10.70**	
23																								
24																								
25	7.78	7.77	7.79	7.58	0.40	0.90	3.20	2.80	1.10	0.60	1.00	0.80	1.35		**11.05**		10	5	**11.65**		10	5	**12.30**	
26																								
27																								
28	7.76	7.77	7.79	7.56	0.80	1.00	2.80	3.00	0.80	1.00	1.20	1.00	1.45		**8.75**		10	5	**6.40**		10	5	**7.90**	
29																								
30																								
31	7.64	7.57	7.69	7.47	1.00	0.80	3.00	2.60	1.00	0.80	1.00	1.00	1.40		**10.65**		10	5	**10.25**		10	5	**11.60**	
32																								
33																								
34	7.78	7.70	7.79	7.56	1.20	1.10	2.80	2.60	1.10	1.10	1.00	1.10	1.50		**13.25**		10	5	**12.35**		10	5	**13.30**	
35															2.60				2.10				1.70	
36																								
37	7.91	7.87	7.90	7.64											**11.80**		10	5	**11.55**		10	5	**11.90**	
38															- 1.45				- 0.80				- 1.40	
39																								
40	8.00	7.87	7.94	7.67											**15.80**		10	5	**15.40**		10	5	**12.85**	
41															4.00				3.85				0.95	
42																								
43															**13.50**		10	5	**13.60**		10	5	**13.95**	
44															- 2.30				- 1.80				1.10	
45																								
46	7.69	7.68	7.71	7.60											**10.75**		10	5	**9.90**		10	5	**10.30**	
47															- 2.75				- 3.70				- 3.65	
48																								
49																								
50	7.60	7.63	7.77	7.47			2.40	1.60							**10.85**		10	5	**13.25**		10	5	**12.50**	
51																								
52																								
53	7.61	7.55	7.66	7.41										12:00:00	**11.45**		10	5	**10.85**		10	5	**9.65**	
54																								
55																								
56																								
57																								
58																								
59	5.50	4.70	5.40	5.68										12:00:00	**7.15**		10	5	**8.60**		10	5	**4.05**	
60																								
61																								
62	7.22	7.25	7.27	7.12										00:00:00	***0.01***		10	5	***0.01***		10	5	***0.01***	
63															<0.05				<0.05				<0.05	
64	6.87	6.81	6.87	6.89										22:00:00	**0.45**		10	5	***0.01***		10	5	***0.01***	
65																								
66	6.79	6.93	6.92	6.84										16:30:00	**0.85**		10	-	**0.03**		10	1	**0.90**	
67																			<0.05					
68																								
69	6.52	6.74	6.78	6.71	0.4	0.4	13.8	11.4	0.4	0.4	0.4	0.4	3.45	17:00:00	**11.50**		10	5	***0.01***		10	2	**0.50**	
70															3.61>3.00		10	2	**<0.05**					
71	6.45	6.21	6.25	6.50										21:00:00	**10.90**		10	5	**11.30**		10	5	**1.00**	
72	6.53	6.26	6.31																					
73																								
74																								
75																								
76	7.04	6.67	7.07	6.94										01:30:00	**47.20**		10	40	**0.10**		10	1	**74.00**	
77	7.28	6.86	7.31												**>3.0**		10	10	**<0.05**		10	10	**>3.0**	
78	6.87	7.00	6.93	7.04										01:00:00	**14.60**		10	10	**7.40**		10	10	**63.60**	
79	7.09	7.23	7.17																				**>3.0**	
80	6.65	6.85	6.73	6.94										18:00:00	**9.90**		10	10	***0.01***		10	10	**45.20**	
81	6.93	7.14	7.03																<0.05					
82														14:00:00	**2.40**		10	10	**11.00**		10	10	**40.20**	
83																								
84	6.85	6.75	6.72	6.97										14:00:00	**18.40**		10	10	**8.70**		10	10	**18.40**	
85	7.13	7.04	7.02																					
86	6.95	6.79	6.81	7.01										20:20:00	**23.10**		10	10	**19.40**		10	10	**24.30**	
87	7.21	7.05	7.10																					
88																								
89														13:45:00	**13.10**		10	10	**12.50**		10	10	**17.00**	
90	6.85	6.87	6.91	7.07																				
91	7.11	7.12	7.20																					
92	6.64	6.60	6.77	6.94										19:30:00	**20.50**		10	10	**31.90**		10	10	**11.70**	
93	6.93	6.85	7.04																**>3.0**					
94																								
95	7.04	7.02	6.85	7.16										08:30:00	**8.00**		10	10	**29.00**		10	10	**9.00**	
96	7.40	7.32	7.14																					
97																								
98	6.91	6.73	6.84	7.12										21:00:00	**25.40**		10	20	**46.40**		10	20	**36.40**	
99	7.18	6.97	7.10																					
100																								
101																								
102	6.73	7.00	6.68	7.04	2.4	3.2	13.6	5.0	1.4	1.4	2.0	1.8	3.85	17:30:00	**3.00**		10	20	**44.20**		10	20	**27.60**	
103	7.02	7.33	7.00		3.1	4.2	14.3	7.0	2.9	2.4	5.2	3.0												
104																								
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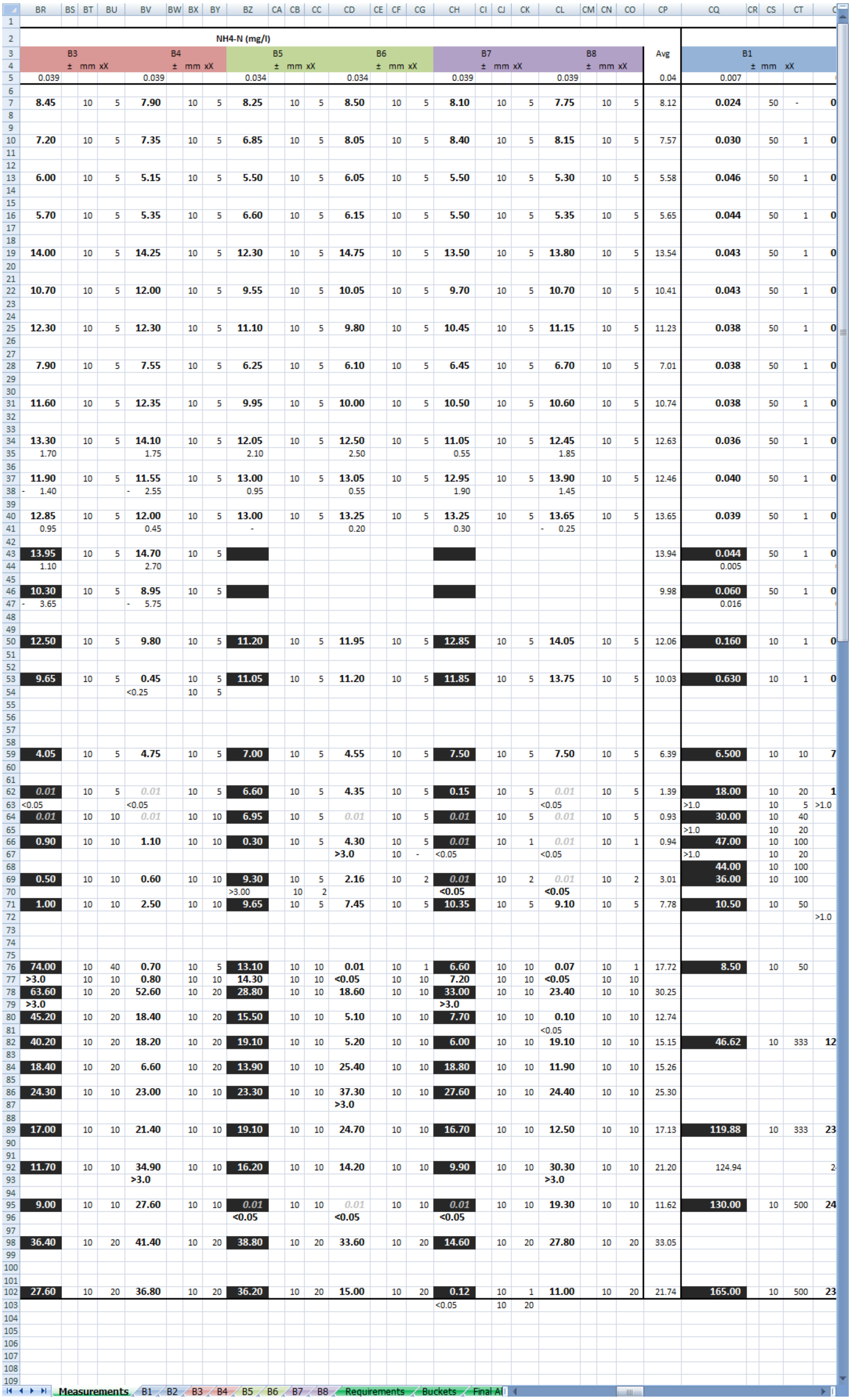
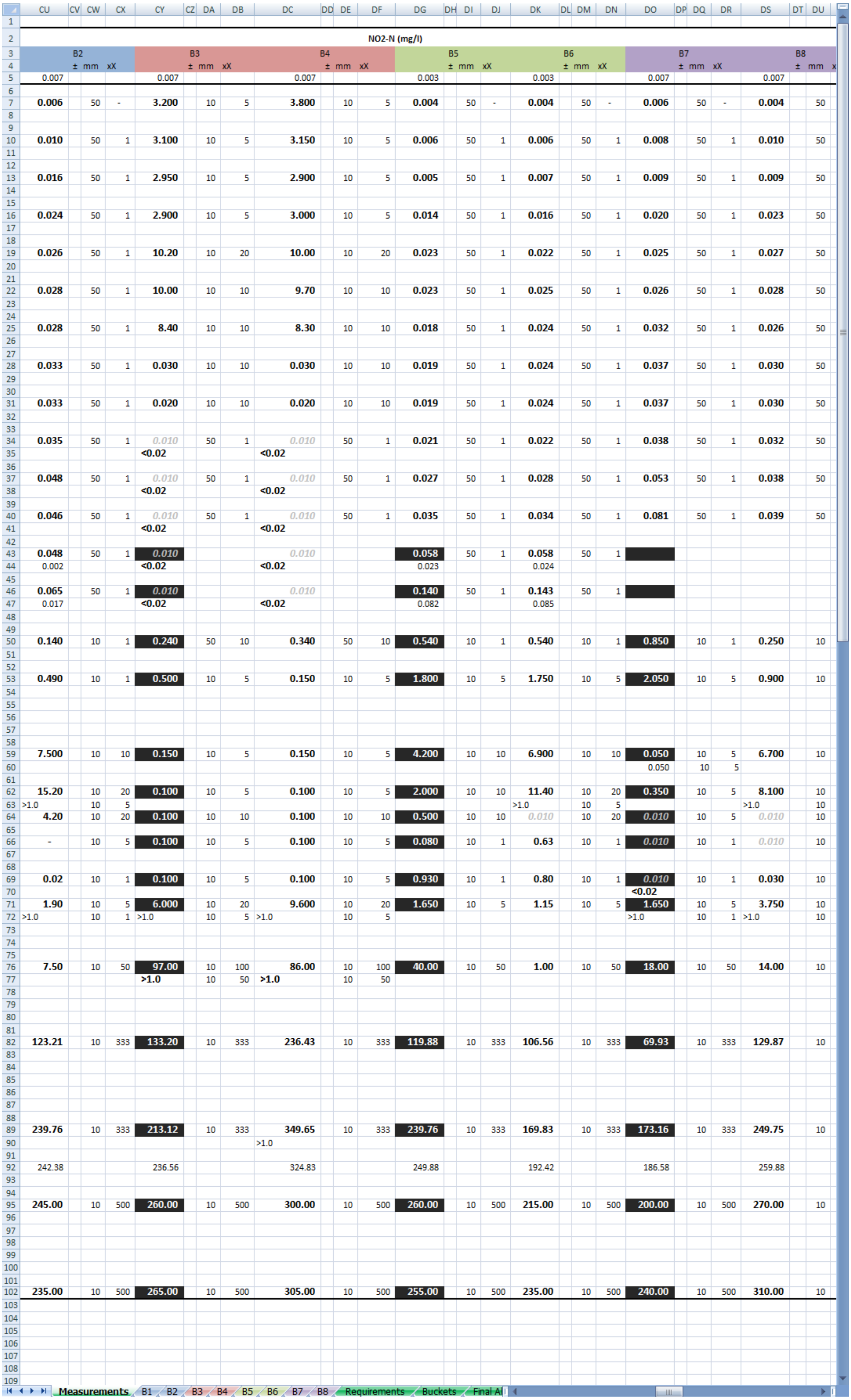
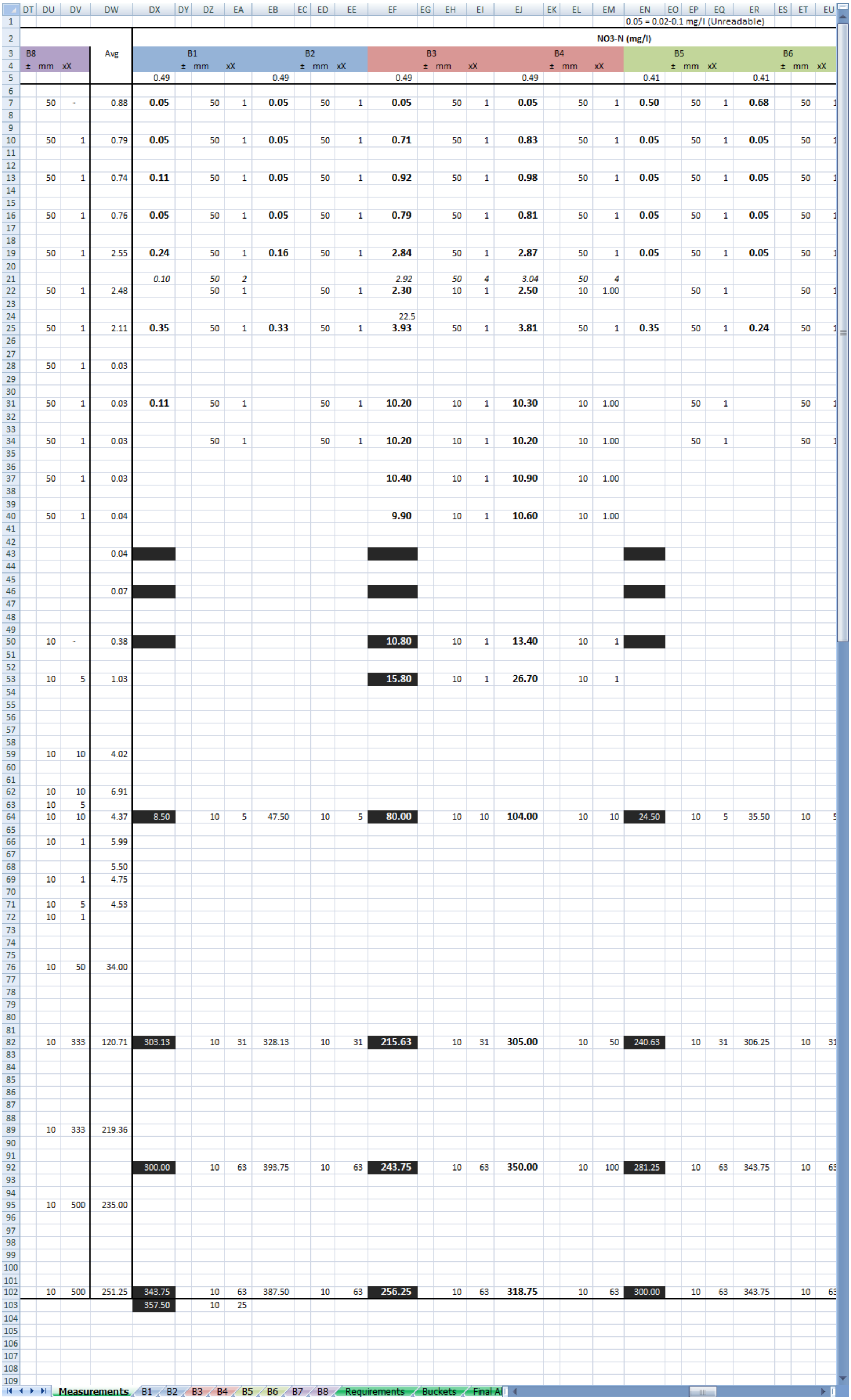


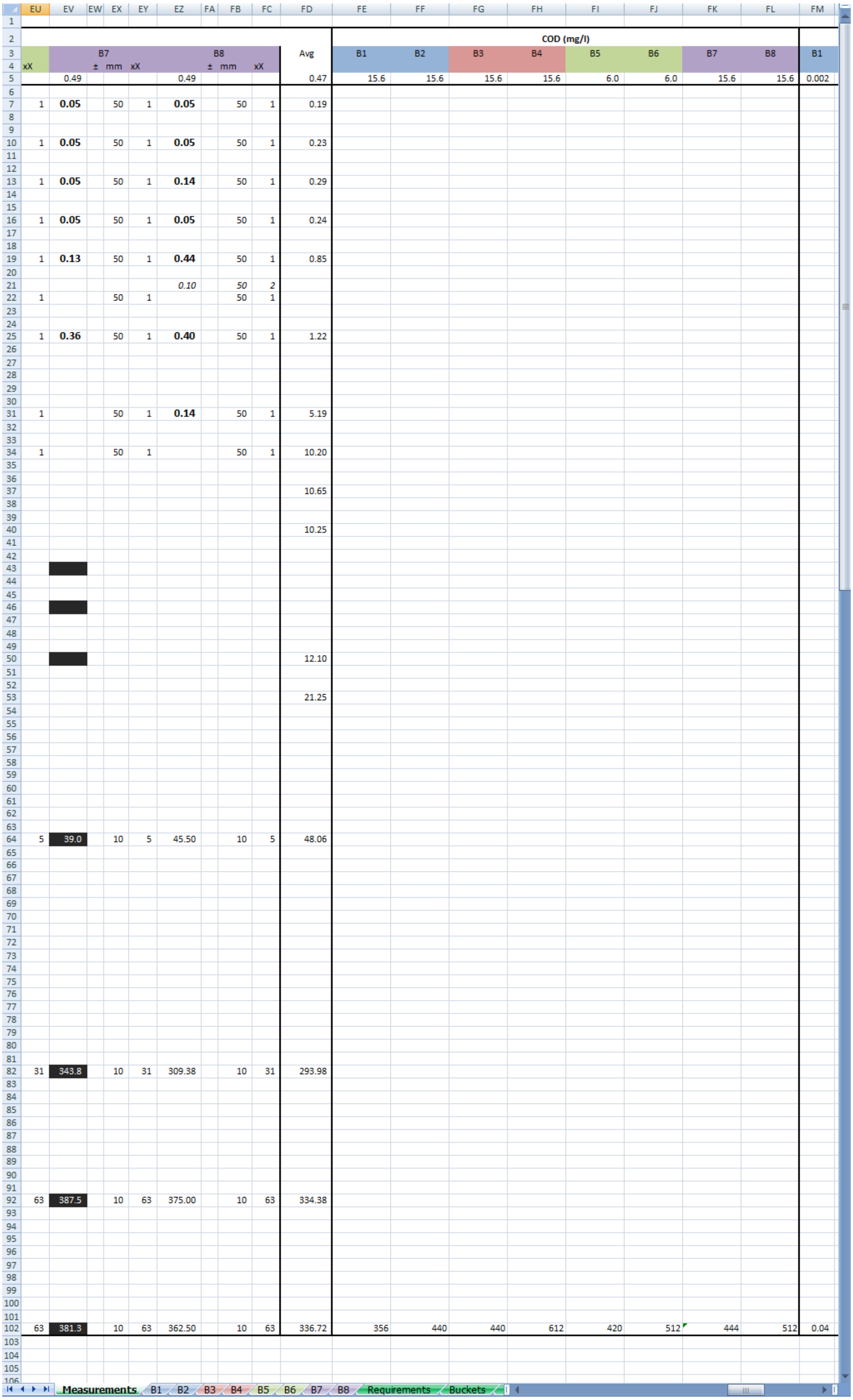
	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR	CS	CT	C
1																														
2									NH4-N (mg/l)																					
3		B3				B4				B5				B6				B7				B8			Avg		B1			
4		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX			±	mm	xX	
5	0.039				0.039				0.034				0.034				0.039				0.039				0.04	0.007				
6																														
7	8.45		10	5	7.90		10	5	8.25		10	5	8.50		10	5	8.10		10	5	7.75		10	5	8.12	0.024		50	-	0
8																														
9																														
10	7.20		10	5	7.35		10	5	6.85		10	5	8.05		10	5	8.40		10	5	8.15		10	5	7.57	0.030		50	1	0
11																														
12																														
13	6.00		10	5	5.15		10	5	5.50		10	5	6.05		10	5	5.50		10	5	5.30		10	5	5.58	0.046		50	1	0
14																														
15																														
16	5.70		10	5	5.35		10	5	6.60		10	5	6.15		10	5	5.50		10	5	5.35		10	5	5.65	0.044		50	1	0
17																														
18																														
19	14.00		10	5	14.25		10	5	12.30		10	5	14.75		10	5	13.50		10	5	13.80		10	5	13.54	0.043		50	1	0
20																														
21																														
22	10.70		10	5	12.00		10	5	9.55		10	5	10.05		10	5	9.70		10	5	10.70		10	5	10.41	0.043		50	1	0
23																														
24																														
25	12.30		10	5	12.30		10	5	11.10		10	5	9.80		10	5	10.45		10	5	11.15		10	5	11.23	0.038		50	1	0
26																														
27																														
28	7.90		10	5	7.55		10	5	6.25		10	5	6.10		10	5	6.45		10	5	6.70		10	5	7.01	0.038		50	1	0
29																														
30																														
31	11.60		10	5	12.35		10	5	9.95		10	5	10.00		10	5	10.50		10	5	10.60		10	5	10.74	0.038		50	1	0
32																														
33																														
34	13.30		10	5	14.10		10	5	12.05		10	5	12.50		10	5	11.05		10	5	12.45		10	5	12.63	0.036		50	1	0
35	1.70				1.75				2.10				2.50				0.55				1.85									
36																														
37	11.90		10	5	11.55		10	5	13.00		10	5	13.05		10	5	12.95		10	5	13.90		10	5	12.46	0.040		50	1	0
38	- 1.40				- 2.55				0.95				0.55				1.90				1.45									
39																														
40	12.85		10	5	12.00		10	5	13.00		10	5	13.25		10	5	13.25		10	5	13.65		10	5	13.65	0.039		50	1	0
41	0.95				0.45				-				0.20				0.30				- 0.25									
42																														
43	13.95		10	5	14.70		10	5																	13.94	0.044		50	1	0
44	1.10				2.70																					0.005				
45																														
46	10.30		10	5	8.95		10	5																	9.98	0.060		50	1	0
47	- 3.65				- 5.75																					0.016				
48																														
49																														
50	12.50		10	5	9.80		10	5	11.20		10	5	11.95		10	5	12.85		10	5	14.05		10	5	12.06	0.160		10	1	0
51																														
52																														
53	9.65		10	5	0.45		10	5	11.05		10	5	11.20		10	5	11.85		10	5	13.75		10	5	10.03	0.630		10	1	0
54					<0.25		10	5																						
55																														
56																														
57																														
58																														
59	4.05		10	5	4.75		10	5	7.00		10	5	4.55		10	5	7.50		10	5	7.50		10	5	6.39	6.500		10	10	7
60																														
61																														
62	*0.01*		10	5	*0.01*		10	5	6.60		10	5	4.35		10	5	0.15		10	5	*0.01*		10	5	1.39	18.00		10	20	1
63	<0.05				<0.05																<0.05					>1.0		10	5	>1.0
64	*0.01*		10	10	*0.01*		10	10	6.95		10	5	*0.01*		10	5	*0.01*		10	5	*0.01*		10	5	0.93	30.00		10	40	
65																										>1.0		10	20	
66	0.90		10	10	1.10		10	10	0.30		10	5	4.30		10	5	*0.01*		10	1	*0.01*		10	1	0.94	47.00		10	100	
67													>3.0		10	-	<0.05				<0.05					>1.0		10	20	
68																										44.00		10	100	
69	0.50		10	10	0.60		10	10	9.30		10	5	2.16		10	2	*0.01*		10	2	*0.01*		10	2	3.01	36.00		10	100	
70									>3.00		10	2					<0.05				<0.05									
71	1.00		10	10	2.50		10	10	9.65		10	5	7.45		10	5	10.35		10	5	9.10		10	5	7.78	10.50		10	50	
72																														>1.0
73																														
74																														
75																														
76	74.00		10	40	0.70		10	5	13.10		10	10	0.01		10	1	6.60		10	10	0.07		10	1	17.72	8.50		10	50	
77	>3.0		10	10	0.80		10	10	14.30		10	10	<0.05		10	10	7.20		10	10	<0.05		10	10						
78	63.60		10	20	52.60		10	20	28.80		10	10	18.60		10	10	33.00		10	10	23.40		10	10	30.25					
79	>3.0																>3.0													
80	45.20		10	20	18.40		10	20	15.50		10	10	5.10		10	10	7.70		10	10	0.10		10	10	12.74					
81																					<0.05									
82	40.20		10	20	18.20		10	20	19.10		10	10	5.20		10	10	6.00		10	10	19.10		10	10	15.15	46.62		10	333	12
83																														
84	18.40		10	20	6.60		10	20	13.90		10	10	25.40		10	10	18.80		10	10	11.90		10	10	15.26					
85																														
86	24.30		10	10	23.00		10	10	23.30		10	10	37.30		10	10	27.60		10	10	24.40		10	10	25.30					
87													>3.0																	
88																														
89	17.00		10	10	21.40		10	10	19.10		10	10	24.70		10	10	16.70		10	10	12.50		10	10	17.13	119.88		10	333	23
90																														
91																														
92	11.70		10	10	34.90		10	10	16.20		10	10	14.20		10	10	9.90		10	10	30.30		10	10	21.20	124.94				2
93					>3.0																>3.0									
94																														
95	9.00		10	10	27.60		10	10	*0.01*		10	10	*0.01*		10	10	*0.01*		10	10	19.30		10	10	11.62	130.00		10	500	24
96									<0.05				<0.05				<0.05													
97																														
98	36.40		10	20	41.40		10	20	38.80		10	20	33.60		10	20	14.60		10	20	27.80		10	20	33.05					
99																														
100																														
101																														
102	27.60		10	20	36.80		10	20	36.20		10	20	15.00		10	20	0.12		10	1	11.00		10	20	21.74	165.00		10	500	23
103																	<0.05		10	20										
104																														
105																														
106																														
107																														
108																														
109																														



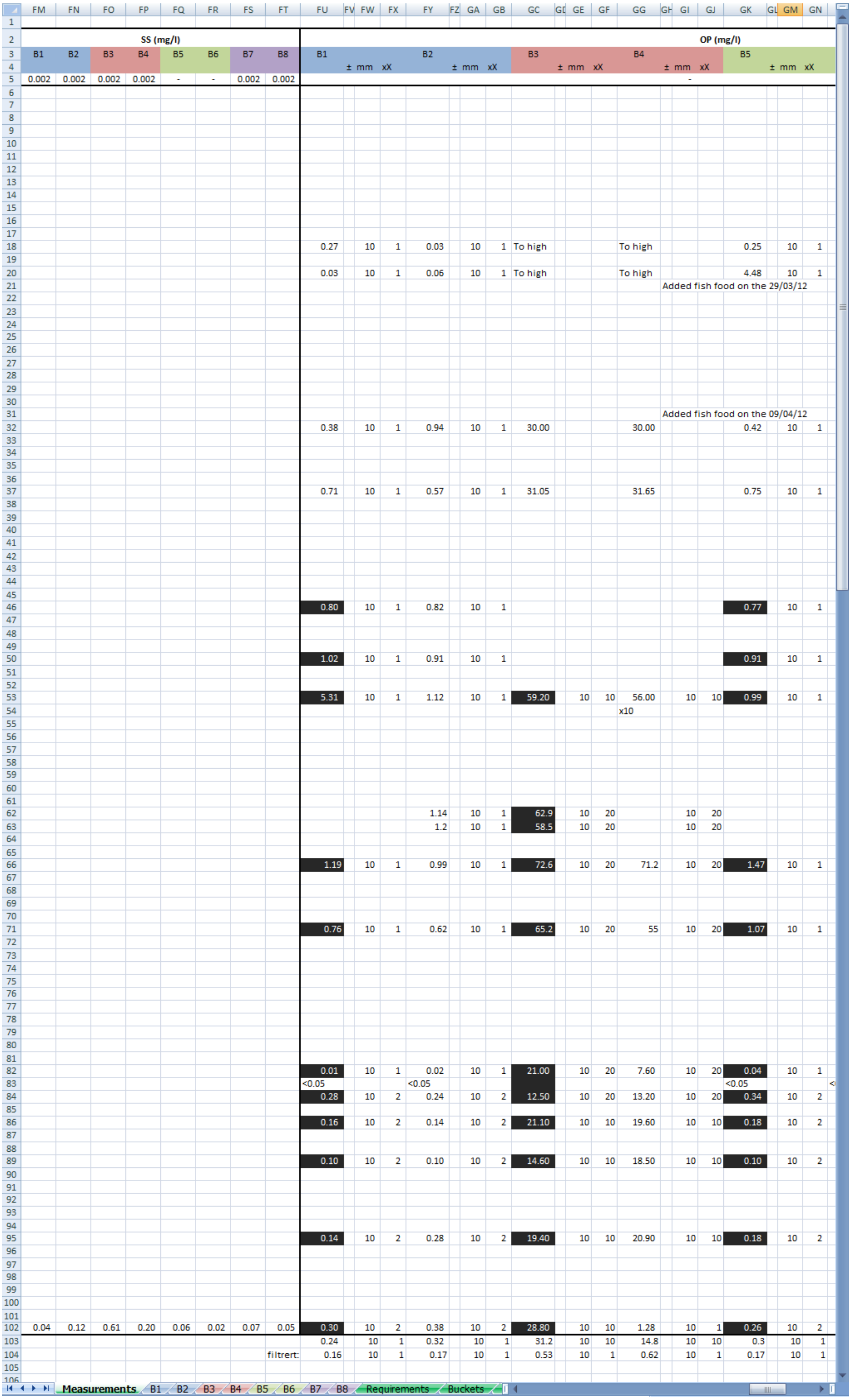
	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP	DQ	DR	DS	DT	DU
1																											
2	NO2-N (mg/l)																										
3	B2				B3				B4				B5				B6				B7				B8		
4		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm
5	0.007				0.007				0.007				0.003				0.003				0.007				0.007		
6																											
7	0.006		50	-	3.200		10	5	3.800		10	5	0.004		50	-	0.004		50	-	0.006		50	-	0.004		50
8																											
9																											
10	0.010		50	1	3.100		10	5	3.150		10	5	0.006		50	1	0.006		50	1	0.008		50	1	0.010		50
11																											
12																											
13	0.016		50	1	2.950		10	5	2.900		10	5	0.005		50	1	0.007		50	1	0.009		50	1	0.009		50
14																											
15																											
16	0.024		50	1	2.900		10	5	3.000		10	5	0.014		50	1	0.016		50	1	0.020		50	1	0.023		50
17																											
18																											
19	0.026		50	1	10.20		10	20	10.00		10	20	0.023		50	1	0.022		50	1	0.025		50	1	0.027		50
20																											
21																											
22	0.028		50	1	10.00		10	10	9.70		10	10	0.023		50	1	0.025		50	1	0.026		50	1	0.028		50
23																											
24																											
25	0.028		50	1	8.40		10	10	8.30		10	10	0.018		50	1	0.024		50	1	0.032		50	1	0.026		50
26																											
27																											
28	0.033		50	1	0.030		10	10	0.030		10	10	0.019		50	1	0.024		50	1	0.037		50	1	0.030		50
29																											
30																											
31	0.033		50	1	0.020		10	10	0.020		10	10	0.019		50	1	0.024		50	1	0.037		50	1	0.030		50
32																											
33																											
34	0.035		50	1	0.010		50	1	0.010		50	1	0.021		50	1	0.022		50	1	0.038		50	1	0.032		50
35					<0.02				<0.02																		
36																											
37	0.048		50	1	0.010		50	1	0.010		50	1	0.027		50	1	0.028		50	1	0.053		50	1	0.038		50
38					<0.02				<0.02																		
39																											
40	0.046		50	1	0.010		50	1	0.010		50	1	0.035		50	1	0.034		50	1	0.081		50	1	0.039		50
41					<0.02				<0.02																		
42																											
43	0.048		50	1	0.010				0.010				0.058		50	1	0.058		50	1							
44	0.002				<0.02				<0.02				0.023				0.024										
45																											
46	0.065		50	1	0.010				0.010				0.140		50	1	0.143		50	1							
47	0.017				<0.02				<0.02				0.082				0.085										
48																											
49																											
50	0.140		10	1	0.240		50	10	0.340		50	10	0.540		10	1	0.540		10	1	0.850		10	1	0.250		10
51																											
52																											
53	0.490		10	1	0.500		10	5	0.150		10	5	1.800		10	5	1.750		10	5	2.050		10	5	0.900		10
54																											
55																											
56																											
57																											
58																											
59	7.500		10	10	0.150		10	5	0.150		10	5	4.200		10	10	6.900		10	10	0.050		10	5	6.700		10
60																					0.050		10	5			
61																											
62	15.20		10	20	0.100		10	5	0.100		10	5	2.000		10	10	11.40		10	20	0.350		10	5	8.100		10
63	>1.0		10	5													>1.0		10	5					>1.0		10
64	4.20		10	20	0.100		10	10	0.100		10	10	0.500		10	10	0.010		10	20	0.010		10	5	0.010		10
65																											
66	-		10	5	0.100		10	5	0.100		10	5	0.080		10	1	0.63		10	1	0.010		10	1	0.010		10
67																											
68																											
69	0.02		10	1	0.100		10	5	0.100		10	5	0.930		10	1	0.80		10	1	0.010		10	1	0.030		10
70																					<0.02						
71	1.90		10	5	6.000		10	20	9.600		10	20	1.650		10	5	1.15		10	5	1.650		10	5	3.750		10
72	>1.0		10	1	>1.0		10	5	>1.0		10	5									>1.0		10	1	>1.0		10
73																											
74																											
75																											
76	7.50		10	50	97.00		10	100	86.00		10	100	40.00		10	50	1.00		10	50	18.00		10	50	14.00		10
77					>1.0		10	50	>1.0		10	50															
78																											
79																											
80																											
81																											
82	123.21		10	333	133.20		10	333	236.43		10	333	119.88		10	333	106.56		10	333	69.93		10	333	129.87		10
83																											
84																											
85																											
86																											
87																											
88																											
89	239.76		10	333	213.12		10	333	349.65		10	333	239.76		10	333	169.83		10	333	173.16		10	333	249.75		10
90									>1.0																		
91																											
92	242.38				236.56				324.83				249.88				192.42				186.58				259.88		
93																											
94																											
95	245.00		10	500	260.00		10	500	300.00		10	500	260.00		10	500	215.00		10	500	200.00		10	500	270.00		10
96																											
97																											
98																											
99																											
100																											
101																											
102	235.00		10	500	265.00		10	500	305.00		10	500	255.00		10	500	235.00		10	500	240.00		10	500	310.00		10
103																											
104																											
105																											
106																											
107																											
108																											
109																											



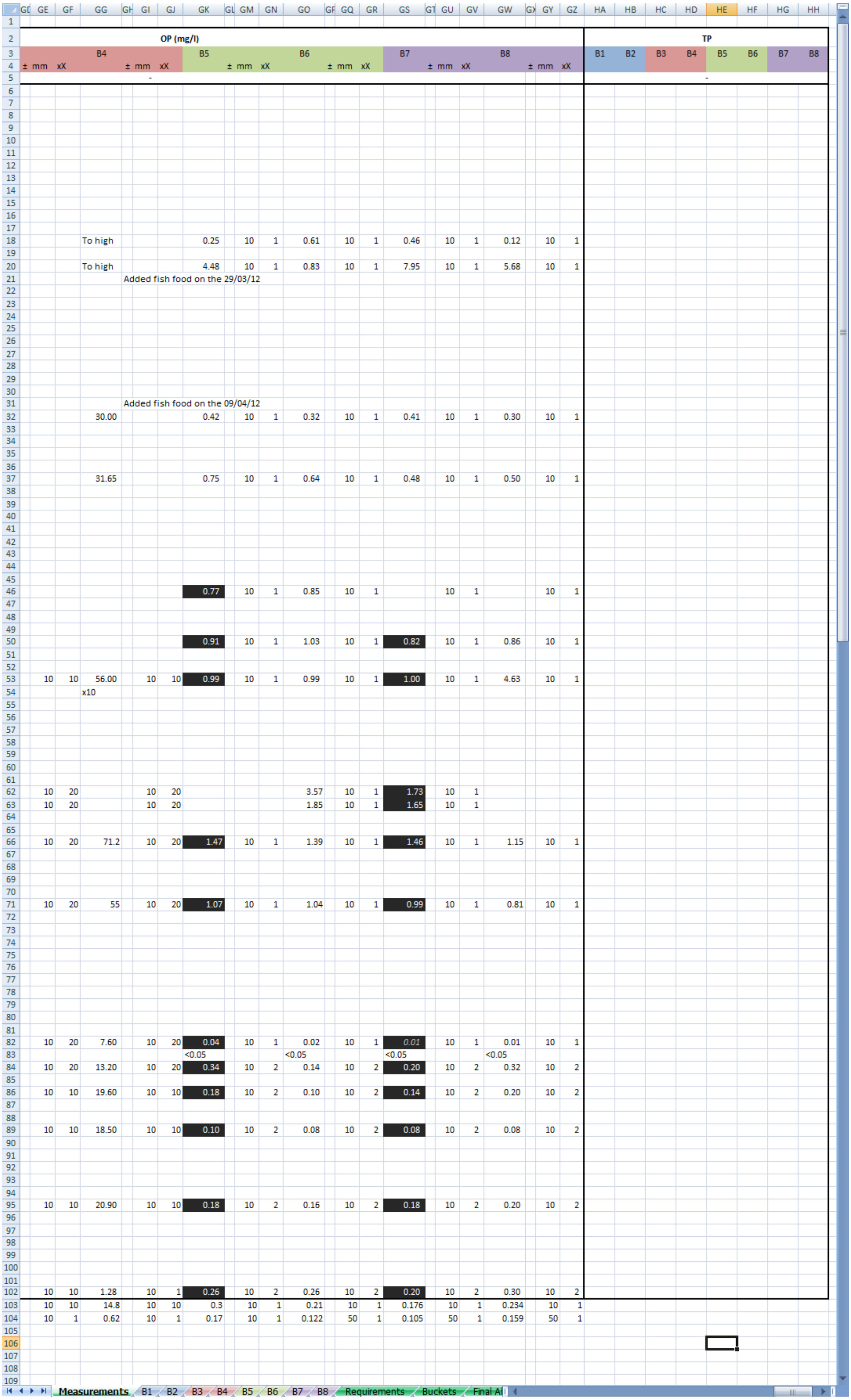
	DT	DU	DV	DW	DX	DY	DZ	EA	EB	EC	ED	EE	EF	EG	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ	ER	ES	ET	EU
1																					0.05 = 0.02-0.1 mg/l (Unreadable)							
2																					NO3-N (mg/l)							
3	B8			Avg			B1				B2				B3				B4				B5				B6	
4	±	mm	xX			±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX		±	mm	xX
5					0.49				0.49				0.49				0.49				0.41				0.41			
6																												
7		50	-	0.88	**0.05**		50	1	**0.05**		50	1	**0.05**		50	1	**0.05**		50	1	**0.50**		50	1	**0.68**		50	1
8																												
9																												
10		50	1	0.79	**0.05**		50	1	**0.05**		50	1	**0.71**		50	1	**0.83**		50	1	**0.05**		50	1	**0.05**		50	1
11																												
12																												
13		50	1	0.74	**0.11**		50	1	**0.05**		50	1	**0.92**		50	1	**0.98**		50	1	**0.05**		50	1	**0.05**		50	1
14																												
15																												
16		50	1	0.76	**0.05**		50	1	**0.05**		50	1	**0.79**		50	1	**0.81**		50	1	**0.05**		50	1	**0.05**		50	1
17																												
18																												
19		50	1	2.55	**0.24**		50	1	**0.16**		50	1	**2.84**		50	1	**2.87**		50	1	**0.05**		50	1	**0.05**		50	1
20																												
21					*0.10*		*50*	*2*					*2.92*		*50*	*4*	*3.04*		*50*	*4*								
22		50	1	2.48			50	1			50	1	**2.30**		10	1	**2.50**		10	1.00			50	1			50	1
23																												
24													22.5															
25		50	1	2.11	**0.35**		50	1	**0.33**		50	1	**3.93**		50	1	**3.81**		50	1	**0.35**		50	1	**0.24**		50	1
26																												
27																												
28		50	1	0.03																								
29																												
30																												
31		50	1	0.03	**0.11**		50	1			50	1	**10.20**		10	1	**10.30**		10	1.00			50	1			50	1
32																												
33																												
34		50	1	0.03			50	1			50	1	**10.20**		10	1	**10.20**		10	1.00			50	1			50	1
35																												
36																												
37		50	1	0.03									**10.40**		10	1	**10.90**		10	1.00								
38																												
39																												
40		50	1	0.04									**9.90**		10	1	**10.60**		10	1.00								
41																												
42																												
43				0.04																								
44																												
45																												
46				0.07																								
47																												
48																												
49																												
50		10	-	0.38									**10.80**		10	1	**13.40**		10	1								
51																												
52																												
53		10	5	1.03									**15.80**		10	1	**26.70**		10	1								
54																												
55																												
56																												
57																												
58																												
59		10	10	4.02																								
60																												
61																												
62		10	10	6.91																								
63		10	5																									
64		10	10	4.37	8.50		10	5	47.50		10	5	**80.00**		10	10	**104.00**		10	10	24.50		10	5	35.50		10	5
65																												
66		10	1	5.99																								
67																												
68				5.50																								
69		10	1	4.75																								
70																												
71		10	5	4.53																								
72		10	1																									
73																												
74																												
75																												
76		10	50	34.00																								
77																												
78																												
79																												
80																												
81																												
82		10	333	120.71	303.13		10	31	328.13		10	31	**215.63**		10	31	**305.00**		10	50	240.63		10	31	306.25		10	31
83																												
84																												
85																												
86																												
87																												
88																												
89		10	333	219.36																								
90																												
91																												
92					300.00		10	63	393.75		10	63	**243.75**		10	63	**350.00**		10	100	281.25		10	63	343.75		10	63
93																												
94																												
95		10	500	235.00																								
96																												
97																												
98																												
99																												
100																												
101																												
102		10	500	251.25	343.75		10	63	387.50		10	63	**256.25**		10	63	**318.75**		10	63	300.00		10	63	343.75		10	63
103					357.50		10	25																				
104																												
105																												
106																												
107																												
108																												
109																												



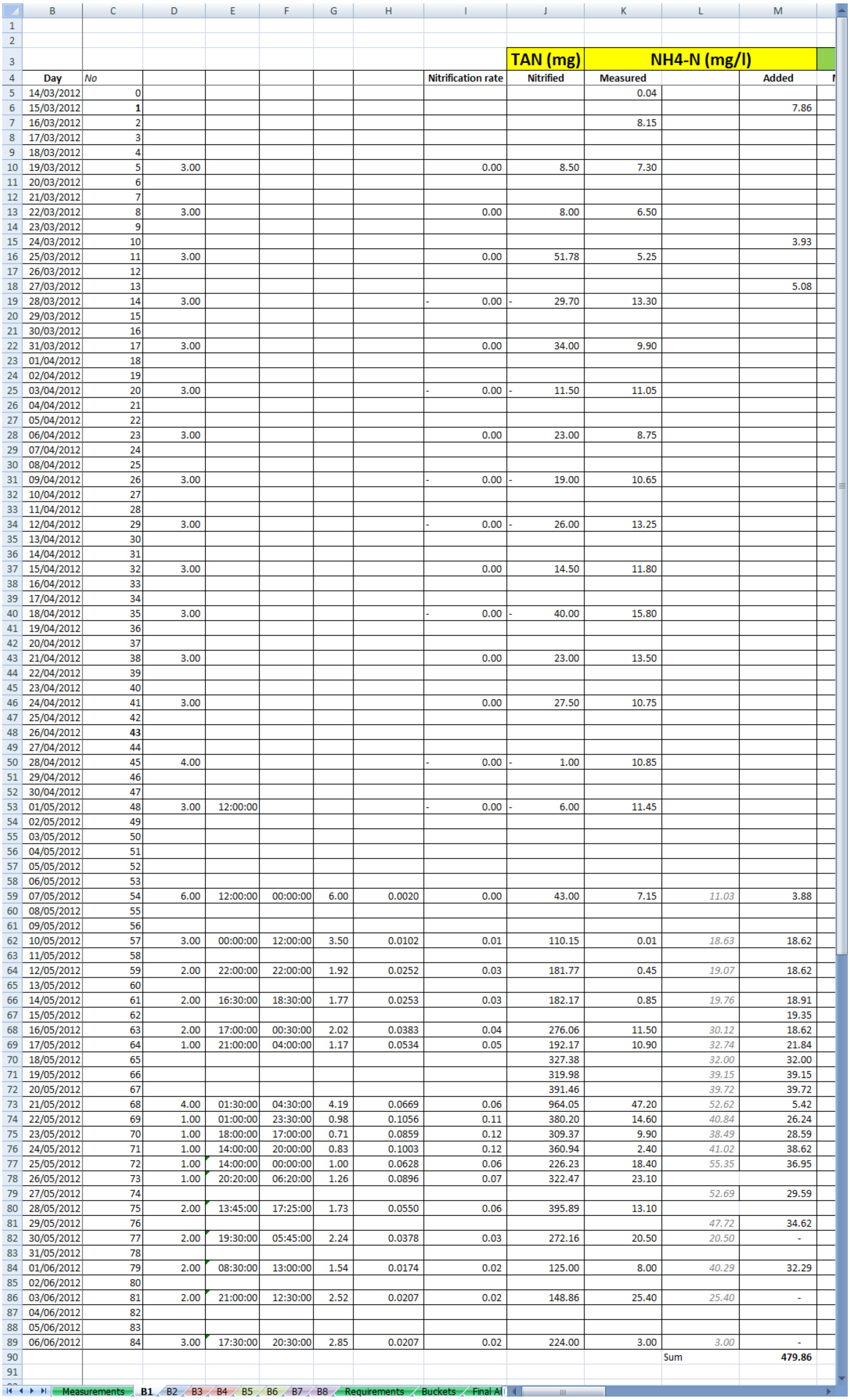
	EU	EV	EW	EX	EY	EZ	FA	FB	FC	FD	FE	FF	FG	FH	FI	FJ	FK	FL	FM
2											COD (mg/l)								
3		B7				B8				Avg	B1	B2	B3	B4	B5	B6	B7	B8	B1
4	xX		±	mm	xX		±	mm	xX										
5		0.49				0.49				0.47	15.6	15.6	15.6	15.6	6.0	6.0	15.6	15.6	0.002
7	1	**0.05**		50	1	**0.05**		50	1	0.19									
10	1	**0.05**		50	1	**0.05**		50	1	0.23									
13	1	**0.05**		50	1	**0.14**		50	1	0.29									
16	1	**0.05**		50	1	**0.05**		50	1	0.24									
19	1	**0.13**		50	1	**0.44**		50	1	0.85									
21						*0.10*		*50*	*2*										
22	1			50	1			50	1										
25	1	**0.36**		50	1	**0.40**		50	1	1.22									
31	1			50	1	**0.14**		50	1	5.19									
34	1			50	1			50	1	10.20									
37										10.65									
40										10.25									
50										12.10									
53										21.25									
64	5	39.0		10	5	45.50		10	5	48.06									
82	31	343.8		10	31	309.38		10	31	293.98									
92	63	387.5		10	63	375.00		10	63	334.38									
102	63	381.3		10	63	362.50		10	63	336.72	356	440	440	612	420	512	444	512	0.04



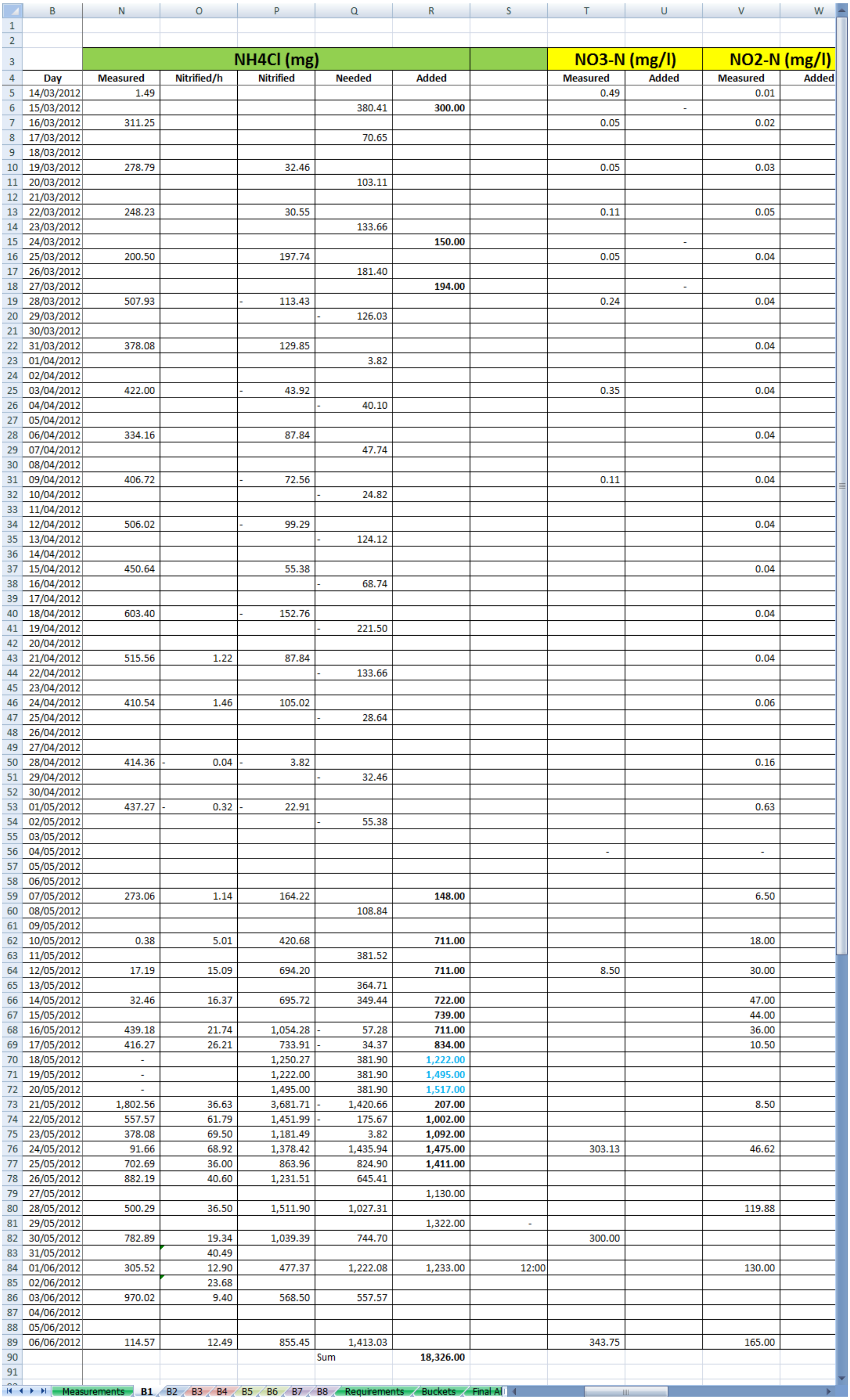
	FM	FN	FO	FP	FQ	FR	FS	FT	FU	FV	FW	FX	FY	FZ	GA	GB	GC	GD	GE	GF	GG	GH	GI	GJ	GK	GL	GM	GN
2	SS (mg/l)								OP (mg/l)																			
3	B1	B2	B3	B4	B5	B6	B7	B8	B1				B2				B3				B4				B5			
4											± mm	xX			± mm	xX			± mm	xX			± mm	xX			± mm	xX
5	0.002	0.002	0.002	0.002	-	-	0.002	0.002															-					
18									0.27		10	1	0.03		10	1	To high				To high				0.25		10	1
20									0.03		10	1	0.06		10	1	To high				To high				4.48		10	1
21																						Added fish food on the 29/03/12						
31																						Added fish food on the 09/04/12						
32									0.38		10	1	0.94		10	1	30.00				30.00				0.42		10	1
37									0.71		10	1	0.57		10	1	31.05				31.65				0.75		10	1
46									0.80		10	1	0.82		10	1									0.77		10	1
50									1.02		10	1	0.91		10	1									0.91		10	1
53									5.31		10	1	1.12		10	1	59.20		10	10	56.00		10	10	0.99		10	1
54																					x10							
62													1.14		10	1	62.9		10	20			10	20				
63													1.2		10	1	58.5		10	20			10	20				
66									1.19		10	1	0.99		10	1	72.6		10	20	71.2		10	20	1.47		10	1
71									0.76		10	1	0.62		10	1	65.2		10	20	55		10	20	1.07		10	1
82									0.01		10	1	0.02		10	1	21.00		10	20	7.60		10	20	0.04		10	1
83									<0.05				<0.05												<0.05			<
84									0.28		10	2	0.24		10	2	12.50		10	20	13.20		10	20	0.34		10	2
86									0.16		10	2	0.14		10	2	21.10		10	10	19.60		10	10	0.18		10	2
89									0.10		10	2	0.10		10	2	14.60		10	10	18.50		10	10	0.10		10	2
95									0.14		10	2	0.28		10	2	19.40		10	10	20.90		10	10	0.18		10	2
102	0.04	0.12	0.61	0.20	0.06	0.02	0.07	0.05	0.30		10	2	0.38		10	2	28.80		10	10	1.28		10	1	0.26		10	2
103									0.24		10	1	0.32		10	1	31.2		10	10	14.8		10	10	0.3		10	1
104								filtrert:	0.16		10	1	0.17		10	1	0.53		10	1	0.62		10	1	0.17		10	1



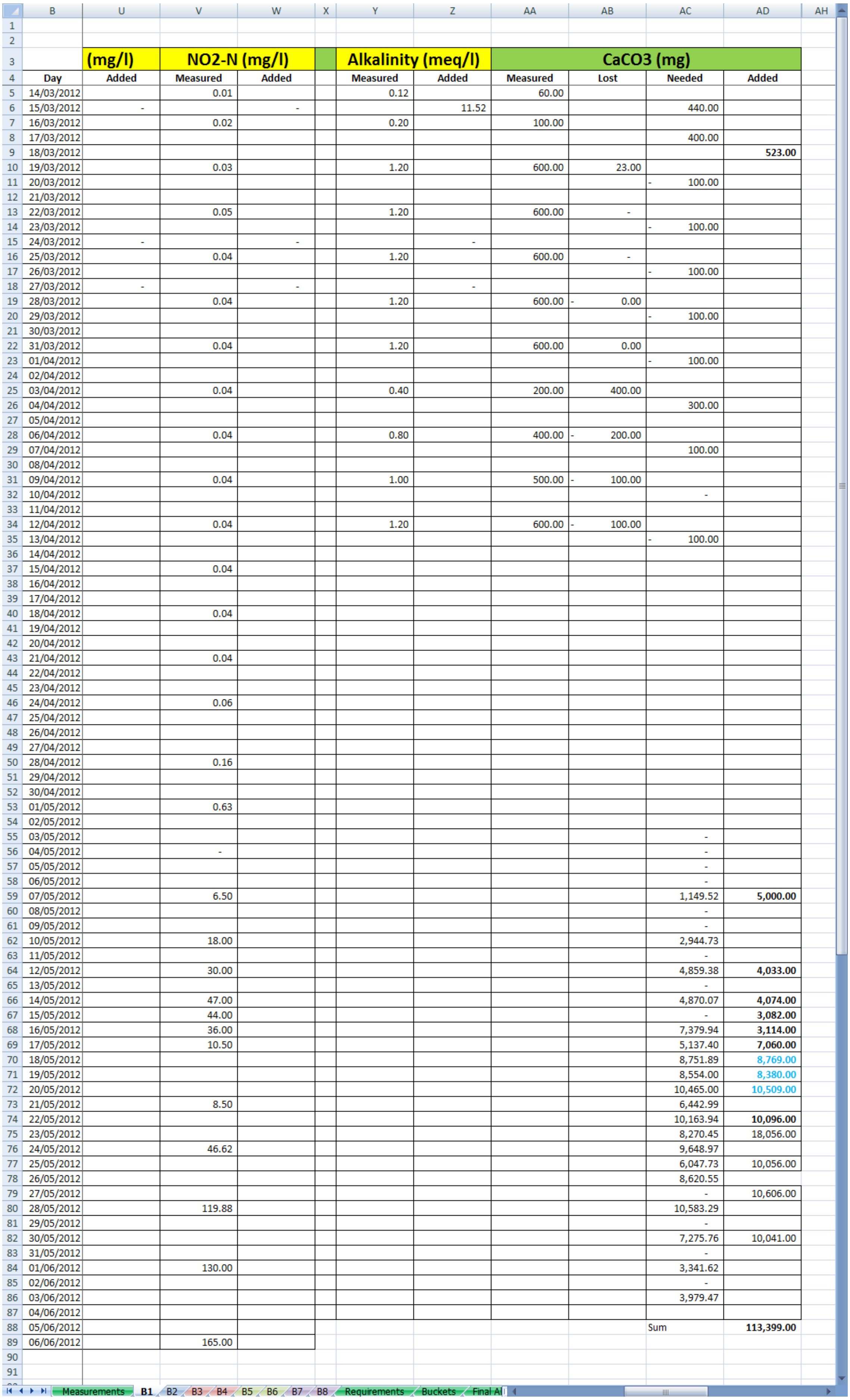
	GE	GF	GG	GI	GJ	GK	GM	GN	GO	GQ	GR	GS	GU	GV	GW	GY	GZ	HA	HB	HC	HD	HE	HF	HG	HH
2					OP (mg/l)																	TP			
3			B4			B5			B6			B7			B8			B1	B2	B3	B4	B5	B6	B7	B8
4	± mm	xX		± mm	xX		± mm	xX		± mm	xX		± mm	xX		± mm	xX								
5				-																		-			
18			To high			0.25	10	1	0.61	10	1	0.46	10	1	0.12	10	1								
20			To high			4.48	10	1	0.83	10	1	7.95	10	1	5.68	10	1								
21				Added fish food on the 29/03/12																					
31				Added fish food on the 09/04/12																					
32			30.00			0.42	10	1	0.32	10	1	0.41	10	1	0.30	10	1								
37			31.65			0.75	10	1	0.64	10	1	0.48	10	1	0.50	10	1								
46						0.77	10	1	0.85	10	1		10	1		10	1								
50						0.91	10	1	1.03	10	1	0.82	10	1	0.86	10	1								
53	10	10	56.00	10	10	0.99	10	1	0.99	10	1	1.00	10	1	4.63	10	1								
54			x10																						
62	10	20		10	20				3.57	10	1	1.73	10	1											
63	10	20		10	20				1.85	10	1	1.65	10	1											
66	10	20	71.2	10	20	1.47	10	1	1.39	10	1	1.46	10	1	1.15	10	1								
71	10	20	55	10	20	1.07	10	1	1.04	10	1	0.99	10	1	0.81	10	1								
82	10	20	7.60	10	20	0.04	10	1	0.02	10	1	*0.01*	10	1	0.01	10	1								
83						<0.05			<0.05			<0.05			<0.05										
84	10	20	13.20	10	20	0.34	10	2	0.14	10	2	0.20	10	2	0.32	10	2								
86	10	10	19.60	10	10	0.18	10	2	0.10	10	2	0.14	10	2	0.20	10	2								
89	10	10	18.50	10	10	0.10	10	2	0.08	10	2	0.08	10	2	0.08	10	2								
95	10	10	20.90	10	10	0.18	10	2	0.16	10	2	0.18	10	2	0.20	10	2								
102	10	10	1.28	10	1	0.26	10	2	0.26	10	2	0.20	10	2	0.30	10	2								
103	10	10	14.8	10	10	0.3	10	1	0.21	10	1	0.176	10	1	0.234	10	1								
104	10	1	0.62	10	1	0.17	10	1	0.122	50	1	0.105	50	1	0.159	50	1								



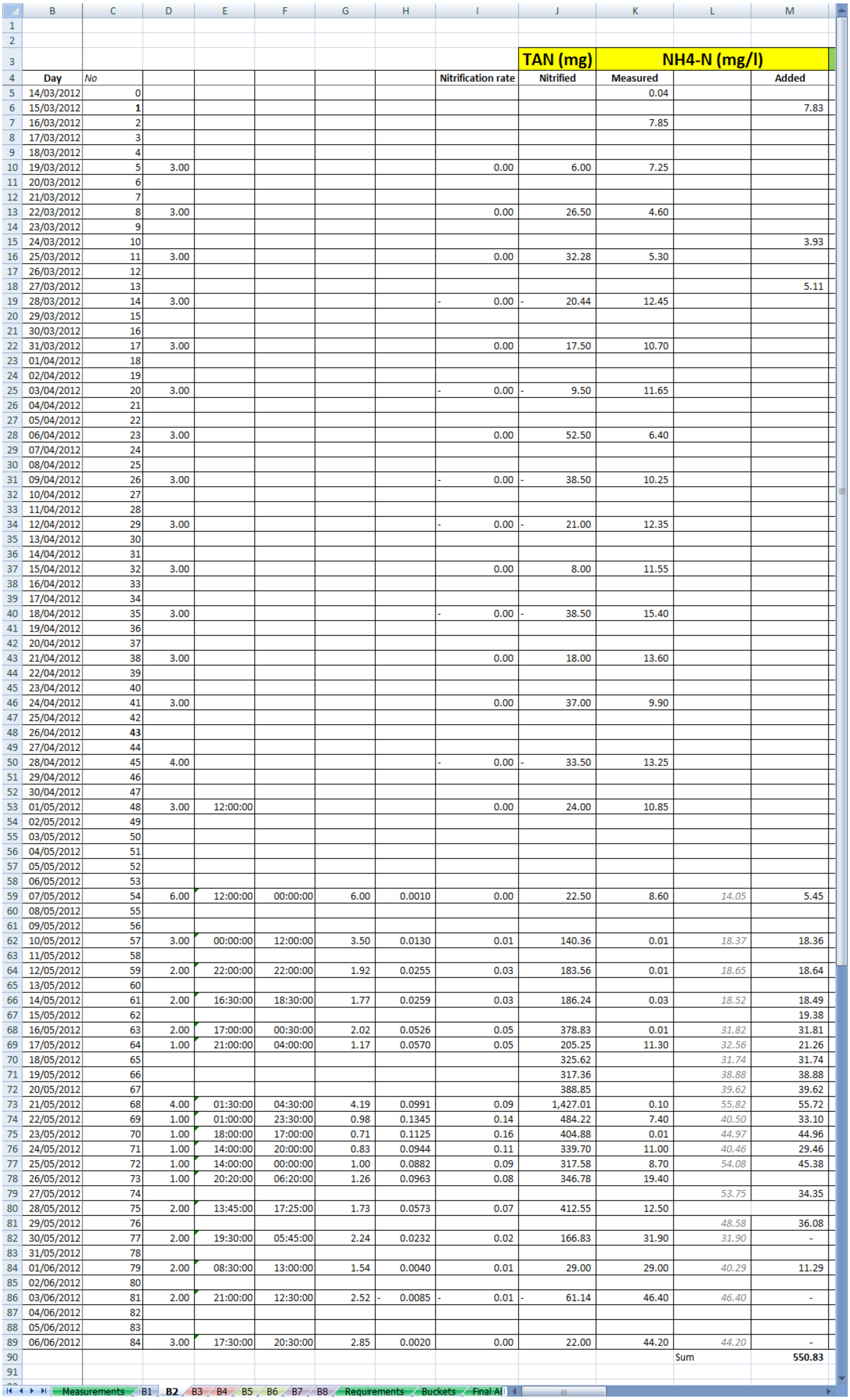
	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									TAN (mg)	NH4-N (mg/l)		
4	Day	*No*						Nitrification rate	Nitrified	Measured		Added
5	14/03/2012	0								0.04		
6	15/03/2012	**1**										7.86
7	16/03/2012	2								8.15		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					0.00	8.50	7.30		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	8.00	6.50		
14	23/03/2012	9										
15	24/03/2012	10										3.93
16	25/03/2012	11	3.00					0.00	51.78	5.25		
17	26/03/2012	12										
18	27/03/2012	13										5.08
19	28/03/2012	14	3.00					- 0.00	- 29.70	13.30		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	34.00	9.90		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 11.50	11.05		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	23.00	8.75		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 19.00	10.65		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 26.00	13.25		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					0.00	14.50	11.80		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					- 0.00	- 40.00	15.80		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00					0.00	23.00	13.50		
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00					0.00	27.50	10.75		
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					- 0.00	- 1.00	10.85		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				- 0.00	- 6.00	11.45		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0020	0.00	43.00	7.15	*11.03*	3.88
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0102	0.01	110.15	0.01	*18.63*	18.62
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0252	0.03	181.77	0.45	*19.07*	18.62
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0253	0.03	182.17	0.85	*19.76*	18.91
67	15/05/2012	62										19.35
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0383	0.04	276.06	11.50	*30.12*	18.62
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0534	0.05	192.17	10.90	*32.74*	21.84
70	18/05/2012	65							327.38		*32.00*	32.00
71	19/05/2012	66							319.98		*39.15*	39.15
72	20/05/2012	67							391.46		*39.72*	39.72
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.0669	0.06	964.05	47.20	*52.62*	5.42
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.1056	0.11	380.20	14.60	*40.84*	26.24
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.0859	0.12	309.37	9.90	*38.49*	28.59
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.1003	0.12	360.94	2.40	*41.02*	38.62
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0628	0.06	226.23	18.40	*55.35*	36.95
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0896	0.07	322.47	23.10		
79	27/05/2012	74									*52.69*	29.59
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0550	0.06	395.89	13.10		
81	29/05/2012	76									*47.72*	34.62
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0378	0.03	272.16	20.50	*20.50*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0174	0.02	125.00	8.00	*40.29*	32.29
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	0.0207	0.02	148.86	25.40	*25.40*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0207	0.02	224.00	3.00	*3.00*	-
90											Sum	**479.86**
91												



	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		NH4Cl (mg)						NO3-N (mg/l)		NO2-N (mg/l)	
4	Day	Measured	Nitrified/h	Nitrified	Needed	Added		Measured	Added	Measured	Added
5	14/03/2012	1.49						0.49		0.01	
6	15/03/2012				380.41	**300.00**			-		
7	16/03/2012	311.25						0.05		0.02	
8	17/03/2012				70.65						
9	18/03/2012										
10	19/03/2012	278.79		32.46				0.05		0.03	
11	20/03/2012				103.11						
12	21/03/2012										
13	22/03/2012	248.23		30.55				0.11		0.05	
14	23/03/2012				133.66						
15	24/03/2012					**150.00**			-		
16	25/03/2012	200.50		197.74				0.05		0.04	
17	26/03/2012				181.40						
18	27/03/2012					**194.00**			-		
19	28/03/2012	507.93		- 113.43				0.24		0.04	
20	29/03/2012				- 126.03						
21	30/03/2012										
22	31/03/2012	378.08		129.85						0.04	
23	01/04/2012				3.82						
24	02/04/2012										
25	03/04/2012	422.00		- 43.92				0.35		0.04	
26	04/04/2012				- 40.10						
27	05/04/2012										
28	06/04/2012	334.16		87.84						0.04	
29	07/04/2012				47.74						
30	08/04/2012										
31	09/04/2012	406.72		- 72.56				0.11		0.04	
32	10/04/2012				- 24.82						
33	11/04/2012										
34	12/04/2012	506.02		- 99.29						0.04	
35	13/04/2012				- 124.12						
36	14/04/2012										
37	15/04/2012	450.64		55.38						0.04	
38	16/04/2012				- 68.74						
39	17/04/2012										
40	18/04/2012	603.40		- 152.76						0.04	
41	19/04/2012				- 221.50						
42	20/04/2012										
43	21/04/2012	515.56	1.22	87.84						0.04	
44	22/04/2012				- 133.66						
45	23/04/2012										
46	24/04/2012	410.54	1.46	105.02						0.06	
47	25/04/2012				- 28.64						
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	414.36	- 0.04	- 3.82						0.16	
51	29/04/2012				- 32.46						
52	30/04/2012										
53	01/05/2012	437.27	- 0.32	- 22.91						0.63	
54	02/05/2012				- 55.38						
55	03/05/2012										
56	04/05/2012							-		-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	273.06	1.14	164.22		**148.00**				6.50	
60	08/05/2012				108.84						
61	09/05/2012										
62	10/05/2012	0.38	5.01	420.68		**711.00**				18.00	
63	11/05/2012				381.52						
64	12/05/2012	17.19	15.09	694.20		**711.00**		8.50		30.00	
65	13/05/2012				364.71						
66	14/05/2012	32.46	16.37	695.72	349.44	**722.00**				47.00	
67	15/05/2012					**739.00**				44.00	
68	16/05/2012	439.18	21.74	1,054.28	- 57.28	**711.00**				36.00	
69	17/05/2012	416.27	26.21	733.91	- 34.37	**834.00**				10.50	
70	18/05/2012	-		1,250.27	381.90	**1,222.00**					
71	19/05/2012	-		1,222.00	381.90	**1,495.00**					
72	20/05/2012	-		1,495.00	381.90	**1,517.00**					
73	21/05/2012	1,802.56	36.63	3,681.71	- 1,420.66	**207.00**				8.50	
74	22/05/2012	557.57	61.79	1,451.99	- 175.67	**1,002.00**					
75	23/05/2012	378.08	69.50	1,181.49	3.82	**1,092.00**					
76	24/05/2012	91.66	68.92	1,378.42	1,435.94	**1,475.00**		303.13		46.62	
77	25/05/2012	702.69	36.00	863.96	824.90	**1,411.00**					
78	26/05/2012	882.19	40.60	1,231.51	645.41						
79	27/05/2012					1,130.00					
80	28/05/2012	500.29	36.50	1,511.90	1,027.31					119.88	
81	29/05/2012					1,322.00	-				
82	30/05/2012	782.89	19.34	1,039.39	744.70			300.00			
83	31/05/2012		40.49								
84	01/06/2012	305.52	12.90	477.37	1,222.08	1,233.00	12:00			130.00	
85	02/06/2012		23.68								
86	03/06/2012	970.02	9.40	568.50	557.57						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	114.57	12.49	855.45	1,413.03			343.75		165.00	
90					Sum	**18,326.00**					
91											

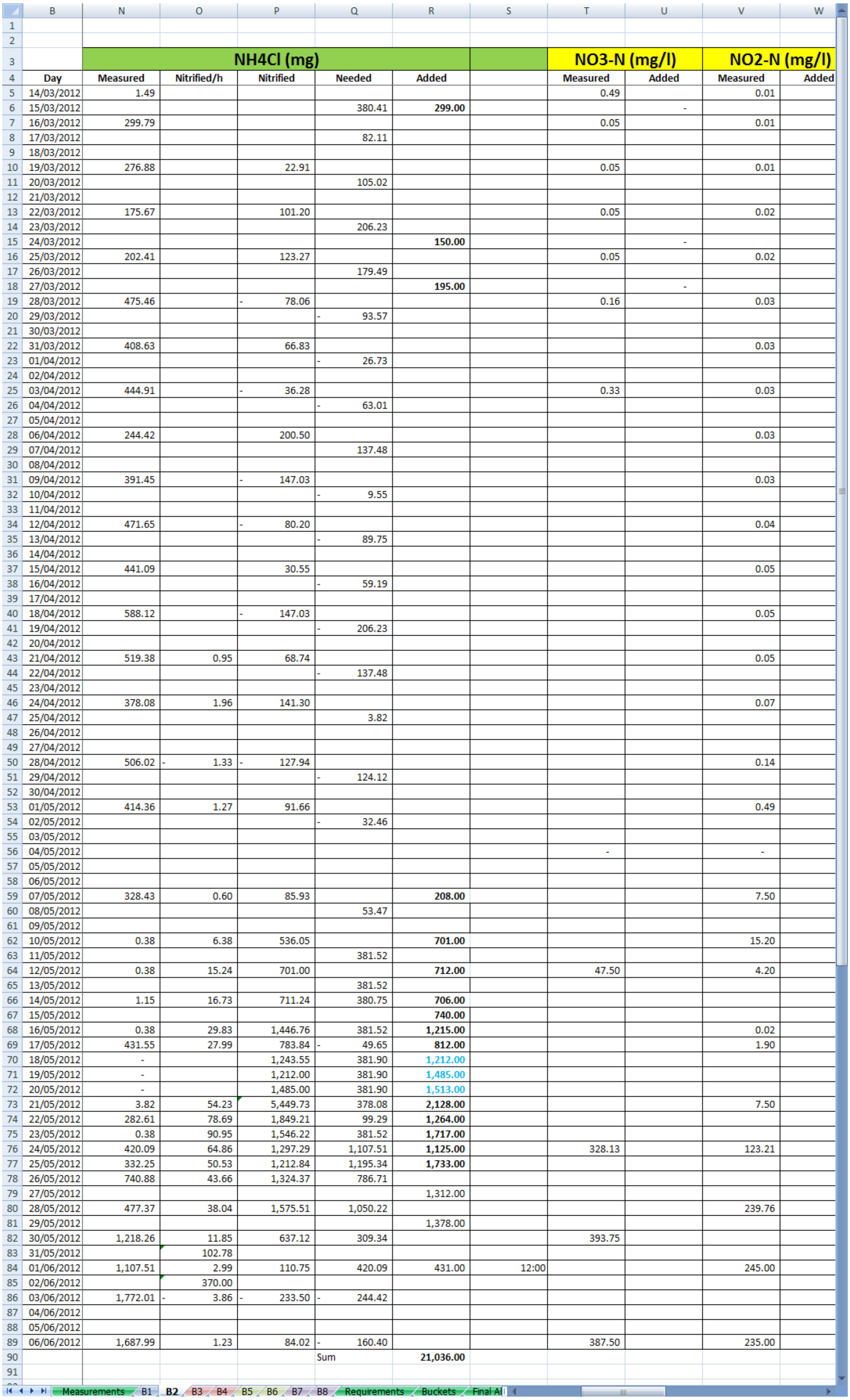


	B	U	V	W	X	Y	Z	AA	AB	AC	AD	AH
1												
2												
3		(mg/l)	NO2-N (mg/l)			Alkalinity (meq/l)		CaCO3 (mg)				
4	Day	Added	Measured	Added		Measured	Added	Measured	Lost	Needed	Added	
5	14/03/2012		0.01			0.12		60.00				
6	15/03/2012	-		-			11.52			440.00		
7	16/03/2012		0.02			0.20		100.00				
8	17/03/2012									400.00		
9	18/03/2012										**523.00**	
10	19/03/2012		0.03			1.20		600.00	23.00			
11	20/03/2012									- 100.00		
12	21/03/2012											
13	22/03/2012		0.05			1.20		600.00	-			
14	23/03/2012									- 100.00		
15	24/03/2012	-		-			-					
16	25/03/2012		0.04			1.20		600.00	-			
17	26/03/2012									- 100.00		
18	27/03/2012	-		-			-					
19	28/03/2012		0.04			1.20		600.00	- 0.00			
20	29/03/2012									- 100.00		
21	30/03/2012											
22	31/03/2012		0.04			1.20		600.00	0.00			
23	01/04/2012									- 100.00		
24	02/04/2012											
25	03/04/2012		0.04			0.40		200.00	400.00			
26	04/04/2012									300.00		
27	05/04/2012											
28	06/04/2012		0.04			0.80		400.00	- 200.00			
29	07/04/2012									100.00		
30	08/04/2012											
31	09/04/2012		0.04			1.00		500.00	- 100.00			
32	10/04/2012									-		
33	11/04/2012											
34	12/04/2012		0.04			1.20		600.00	- 100.00			
35	13/04/2012									- 100.00		
36	14/04/2012											
37	15/04/2012		0.04									
38	16/04/2012											
39	17/04/2012											
40	18/04/2012		0.04									
41	19/04/2012											
42	20/04/2012											
43	21/04/2012		0.04									
44	22/04/2012											
45	23/04/2012											
46	24/04/2012		0.06									
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		0.16									
51	29/04/2012											
52	30/04/2012											
53	01/05/2012		0.63									
54	02/05/2012											
55	03/05/2012									-		
56	04/05/2012		-							-		
57	05/05/2012									-		
58	06/05/2012									-		
59	07/05/2012		6.50							1,149.52	**5,000.00**	
60	08/05/2012									-		
61	09/05/2012									-		
62	10/05/2012		18.00							2,944.73		
63	11/05/2012									-		
64	12/05/2012		30.00							4,859.38	**4,033.00**	
65	13/05/2012									-		
66	14/05/2012		47.00							4,870.07	**4,074.00**	
67	15/05/2012		44.00							-	**3,082.00**	
68	16/05/2012		36.00							7,379.94	**3,114.00**	
69	17/05/2012		10.50							5,137.40	**7,060.00**	
70	18/05/2012									8,751.89	8,769.00	
71	19/05/2012									8,554.00	8,380.00	
72	20/05/2012									10,465.00	10,509.00	
73	21/05/2012		8.50							6,442.99		
74	22/05/2012									10,163.94	**10,096.00**	
75	23/05/2012									8,270.45	18,056.00	
76	24/05/2012		46.62							9,648.97		
77	25/05/2012									6,047.73	10,056.00	
78	26/05/2012									8,620.55		
79	27/05/2012									-	10,606.00	
80	28/05/2012		119.88							10,583.29		
81	29/05/2012									-		
82	30/05/2012									7,275.76	10,041.00	
83	31/05/2012									-		
84	01/06/2012		130.00							3,341.62		
85	02/06/2012									-		
86	03/06/2012									3,979.47		
87	04/06/2012											
88	05/06/2012									Sum	**113,399.00**	
89	06/06/2012		165.00									
90												
91												

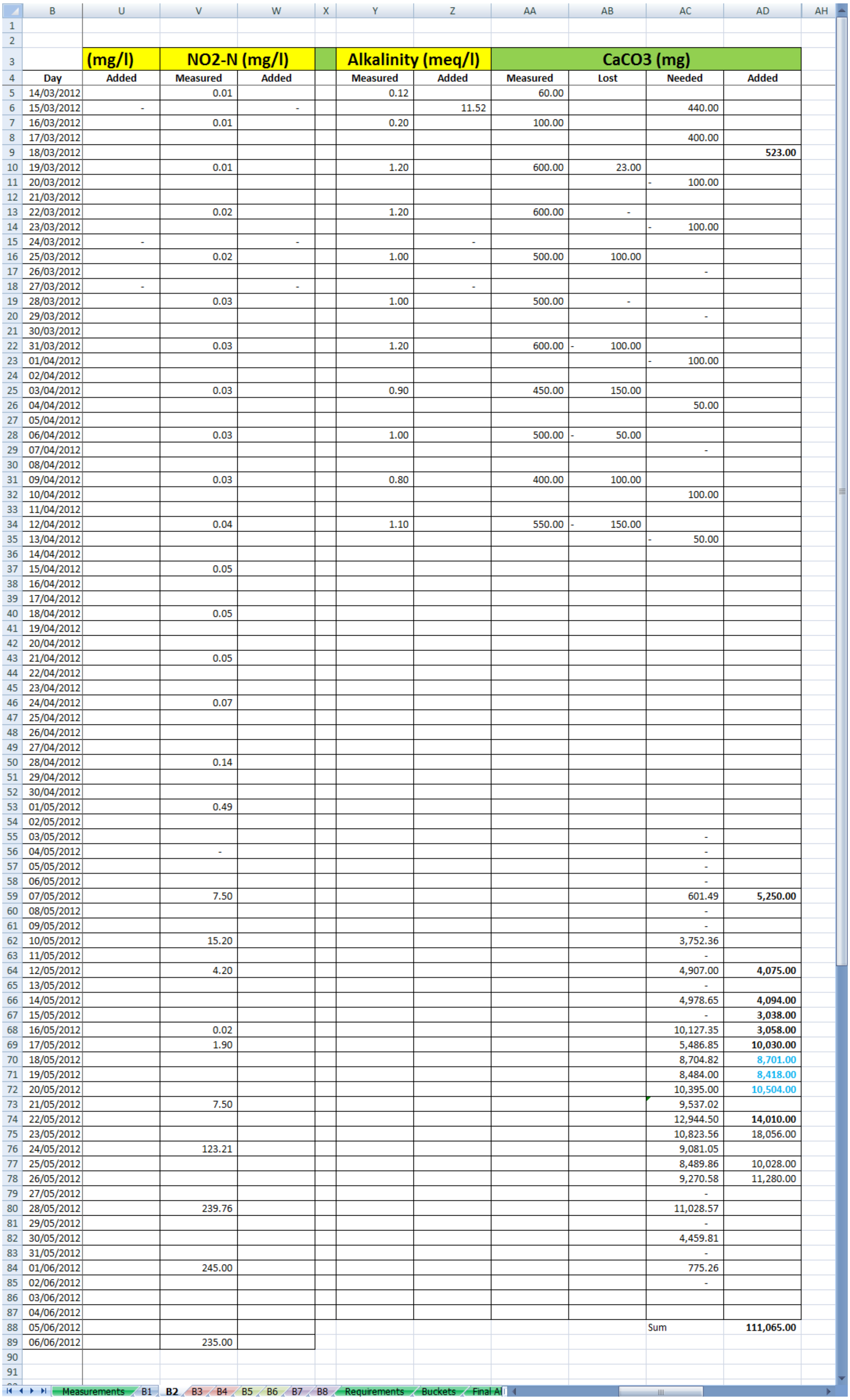


	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									TAN (mg)	NH4-N (mg/l)		
4	Day	*No*						Nitrification rate	Nitrified	Measured		Added
5	14/03/2012	0								0.04		
6	15/03/2012	**1**										7.83
7	16/03/2012	2								7.85		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					0.00	6.00	7.25		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	26.50	4.60		
14	23/03/2012	9										
15	24/03/2012	10										3.93
16	25/03/2012	11	3.00					0.00	32.28	5.30		
17	26/03/2012	12										
18	27/03/2012	13										5.11
19	28/03/2012	14	3.00					- 0.00	- 20.44	12.45		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	17.50	10.70		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 9.50	11.65		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	52.50	6.40		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 38.50	10.25		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 21.00	12.35		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					0.00	8.00	11.55		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					- 0.00	- 38.50	15.40		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00					0.00	18.00	13.60		
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00					0.00	37.00	9.90		
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					- 0.00	- 33.50	13.25		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.00	24.00	10.85		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0010	0.00	22.50	8.60	*14.05*	5.45
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0130	0.01	140.36	0.01	*18.37*	18.36
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0255	0.03	183.56	0.01	*18.65*	18.64
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0259	0.03	186.24	0.03	*18.52*	18.49
67	15/05/2012	62										19.38
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0526	0.05	378.83	0.01	*31.82*	31.81
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0570	0.05	205.25	11.30	*32.56*	21.26
70	18/05/2012	65							325.62		*31.74*	31.74
71	19/05/2012	66							317.36		*38.88*	38.88
72	20/05/2012	67							388.85		*39.62*	39.62
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.0991	0.09	1,427.01	0.10	*55.82*	55.72
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.1345	0.14	484.22	7.40	*40.50*	33.10
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.1125	0.16	404.88	0.01	*44.97*	44.96
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0944	0.11	339.70	11.00	*40.46*	29.46
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0882	0.09	317.58	8.70	*54.08*	45.38
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0963	0.08	346.78	19.40		
79	27/05/2012	74									*53.75*	34.35
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0573	0.07	412.55	12.50		
81	29/05/2012	76									*48.58*	36.08
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0232	0.02	166.83	31.90	*31.90*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0040	0.01	29.00	29.00	*40.29*	11.29
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	- 0.0085	- 0.01	- 61.14	46.40	*46.40*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0020	0.00	22.00	44.20	*44.20*	-
90											Sum	**550.83**
91												

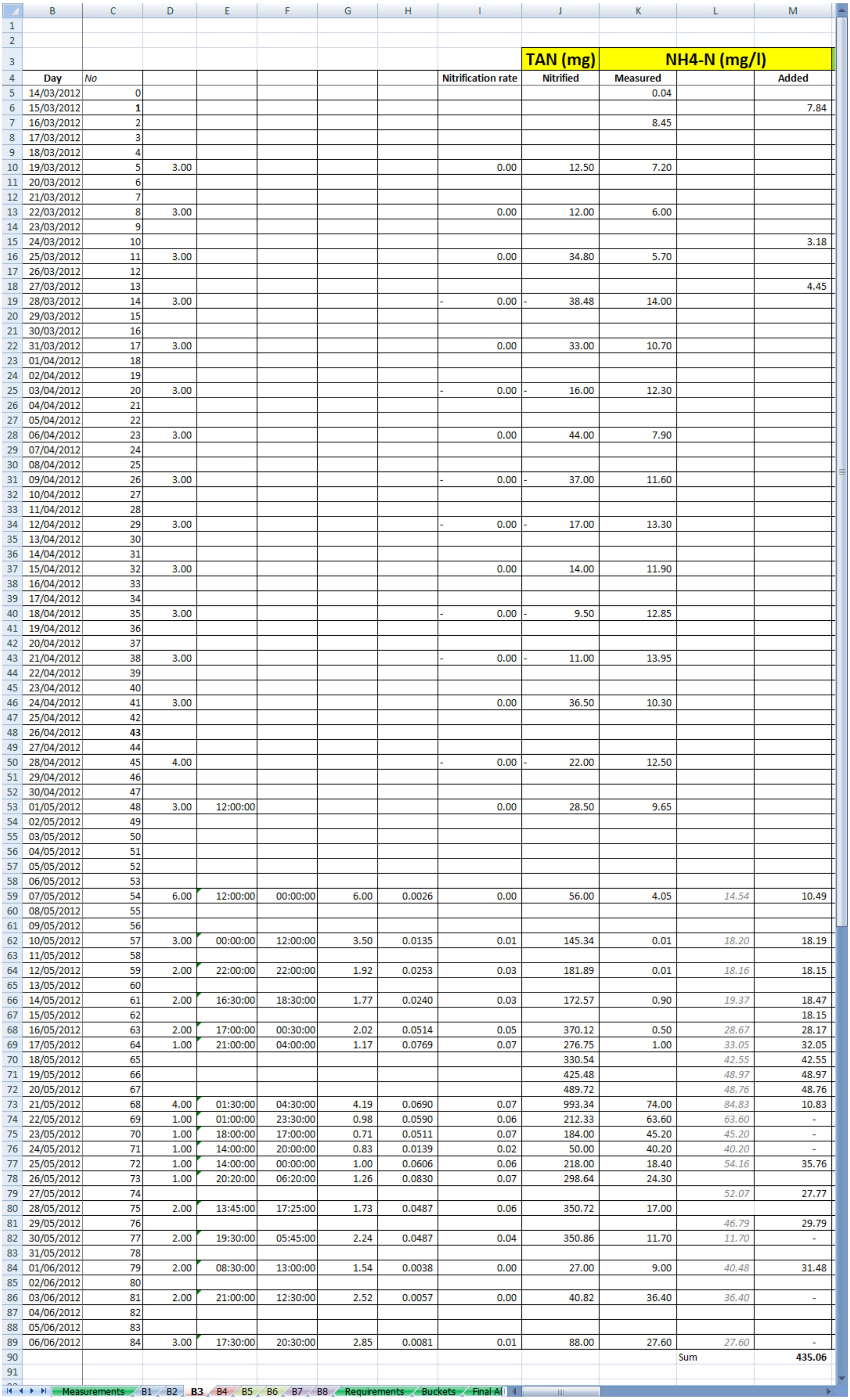
Measurements / B1 / **B2** / B3 / B4 / B5 / B6 / B7 / B8 / Requirements / Buckets / Final Al



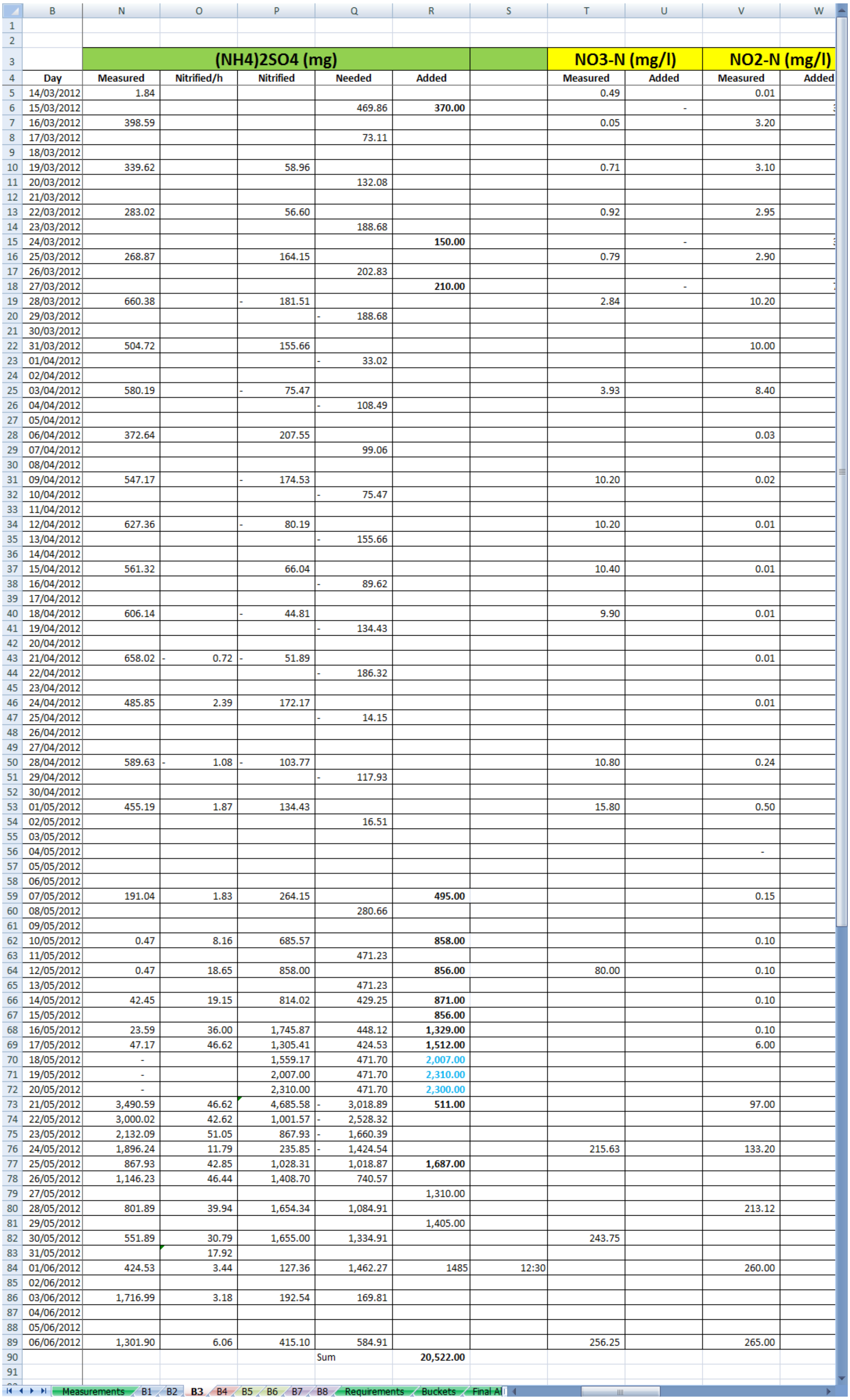
	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		**NH4Cl (mg)**						**NO3-N (mg/l)**		**NO2-N (mg/l)**	
4	**Day**	**Measured**	**Nitrified/h**	**Nitrified**	**Needed**	**Added**		**Measured**	**Added**	**Measured**	**Added**
5	14/03/2012	1.49						0.49		0.01	
6	15/03/2012				380.41	**299.00**			-		
7	16/03/2012	299.79						0.05		0.01	
8	17/03/2012				82.11						
9	18/03/2012										
10	19/03/2012	276.88		22.91				0.05		0.01	
11	20/03/2012				105.02						
12	21/03/2012										
13	22/03/2012	175.67		101.20				0.05		0.02	
14	23/03/2012				206.23						
15	24/03/2012					**150.00**			-		
16	25/03/2012	202.41		123.27				0.05		0.02	
17	26/03/2012				179.49						
18	27/03/2012					**195.00**			-		
19	28/03/2012	475.46		- 78.06				0.16		0.03	
20	29/03/2012				- 93.57						
21	30/03/2012										
22	31/03/2012	408.63		66.83						0.03	
23	01/04/2012				- 26.73						
24	02/04/2012										
25	03/04/2012	444.91		- 36.28				0.33		0.03	
26	04/04/2012				- 63.01						
27	05/04/2012										
28	06/04/2012	244.42		200.50						0.03	
29	07/04/2012				137.48						
30	08/04/2012										
31	09/04/2012	391.45		- 147.03						0.03	
32	10/04/2012				- 9.55						
33	11/04/2012										
34	12/04/2012	471.65		- 80.20						0.04	
35	13/04/2012				- 89.75						
36	14/04/2012										
37	15/04/2012	441.09		30.55						0.05	
38	16/04/2012				- 59.19						
39	17/04/2012										
40	18/04/2012	588.12		- 147.03						0.05	
41	19/04/2012				- 206.23						
42	20/04/2012										
43	21/04/2012	519.38	0.95	68.74						0.05	
44	22/04/2012				- 137.48						
45	23/04/2012										
46	24/04/2012	378.08	1.96	141.30						0.07	
47	25/04/2012				3.82						
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	506.02	- 1.33	- 127.94						0.14	
51	29/04/2012				- 124.12						
52	30/04/2012										
53	01/05/2012	414.36	1.27	91.66						0.49	
54	02/05/2012				- 32.46						
55	03/05/2012										
56	04/05/2012							-		-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	328.43	0.60	85.93		**208.00**				7.50	
60	08/05/2012				53.47						
61	09/05/2012										
62	10/05/2012	0.38	6.38	536.05		**701.00**				15.20	
63	11/05/2012				381.52						
64	12/05/2012	0.38	15.24	701.00		**712.00**		47.50		4.20	
65	13/05/2012				381.52						
66	14/05/2012	1.15	16.73	711.24	380.75	**706.00**					
67	15/05/2012					**740.00**					
68	16/05/2012	0.38	29.83	1,446.76	381.52	**1,215.00**				0.02	
69	17/05/2012	431.55	27.99	783.84	- 49.65	**812.00**				1.90	
70	18/05/2012	-		1,243.55	381.90	**1,212.00**					
71	19/05/2012	-		1,212.00	381.90	**1,485.00**					
72	20/05/2012	-		1,485.00	381.90	**1,513.00**					
73	21/05/2012	3.82	54.23	5,449.73	378.08	**2,128.00**				7.50	
74	22/05/2012	282.61	78.69	1,849.21	99.29	**1,264.00**					
75	23/05/2012	0.38	90.95	1,546.22	381.52	**1,717.00**					
76	24/05/2012	420.09	64.86	1,297.29	1,107.51	**1,125.00**		328.13		123.21	
77	25/05/2012	332.25	50.53	1,212.84	1,195.34	**1,733.00**					
78	26/05/2012	740.88	43.66	1,324.37	786.71						
79	27/05/2012					1,312.00					
80	28/05/2012	477.37	38.04	1,575.51	1,050.22					239.76	
81	29/05/2012					1,378.00					
82	30/05/2012	1,218.26	11.85	637.12	309.34			393.75			
83	31/05/2012		102.78								
84	01/06/2012	1,107.51	2.99	110.75	420.09	431.00	12:00			245.00	
85	02/06/2012		370.00								
86	03/06/2012	1,772.01	- 3.86	- 233.50	- 244.42						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	1,687.99	1.23	84.02	- 160.40			387.50		235.00	
90					Sum	**21,036.00**					
91											



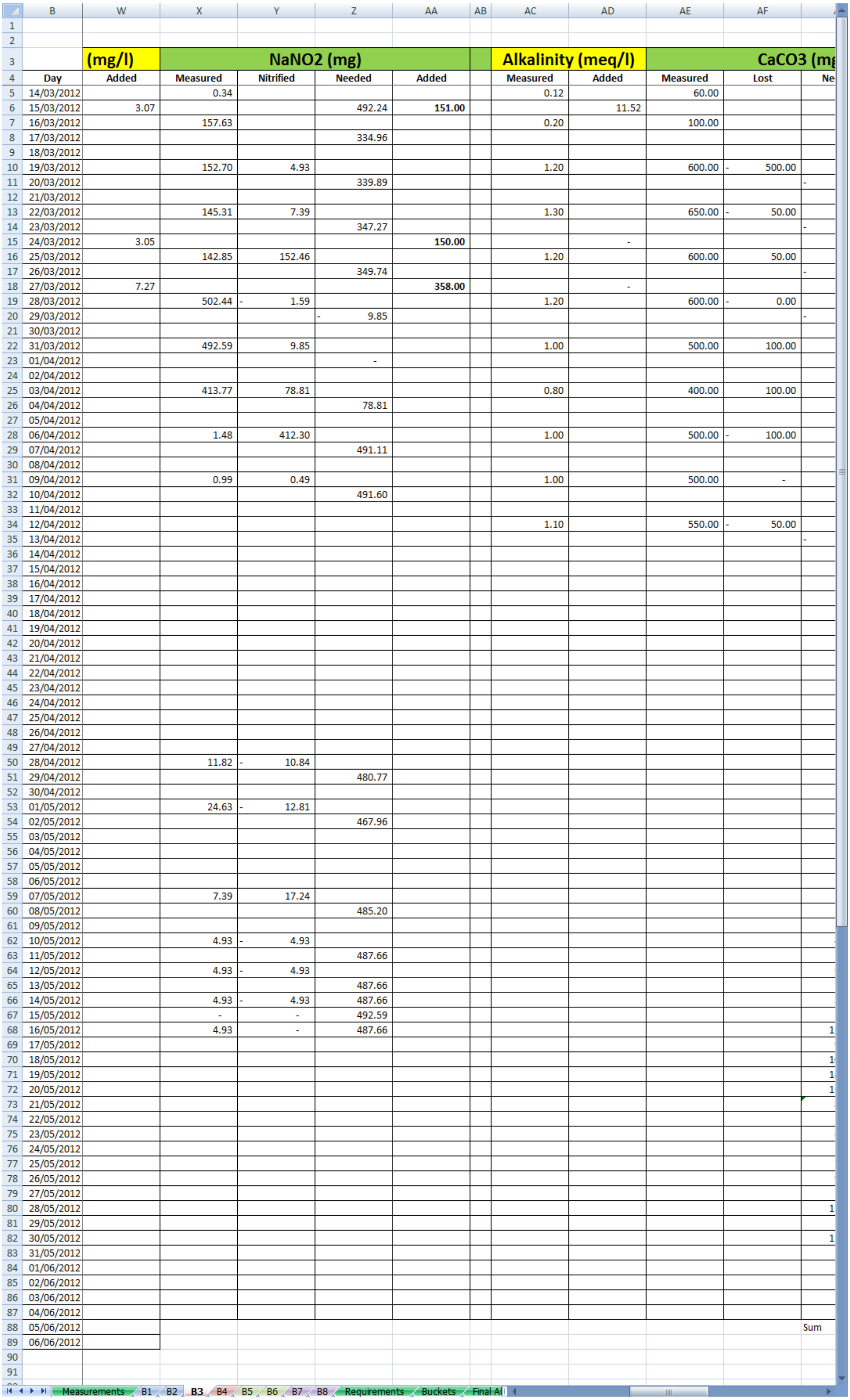
	B	U	V	W	X	Y	Z	AA	AB	AC	AD	AH
1												
2												
3		**(mg/l)**	**NO2-N (mg/l)**			**Alkalinity (meq/l)**		**CaCO3 (mg)**				
4	**Day**	**Added**	**Measured**	**Added**		**Measured**	**Added**	**Measured**	**Lost**	**Needed**	**Added**	
5	14/03/2012		0.01			0.12		60.00				
6	15/03/2012	-		-			11.52			440.00		
7	16/03/2012		0.01			0.20		100.00				
8	17/03/2012									400.00		
9	18/03/2012										**523.00**	
10	19/03/2012		0.01			1.20		600.00	23.00			
11	20/03/2012									- 100.00		
12	21/03/2012											
13	22/03/2012		0.02			1.20		600.00	-			
14	23/03/2012									- 100.00		
15	24/03/2012	-		-			-					
16	25/03/2012		0.02			1.00		500.00	100.00			
17	26/03/2012									-		
18	27/03/2012	-		-			-					
19	28/03/2012		0.03			1.00		500.00	-			
20	29/03/2012									-		
21	30/03/2012											
22	31/03/2012		0.03			1.20		600.00	- 100.00			
23	01/04/2012									- 100.00		
24	02/04/2012											
25	03/04/2012		0.03			0.90		450.00	150.00			
26	04/04/2012									50.00		
27	05/04/2012											
28	06/04/2012		0.03			1.00		500.00	- 50.00			
29	07/04/2012									-		
30	08/04/2012											
31	09/04/2012		0.03			0.80		400.00	100.00			
32	10/04/2012									100.00		
33	11/04/2012											
34	12/04/2012		0.04			1.10		550.00	- 150.00			
35	13/04/2012									- 50.00		
36	14/04/2012											
37	15/04/2012		0.05									
38	16/04/2012											
39	17/04/2012											
40	18/04/2012		0.05									
41	19/04/2012											
42	20/04/2012											
43	21/04/2012		0.05									
44	22/04/2012											
45	23/04/2012											
46	24/04/2012		0.07									
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		0.14									
51	29/04/2012											
52	30/04/2012											
53	01/05/2012		0.49									
54	02/05/2012											
55	03/05/2012									-		
56	04/05/2012		-							-		
57	05/05/2012									-		
58	06/05/2012									-		
59	07/05/2012		7.50							601.49	**5,250.00**	
60	08/05/2012									-		
61	09/05/2012									-		
62	10/05/2012		15.20							3,752.36		
63	11/05/2012									-		
64	12/05/2012		4.20							4,907.00	**4,075.00**	
65	13/05/2012									-		
66	14/05/2012									4,978.65	**4,094.00**	
67	15/05/2012									-	**3,038.00**	
68	16/05/2012		0.02							10,127.35	**3,058.00**	
69	17/05/2012		1.90							5,486.85	**10,030.00**	
70	18/05/2012									8,704.82	**8,701.00**	
71	19/05/2012									8,484.00	**8,418.00**	
72	20/05/2012									10,395.00	**10,504.00**	
73	21/05/2012		7.50							9,537.02		
74	22/05/2012									12,944.50	**14,010.00**	
75	23/05/2012									10,823.56	18,056.00	
76	24/05/2012		123.21							9,081.05		
77	25/05/2012									8,489.86	10,028.00	
78	26/05/2012									9,270.58	11,280.00	
79	27/05/2012									-		
80	28/05/2012		239.76							11,028.57		
81	29/05/2012									-		
82	30/05/2012									4,459.81		
83	31/05/2012									-		
84	01/06/2012		245.00							775.26		
85	02/06/2012									-		
86	03/06/2012											
87	04/06/2012											
88	05/06/2012									Sum	**111,065.00**	
89	06/06/2012		235.00									
90												
91												



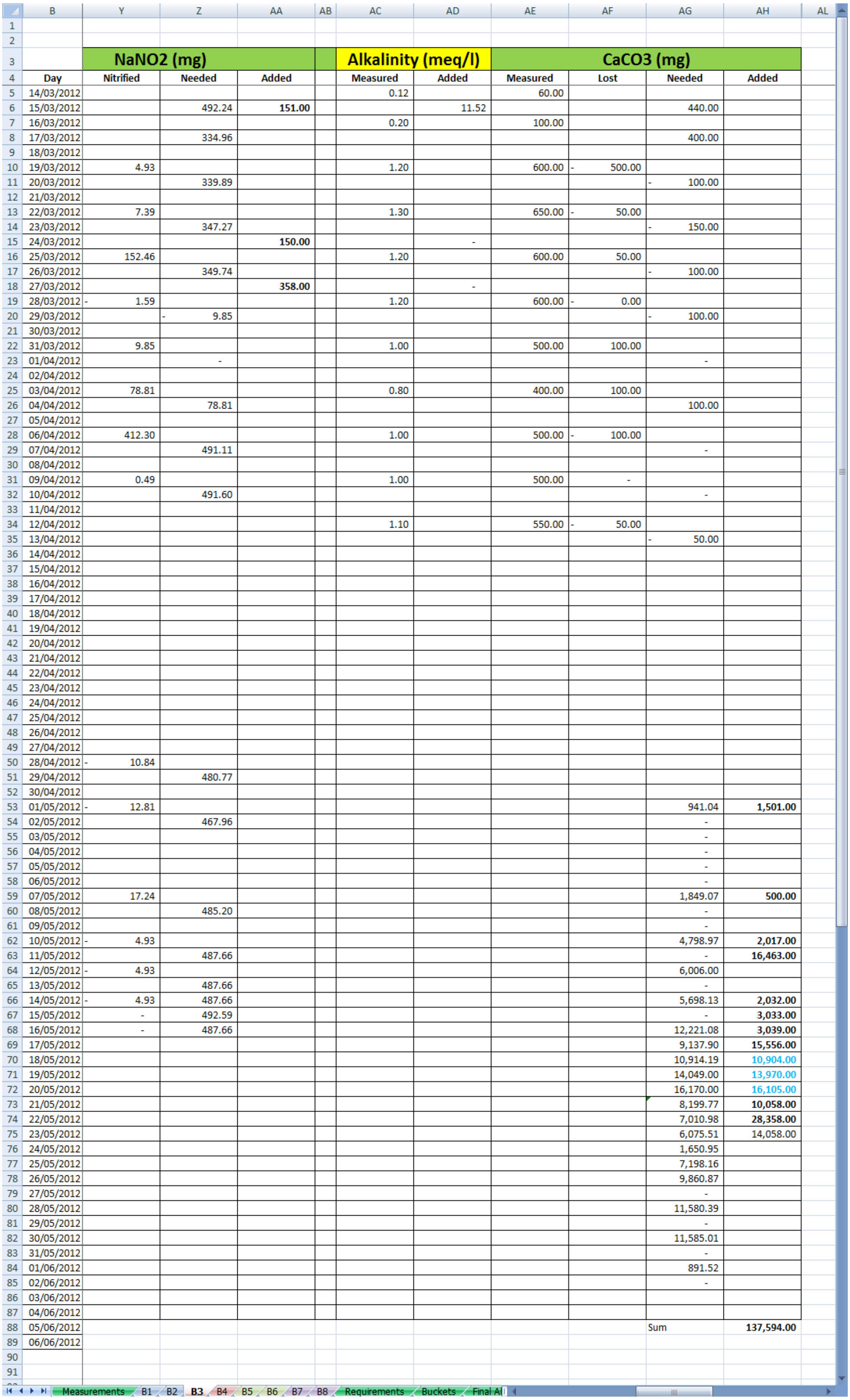
	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									**TAN (mg)**	**NH4-N (mg/l)**		
4	**Day**	*No*						**Nitrification rate**	**Nitrified**	**Measured**		**Added**
5	14/03/2012	0								0.04		
6	15/03/2012	**1**										7.84
7	16/03/2012	2								8.45		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					0.00	12.50	7.20		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	12.00	6.00		
14	23/03/2012	9										
15	24/03/2012	10										3.18
16	25/03/2012	11	3.00					0.00	34.80	5.70		
17	26/03/2012	12										
18	27/03/2012	13										4.45
19	28/03/2012	14	3.00					- 0.00	- 38.48	14.00		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	33.00	10.70		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 16.00	12.30		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	44.00	7.90		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 37.00	11.60		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 17.00	13.30		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					0.00	14.00	11.90		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					- 0.00	- 9.50	12.85		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00					- 0.00	- 11.00	13.95		
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00					0.00	36.50	10.30		
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					- 0.00	- 22.00	12.50		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.00	28.50	9.65		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0026	0.00	56.00	4.05	*14.54*	10.49
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0135	0.01	145.34	0.01	*18.20*	18.19
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0253	0.03	181.89	0.01	*18.16*	18.15
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0240	0.03	172.57	0.90	*19.37*	18.47
67	15/05/2012	62										18.15
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0514	0.05	370.12	0.50	*28.67*	28.17
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0769	0.07	276.75	1.00	*33.05*	32.05
70	18/05/2012	65							330.54		*42.55*	42.55
71	19/05/2012	66							425.48		*48.97*	48.97
72	20/05/2012	67							489.72		*48.76*	48.76
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.0690	0.07	993.34	74.00	*84.83*	10.83
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.0590	0.06	212.33	63.60	*63.60*	-
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.0511	0.07	184.00	45.20	*45.20*	-
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0139	0.02	50.00	40.20	*40.20*	-
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0606	0.06	218.00	18.40	*54.16*	35.76
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0830	0.07	298.64	24.30		
79	27/05/2012	74									*52.07*	27.77
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0487	0.06	350.72	17.00		
81	29/05/2012	76									*46.79*	29.79
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0487	0.04	350.86	11.70	*11.70*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0038	0.00	27.00	9.00	*40.48*	31.48
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	0.0057	0.00	40.82	36.40	*36.40*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0081	0.01	88.00	27.60	*27.60*	-
90											Sum	**435.06**
91												



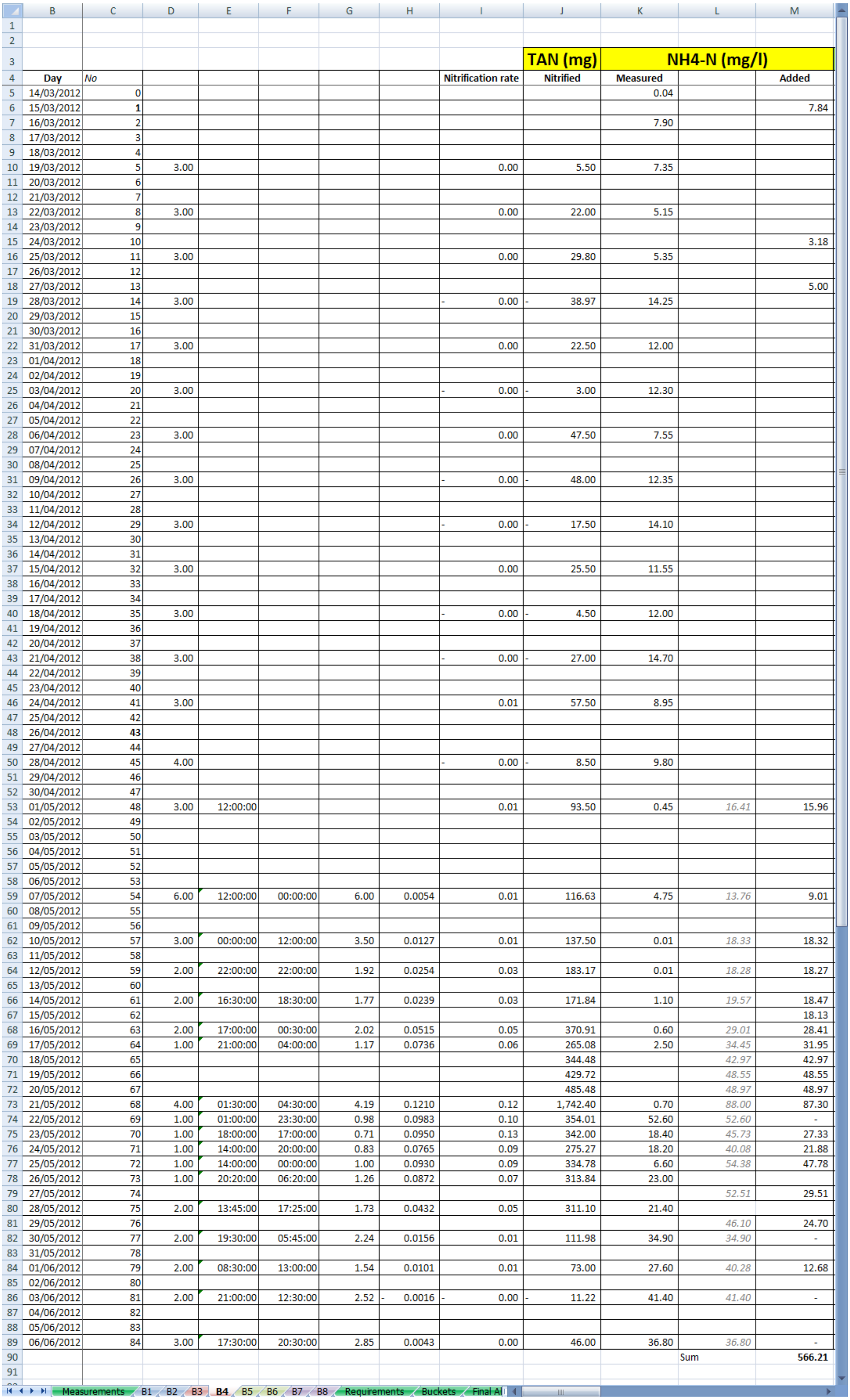
	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		(NH4)2SO4 (mg)						NO3-N (mg/l)		NO2-N (mg/l)	
4	Day	Measured	Nitrified/h	Nitrified	Needed	Added		Measured	Added	Measured	Added
5	14/03/2012	1.84						0.49		0.01	
6	15/03/2012				469.86	**370.00**			-		
7	16/03/2012	398.59						0.05		3.20	
8	17/03/2012				73.11						
9	18/03/2012										
10	19/03/2012	339.62		58.96				0.71		3.10	
11	20/03/2012				132.08						
12	21/03/2012										
13	22/03/2012	283.02		56.60				0.92		2.95	
14	23/03/2012				188.68						
15	24/03/2012					**150.00**			-		
16	25/03/2012	268.87		164.15				0.79		2.90	
17	26/03/2012				202.83						
18	27/03/2012					**210.00**			-		
19	28/03/2012	660.38		- 181.51				2.84		10.20	
20	29/03/2012				- 188.68						
21	30/03/2012										
22	31/03/2012	504.72		155.66						10.00	
23	01/04/2012				- 33.02						
24	02/04/2012										
25	03/04/2012	580.19		- 75.47				3.93		8.40	
26	04/04/2012				- 108.49						
27	05/04/2012										
28	06/04/2012	372.64		207.55						0.03	
29	07/04/2012				99.06						
30	08/04/2012										
31	09/04/2012	547.17		- 174.53				10.20		0.02	
32	10/04/2012				- 75.47						
33	11/04/2012										
34	12/04/2012	627.36		- 80.19				10.20		0.01	
35	13/04/2012				- 155.66						
36	14/04/2012										
37	15/04/2012	561.32		66.04				10.40		0.01	
38	16/04/2012				- 89.62						
39	17/04/2012										
40	18/04/2012	606.14		- 44.81				9.90		0.01	
41	19/04/2012				- 134.43						
42	20/04/2012										
43	21/04/2012	658.02	- 0.72	- 51.89						0.01	
44	22/04/2012				- 186.32						
45	23/04/2012										
46	24/04/2012	485.85	2.39	172.17						0.01	
47	25/04/2012				- 14.15						
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	589.63	- 1.08	- 103.77				10.80		0.24	
51	29/04/2012				- 117.93						
52	30/04/2012										
53	01/05/2012	455.19	1.87	134.43				15.80		0.50	
54	02/05/2012				16.51						
55	03/05/2012										
56	04/05/2012									-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	191.04	1.83	264.15		**495.00**				0.15	
60	08/05/2012				280.66						
61	09/05/2012										
62	10/05/2012	0.47	8.16	685.57		**858.00**				0.10	
63	11/05/2012				471.23						
64	12/05/2012	0.47	18.65	858.00		**856.00**		80.00		0.10	
65	13/05/2012				471.23						
66	14/05/2012	42.45	19.15	814.02	429.25	**871.00**				0.10	
67	15/05/2012					**856.00**					
68	16/05/2012	23.59	36.00	1,745.87	448.12	**1,329.00**				0.10	
69	17/05/2012	47.17	46.62	1,305.41	424.53	**1,512.00**				6.00	
70	18/05/2012	-		1,559.17	471.70	2,007.00					
71	19/05/2012	-		2,007.00	471.70	2,310.00					
72	20/05/2012	-		2,310.00	471.70	2,300.00					
73	21/05/2012	3,490.59	46.62	4,685.58	- 3,018.89	**511.00**				97.00	
74	22/05/2012	3,000.02	42.62	1,001.57	- 2,528.32						
75	23/05/2012	2,132.09	51.05	867.93	- 1,660.39						
76	24/05/2012	1,896.24	11.79	235.85	- 1,424.54			215.63		133.20	
77	25/05/2012	867.93	42.85	1,028.31	1,018.87	**1,687.00**					
78	26/05/2012	1,146.23	46.44	1,408.70	740.57						
79	27/05/2012					1,310.00					
80	28/05/2012	801.89	39.94	1,654.34	1,084.91					213.12	
81	29/05/2012					1,405.00					
82	30/05/2012	551.89	30.79	1,655.00	1,334.91			243.75			
83	31/05/2012		17.92								
84	01/06/2012	424.53	3.44	127.36	1,462.27	1485	12:30			260.00	
85	02/06/2012										
86	03/06/2012	1,716.99	3.18	192.54	169.81						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	1,301.90	6.06	415.10	584.91			256.25		265.00	
90					Sum	**20,522.00**					
91											



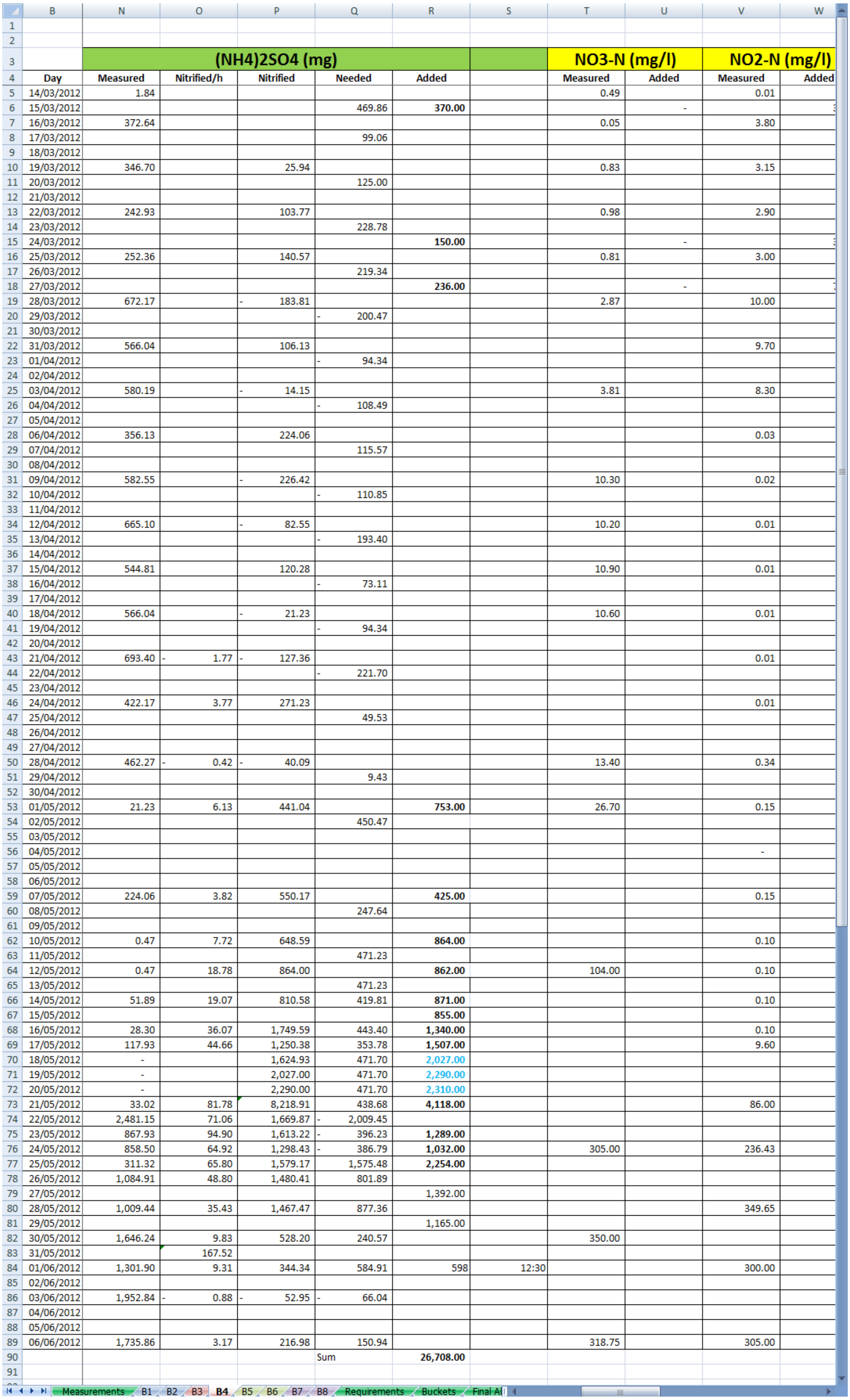
	B	W	X	Y	Z	AA	AB	AC	AD	AE	AF	
1												
2												
3		(mg/l)	NaNO2 (mg)					Alkalinity (meq/l)		CaCO3 (m		
4	Day	Added	Measured	Nitrified	Needed	Added		Measured	Added	Measured	Lost	Ne
5	14/03/2012		0.34					0.12		60.00		
6	15/03/2012	3.07			492.24	**151.00**			11.52			
7	16/03/2012		157.63					0.20		100.00		
8	17/03/2012				334.96							
9	18/03/2012											
10	19/03/2012		152.70	4.93				1.20		600.00	- 500.00	
11	20/03/2012				339.89							-
12	21/03/2012											
13	22/03/2012		145.31	7.39				1.30		650.00	- 50.00	
14	23/03/2012				347.27							-
15	24/03/2012	3.05				**150.00**			-			
16	25/03/2012		142.85	152.46				1.20		600.00	50.00	
17	26/03/2012				349.74							-
18	27/03/2012	7.27				**358.00**			-			
19	28/03/2012		502.44	- 1.59				1.20		600.00	- 0.00	
20	29/03/2012				- 9.85							-
21	30/03/2012											
22	31/03/2012		492.59	9.85				1.00		500.00	100.00	
23	01/04/2012				-							
24	02/04/2012											
25	03/04/2012		413.77	78.81				0.80		400.00	100.00	
26	04/04/2012				78.81							
27	05/04/2012											
28	06/04/2012		1.48	412.30				1.00		500.00	- 100.00	
29	07/04/2012				491.11							
30	08/04/2012											
31	09/04/2012		0.99	0.49				1.00		500.00	-	
32	10/04/2012				491.60							
33	11/04/2012											
34	12/04/2012							1.10		550.00	- 50.00	
35	13/04/2012											-
36	14/04/2012											
37	15/04/2012											
38	16/04/2012											
39	17/04/2012											
40	18/04/2012											
41	19/04/2012											
42	20/04/2012											
43	21/04/2012											
44	22/04/2012											
45	23/04/2012											
46	24/04/2012											
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		11.82	- 10.84								
51	29/04/2012				480.77							
52	30/04/2012											
53	01/05/2012		24.63	- 12.81								
54	02/05/2012				467.96							
55	03/05/2012											
56	04/05/2012											
57	05/05/2012											
58	06/05/2012											
59	07/05/2012		7.39	17.24								
60	08/05/2012				485.20							
61	09/05/2012											
62	10/05/2012		4.93	- 4.93								
63	11/05/2012				487.66							
64	12/05/2012		4.93	- 4.93								
65	13/05/2012				487.66							
66	14/05/2012		4.93	- 4.93	487.66							
67	15/05/2012		-	-	492.59							
68	16/05/2012		4.93	-	487.66							1
69	17/05/2012											
70	18/05/2012											1
71	19/05/2012											1
72	20/05/2012											1
73	21/05/2012											
74	22/05/2012											
75	23/05/2012											
76	24/05/2012											
77	25/05/2012											
78	26/05/2012											
79	27/05/2012											
80	28/05/2012											1
81	29/05/2012											
82	30/05/2012											1
83	31/05/2012											
84	01/06/2012											
85	02/06/2012											
86	03/06/2012											
87	04/06/2012											
88	05/06/2012											Sum
89	06/06/2012											
90												
91												



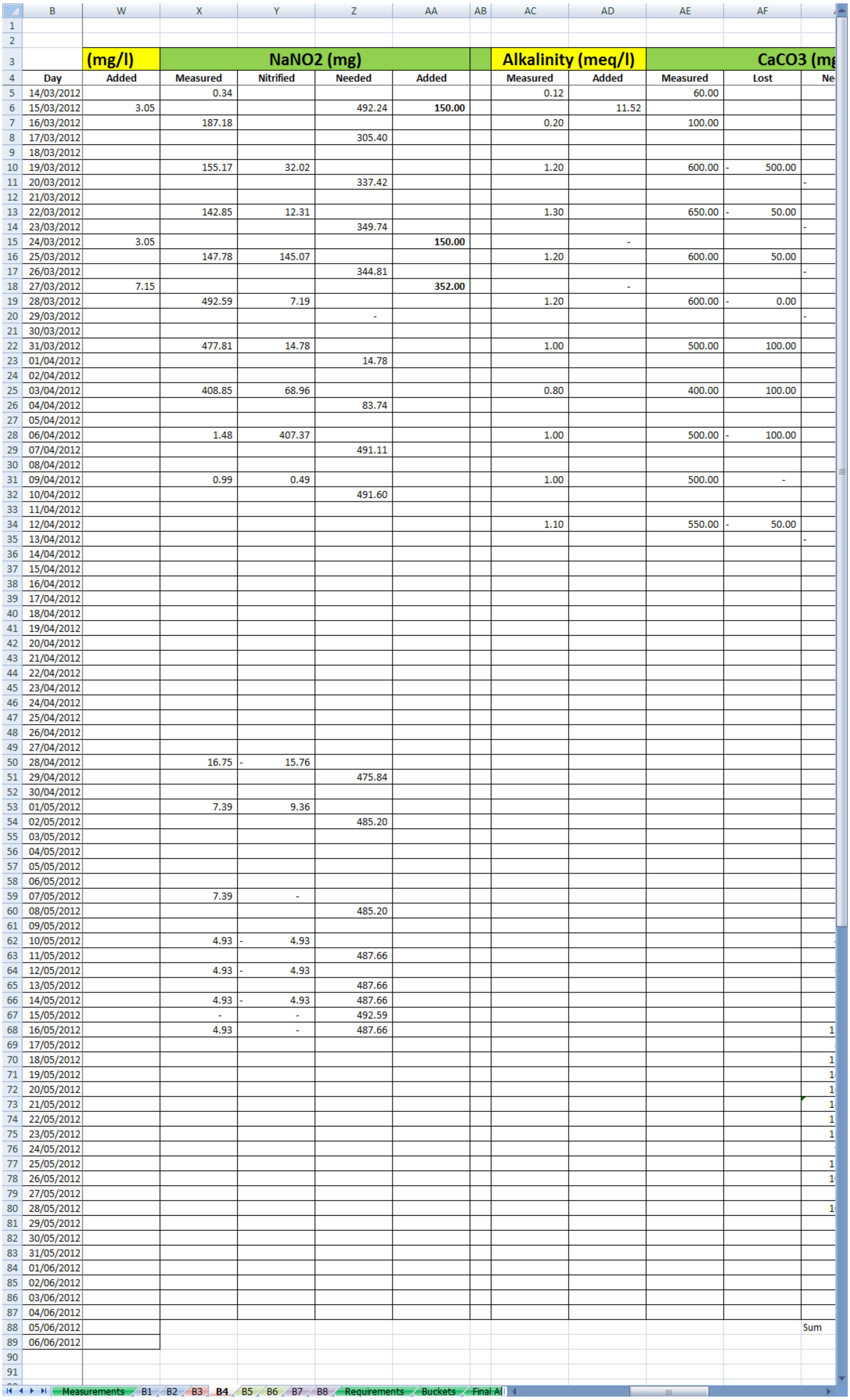
	B	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
1											
2											
3		**NaNO2 (mg)**				**Alkalinity (meq/l)**		**CaCO3 (mg)**			
4	**Day**	**Nitrified**	**Needed**	**Added**		**Measured**	**Added**	**Measured**	**Lost**	**Needed**	**Added**
5	14/03/2012					0.12		60.00			
6	15/03/2012		492.24	**151.00**			11.52			440.00	
7	16/03/2012					0.20		100.00			
8	17/03/2012		334.96							400.00	
9	18/03/2012										
10	19/03/2012	4.93				1.20		600.00	- 500.00		
11	20/03/2012		339.89							- 100.00	
12	21/03/2012										
13	22/03/2012	7.39				1.30		650.00	- 50.00		
14	23/03/2012		347.27							- 150.00	
15	24/03/2012			**150.00**			-				
16	25/03/2012	152.46				1.20		600.00	50.00		
17	26/03/2012		349.74							- 100.00	
18	27/03/2012			**358.00**			-				
19	28/03/2012	- 1.59				1.20		600.00	- 0.00		
20	29/03/2012		- 9.85							- 100.00	
21	30/03/2012										
22	31/03/2012	9.85				1.00		500.00	100.00		
23	01/04/2012		-							-	
24	02/04/2012										
25	03/04/2012	78.81				0.80		400.00	100.00		
26	04/04/2012		78.81							100.00	
27	05/04/2012										
28	06/04/2012	412.30				1.00		500.00	- 100.00		
29	07/04/2012		491.11							-	
30	08/04/2012										
31	09/04/2012	0.49				1.00		500.00	-		
32	10/04/2012		491.60							-	
33	11/04/2012										
34	12/04/2012					1.10		550.00	- 50.00		
35	13/04/2012									- 50.00	
36	14/04/2012										
37	15/04/2012										
38	16/04/2012										
39	17/04/2012										
40	18/04/2012										
41	19/04/2012										
42	20/04/2012										
43	21/04/2012										
44	22/04/2012										
45	23/04/2012										
46	24/04/2012										
47	25/04/2012										
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	- 10.84									
51	29/04/2012		480.77								
52	30/04/2012										
53	01/05/2012	- 12.81								941.04	**1,501.00**
54	02/05/2012		467.96							-	
55	03/05/2012									-	
56	04/05/2012									-	
57	05/05/2012									-	
58	06/05/2012									-	
59	07/05/2012	17.24								1,849.07	**500.00**
60	08/05/2012		485.20							-	
61	09/05/2012									-	
62	10/05/2012	- 4.93								4,798.97	**2,017.00**
63	11/05/2012		487.66							-	**16,463.00**
64	12/05/2012	- 4.93								6,006.00	
65	13/05/2012		487.66							-	
66	14/05/2012	- 4.93	487.66							5,698.13	**2,032.00**
67	15/05/2012	-	492.59							-	**3,033.00**
68	16/05/2012	-	487.66							12,221.08	**3,039.00**
69	17/05/2012									9,137.90	**15,556.00**
70	18/05/2012									10,914.19	10,904.00
71	19/05/2012									14,049.00	13,970.00
72	20/05/2012									16,170.00	16,105.00
73	21/05/2012									8,199.77	**10,058.00**
74	22/05/2012									7,010.98	**28,358.00**
75	23/05/2012									6,075.51	14,058.00
76	24/05/2012									1,650.95	
77	25/05/2012									7,198.16	
78	26/05/2012									9,860.87	
79	27/05/2012									-	
80	28/05/2012									11,580.39	
81	29/05/2012									-	
82	30/05/2012									11,585.01	
83	31/05/2012									-	
84	01/06/2012									891.52	
85	02/06/2012									-	
86	03/06/2012										
87	04/06/2012										
88	05/06/2012									Sum	**137,594.00**
89	06/06/2012										
90											
91											



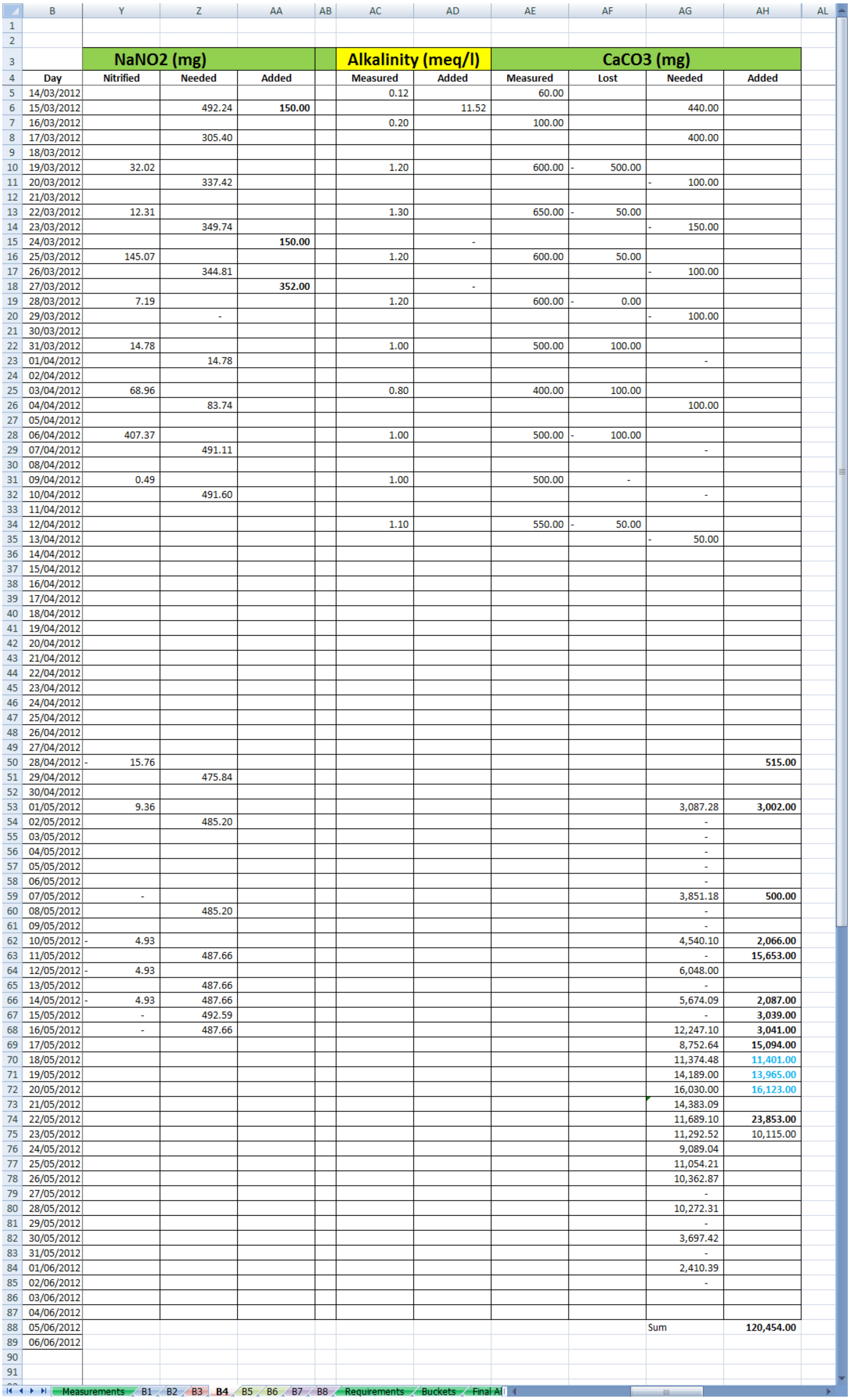
	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									TAN (mg)	NH4-N (mg/l)		
4	Day	*No*						Nitrification rate	Nitrified	Measured		Added
5	14/03/2012	0								0.04		
6	15/03/2012	**1**										7.84
7	16/03/2012	2								7.90		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					0.00	5.50	7.35		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	22.00	5.15		
14	23/03/2012	9										
15	24/03/2012	10										3.18
16	25/03/2012	11	3.00					0.00	29.80	5.35		
17	26/03/2012	12										
18	27/03/2012	13										5.00
19	28/03/2012	14	3.00					- 0.00	- 38.97	14.25		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	22.50	12.00		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 3.00	12.30		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	47.50	7.55		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 48.00	12.35		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 17.50	14.10		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					0.00	25.50	11.55		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					- 0.00	- 4.50	12.00		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00					- 0.00	- 27.00	14.70		
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00					0.01	57.50	8.95		
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					- 0.00	- 8.50	9.80		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.01	93.50	0.45	*16.41*	15.96
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0054	0.01	116.63	4.75	*13.76*	9.01
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0127	0.01	137.50	0.01	*18.33*	18.32
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0254	0.03	183.17	0.01	*18.28*	18.27
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0239	0.03	171.84	1.10	*19.57*	18.47
67	15/05/2012	62										18.13
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0515	0.05	370.91	0.60	*29.01*	28.41
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0736	0.06	265.08	2.50	*34.45*	31.95
70	18/05/2012	65							344.48		*42.97*	42.97
71	19/05/2012	66							429.72		*48.55*	48.55
72	20/05/2012	67							485.48		*48.97*	48.97
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.1210	0.12	1,742.40	0.70	*88.00*	87.30
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.0983	0.10	354.01	52.60	*52.60*	-
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.0950	0.13	342.00	18.40	*45.73*	27.33
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0765	0.09	275.27	18.20	*40.08*	21.88
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0930	0.09	334.78	6.60	*54.38*	47.78
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0872	0.07	313.84	23.00		
79	27/05/2012	74									*52.51*	29.51
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0432	0.05	311.10	21.40		
81	29/05/2012	76									*46.10*	24.70
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0156	0.01	111.98	34.90	*34.90*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0101	0.01	73.00	27.60	*40.28*	12.68
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	- 0.0016	- 0.00	- 11.22	41.40	*41.40*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0043	0.00	46.00	36.80	*36.80*	-
90											Sum	**566.21**
91												



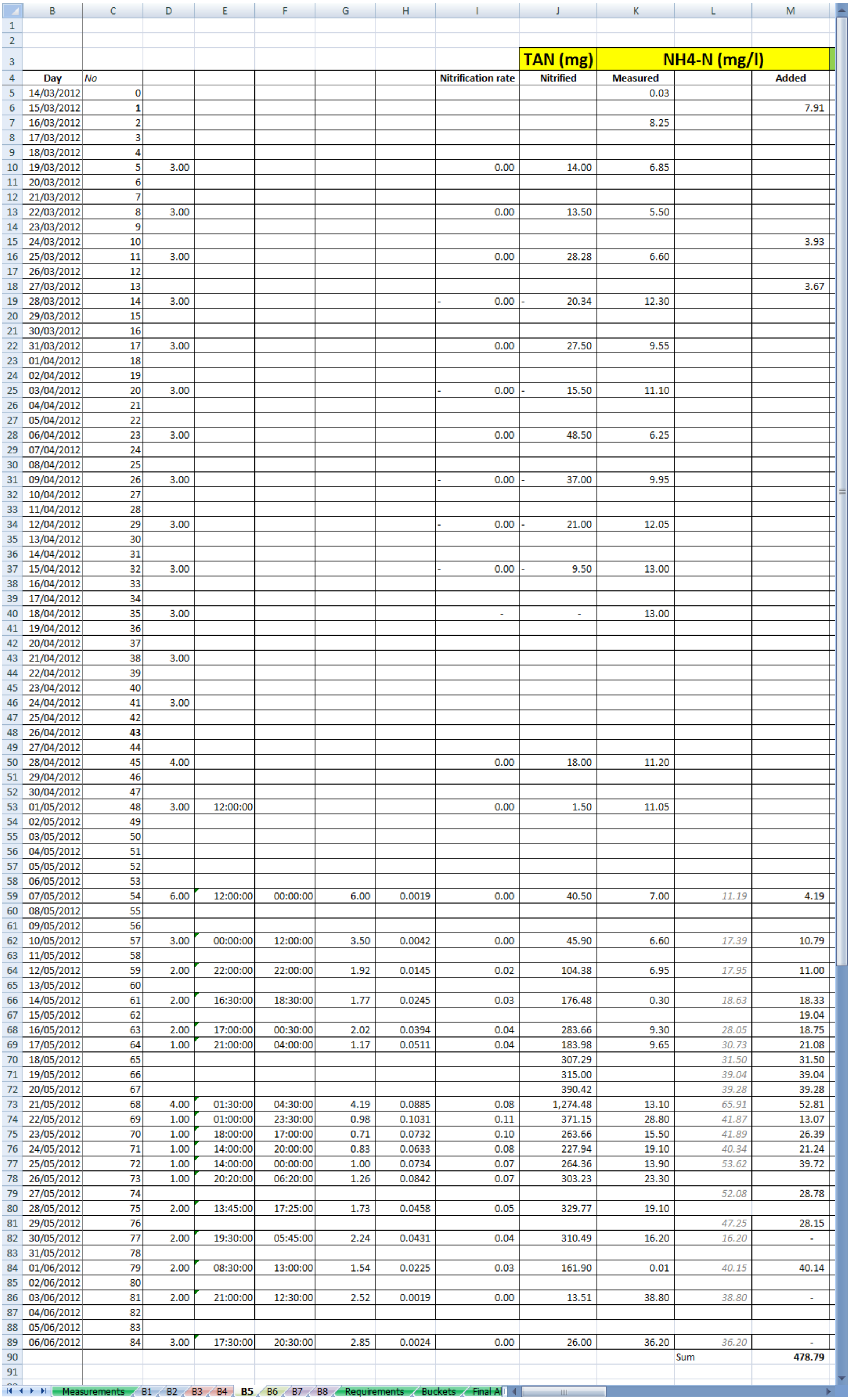
	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		(NH4)2SO4 (mg)						NO3-N (mg/l)		NO2-N (mg/l)	
4	Day	Measured	Nitrified/h	Nitrified	Needed	Added		Measured	Added	Measured	Added
5	14/03/2012	1.84						0.49		0.01	
6	15/03/2012				469.86	**370.00**			-		
7	16/03/2012	372.64						0.05		3.80	
8	17/03/2012				99.06						
9	18/03/2012										
10	19/03/2012	346.70		25.94				0.83		3.15	
11	20/03/2012				125.00						
12	21/03/2012										
13	22/03/2012	242.93		103.77				0.98		2.90	
14	23/03/2012				228.78						
15	24/03/2012					**150.00**			-		
16	25/03/2012	252.36		140.57				0.81		3.00	
17	26/03/2012				219.34						
18	27/03/2012					**236.00**			-		
19	28/03/2012	672.17		- 183.81				2.87		10.00	
20	29/03/2012				- 200.47						
21	30/03/2012										
22	31/03/2012	566.04		106.13						9.70	
23	01/04/2012				- 94.34						
24	02/04/2012										
25	03/04/2012	580.19		- 14.15				3.81		8.30	
26	04/04/2012				- 108.49						
27	05/04/2012										
28	06/04/2012	356.13		224.06						0.03	
29	07/04/2012				115.57						
30	08/04/2012										
31	09/04/2012	582.55		- 226.42				10.30		0.02	
32	10/04/2012				- 110.85						
33	11/04/2012										
34	12/04/2012	665.10		- 82.55				10.20		0.01	
35	13/04/2012				- 193.40						
36	14/04/2012										
37	15/04/2012	544.81		120.28				10.90		0.01	
38	16/04/2012				- 73.11						
39	17/04/2012										
40	18/04/2012	566.04		- 21.23				10.60		0.01	
41	19/04/2012				- 94.34						
42	20/04/2012										
43	21/04/2012	693.40	- 1.77	- 127.36						0.01	
44	22/04/2012				- 221.70						
45	23/04/2012										
46	24/04/2012	422.17	3.77	271.23						0.01	
47	25/04/2012				49.53						
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	462.27	- 0.42	- 40.09				13.40		0.34	
51	29/04/2012				9.43						
52	30/04/2012										
53	01/05/2012	21.23	6.13	441.04		**753.00**		26.70		0.15	
54	02/05/2012				450.47						
55	03/05/2012										
56	04/05/2012									-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	224.06	3.82	550.17		**425.00**				0.15	
60	08/05/2012				247.64						
61	09/05/2012										
62	10/05/2012	0.47	7.72	648.59		**864.00**				0.10	
63	11/05/2012				471.23						
64	12/05/2012	0.47	18.78	864.00		**862.00**		104.00		0.10	
65	13/05/2012				471.23						
66	14/05/2012	51.89	19.07	810.58	419.81	**871.00**				0.10	
67	15/05/2012					**855.00**					
68	16/05/2012	28.30	36.07	1,749.59	443.40	**1,340.00**				0.10	
69	17/05/2012	117.93	44.66	1,250.38	353.78	**1,507.00**				9.60	
70	18/05/2012	-		1,624.93	471.70	**2,027.00**					
71	19/05/2012	-		2,027.00	471.70	**2,290.00**					
72	20/05/2012	-		2,290.00	471.70	**2,310.00**					
73	21/05/2012	33.02	81.78	8,218.91	438.68	**4,118.00**				86.00	
74	22/05/2012	2,481.15	71.06	1,669.87	- 2,009.45						
75	23/05/2012	867.93	94.90	1,613.22	- 396.23	**1,289.00**					
76	24/05/2012	858.50	64.92	1,298.43	- 386.79	**1,032.00**		305.00		236.43	
77	25/05/2012	311.32	65.80	1,579.17	1,575.48	**2,254.00**					
78	26/05/2012	1,084.91	48.80	1,480.41	801.89						
79	27/05/2012					1,392.00					
80	28/05/2012	1,009.44	35.43	1,467.47	877.36					349.65	
81	29/05/2012					1,165.00					
82	30/05/2012	1,646.24	9.83	528.20	240.57			350.00			
83	31/05/2012		167.52								
84	01/06/2012	1,301.90	9.31	344.34	584.91	598	12:30			300.00	
85	02/06/2012										
86	03/06/2012	1,952.84	- 0.88	- 52.95	- 66.04						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	1,735.86	3.17	216.98	150.94			318.75		305.00	
90					Sum	**26,708.00**					
91											



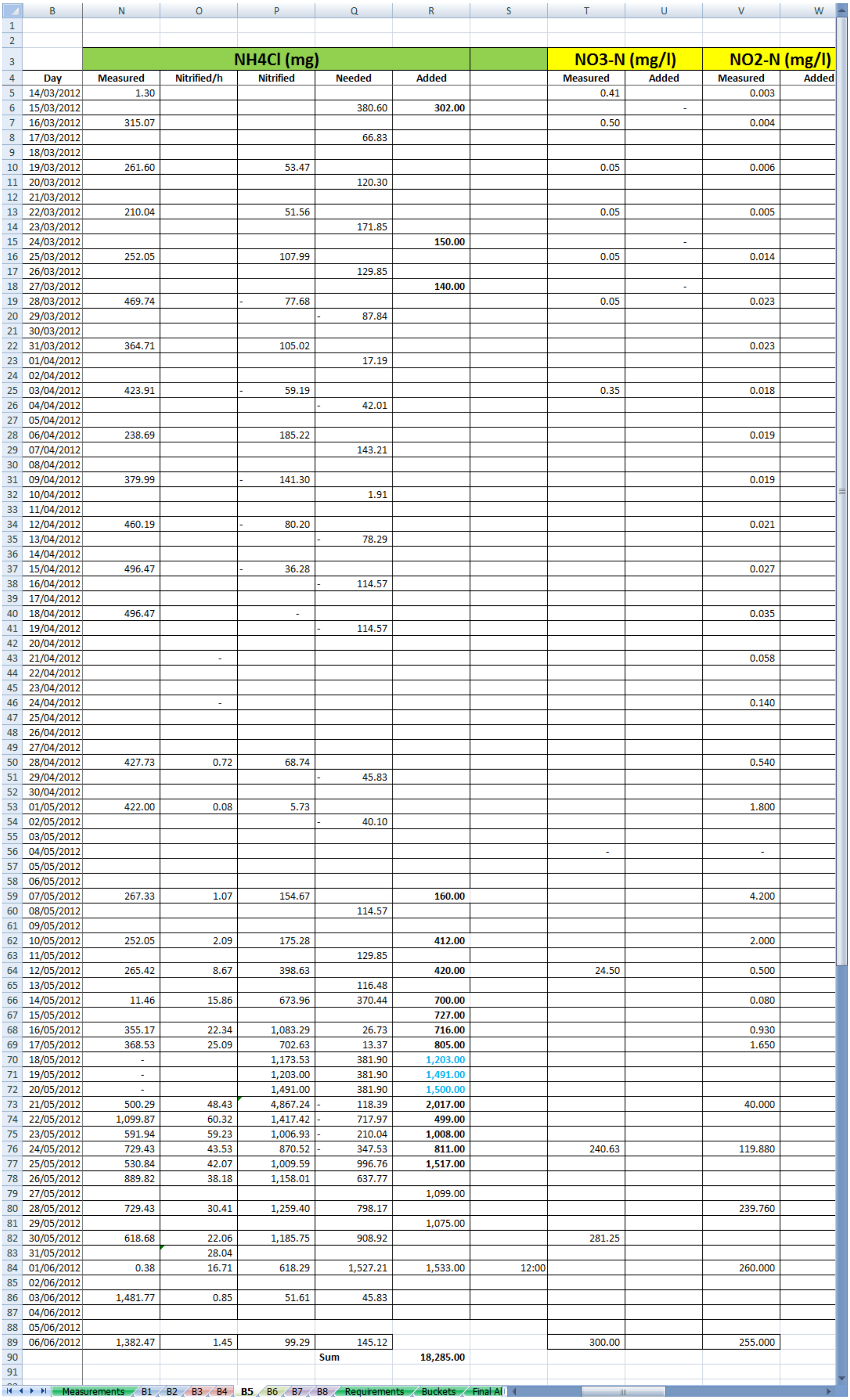
	B	W	X	Y	Z	AA	AB	AC	AD	AE	AF	
1												
2												
3		(mg/l)	NaNO2 (mg)					Alkalinity (meq/l)		CaCO3 (mg		
4	Day	Added	Measured	Nitrified	Needed	Added		Measured	Added	Measured	Lost	Ne
5	14/03/2012		0.34					0.12		60.00		
6	15/03/2012	3.05			492.24	**150.00**			11.52			
7	16/03/2012		187.18					0.20		100.00		
8	17/03/2012				305.40							
9	18/03/2012											
10	19/03/2012		155.17	32.02				1.20		600.00	- 500.00	
11	20/03/2012				337.42							-
12	21/03/2012											
13	22/03/2012		142.85	12.31				1.30		650.00	- 50.00	
14	23/03/2012				349.74							-
15	24/03/2012	3.05				**150.00**			-			
16	25/03/2012		147.78	145.07				1.20		600.00	50.00	
17	26/03/2012				344.81							-
18	27/03/2012	7.15				**352.00**			-			
19	28/03/2012		492.59	7.19				1.20		600.00	- 0.00	
20	29/03/2012				-							-
21	30/03/2012											
22	31/03/2012		477.81	14.78				1.00		500.00	100.00	
23	01/04/2012				14.78							
24	02/04/2012											
25	03/04/2012		408.85	68.96				0.80		400.00	100.00	
26	04/04/2012				83.74							
27	05/04/2012											
28	06/04/2012		1.48	407.37				1.00		500.00	- 100.00	
29	07/04/2012				491.11							
30	08/04/2012											
31	09/04/2012		0.99	0.49				1.00		500.00	-	
32	10/04/2012				491.60							
33	11/04/2012											
34	12/04/2012							1.10		550.00	- 50.00	
35	13/04/2012											-
36	14/04/2012											
37	15/04/2012											
38	16/04/2012											
39	17/04/2012											
40	18/04/2012											
41	19/04/2012											
42	20/04/2012											
43	21/04/2012											
44	22/04/2012											
45	23/04/2012											
46	24/04/2012											
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		16.75	- 15.76								
51	29/04/2012				475.84							
52	30/04/2012											
53	01/05/2012		7.39	9.36								
54	02/05/2012				485.20							
55	03/05/2012											
56	04/05/2012											
57	05/05/2012											
58	06/05/2012											
59	07/05/2012		7.39	-								
60	08/05/2012				485.20							
61	09/05/2012											
62	10/05/2012		4.93	- 4.93								
63	11/05/2012				487.66							
64	12/05/2012		4.93	- 4.93								
65	13/05/2012				487.66							
66	14/05/2012		4.93	- 4.93	487.66							
67	15/05/2012		-	-	492.59							
68	16/05/2012		4.93	-	487.66							1
69	17/05/2012											
70	18/05/2012											1
71	19/05/2012											1
72	20/05/2012											1
73	21/05/2012											1
74	22/05/2012											1
75	23/05/2012											1
76	24/05/2012											
77	25/05/2012											1
78	26/05/2012											1
79	27/05/2012											
80	28/05/2012											1
81	29/05/2012											
82	30/05/2012											
83	31/05/2012											
84	01/06/2012											
85	02/06/2012											
86	03/06/2012											
87	04/06/2012											
88	05/06/2012											Sum
89	06/06/2012											
90												
91												



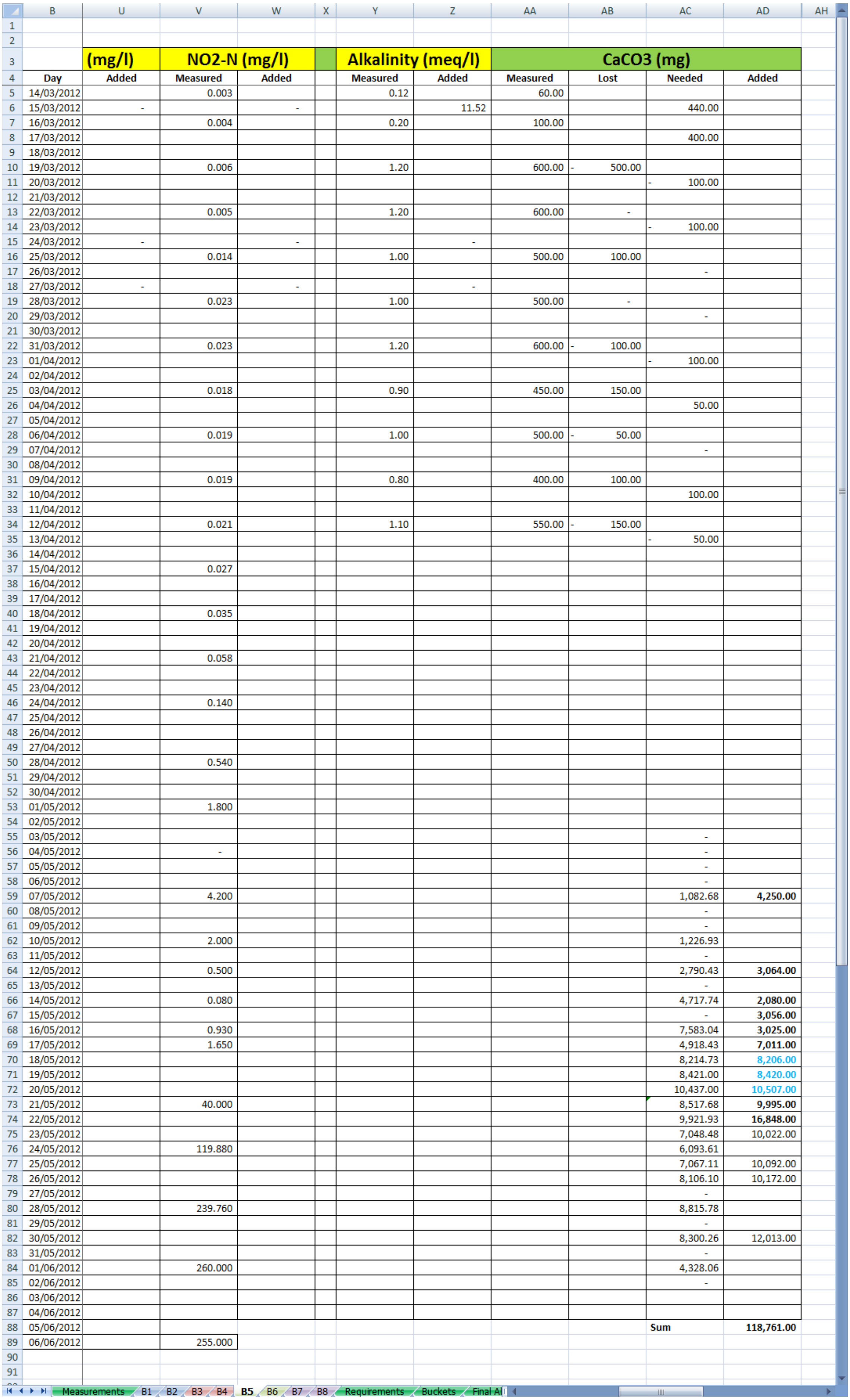
	B	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AL
1												
2												
3		NaNO2 (mg)				Alkalinity (meq/l)		CaCO3 (mg)				
4	Day	Nitrified	Needed	Added		Measured	Added	Measured	Lost	Needed	Added	
5	14/03/2012					0.12		60.00				
6	15/03/2012		492.24	**150.00**			11.52			440.00		
7	16/03/2012					0.20		100.00				
8	17/03/2012		305.40							400.00		
9	18/03/2012											
10	19/03/2012	32.02				1.20		600.00	- 500.00			
11	20/03/2012		337.42							- 100.00		
12	21/03/2012											
13	22/03/2012	12.31				1.30		650.00	- 50.00			
14	23/03/2012		349.74							- 150.00		
15	24/03/2012			**150.00**			-					
16	25/03/2012	145.07				1.20		600.00	50.00			
17	26/03/2012		344.81							- 100.00		
18	27/03/2012			**352.00**			-					
19	28/03/2012	7.19				1.20		600.00	- 0.00			
20	29/03/2012		-							- 100.00		
21	30/03/2012											
22	31/03/2012	14.78				1.00		500.00	100.00			
23	01/04/2012		14.78							-		
24	02/04/2012											
25	03/04/2012	68.96				0.80		400.00	100.00			
26	04/04/2012		83.74							100.00		
27	05/04/2012											
28	06/04/2012	407.37				1.00		500.00	- 100.00			
29	07/04/2012		491.11							-		
30	08/04/2012											
31	09/04/2012	0.49				1.00		500.00	-			
32	10/04/2012		491.60							-		
33	11/04/2012											
34	12/04/2012					1.10		550.00	- 50.00			
35	13/04/2012									- 50.00		
36	14/04/2012											
37	15/04/2012											
38	16/04/2012											
39	17/04/2012											
40	18/04/2012											
41	19/04/2012											
42	20/04/2012											
43	21/04/2012											
44	22/04/2012											
45	23/04/2012											
46	24/04/2012											
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012	- 15.76									**515.00**	
51	29/04/2012		475.84									
52	30/04/2012											
53	01/05/2012	9.36								3,087.28	**3,002.00**	
54	02/05/2012		485.20							-		
55	03/05/2012									-		
56	04/05/2012									-		
57	05/05/2012									-		
58	06/05/2012									-		
59	07/05/2012	-								3,851.18	**500.00**	
60	08/05/2012		485.20							-		
61	09/05/2012									-		
62	10/05/2012	- 4.93								4,540.10	**2,066.00**	
63	11/05/2012		487.66							-	**15,653.00**	
64	12/05/2012	- 4.93								6,048.00		
65	13/05/2012		487.66							-		
66	14/05/2012	- 4.93	487.66							5,674.09	**2,087.00**	
67	15/05/2012	-	492.59							-	**3,039.00**	
68	16/05/2012	-	487.66							12,247.10	**3,041.00**	
69	17/05/2012									8,752.64	**15,094.00**	
70	18/05/2012									11,374.48	**11,401.00**	
71	19/05/2012									14,189.00	**13,965.00**	
72	20/05/2012									16,030.00	**16,123.00**	
73	21/05/2012									14,383.09		
74	22/05/2012									11,689.10	**23,853.00**	
75	23/05/2012									11,292.52	10,115.00	
76	24/05/2012									9,089.04		
77	25/05/2012									11,054.21		
78	26/05/2012									10,362.87		
79	27/05/2012									-		
80	28/05/2012									10,272.31		
81	29/05/2012									-		
82	30/05/2012									3,697.42		
83	31/05/2012									-		
84	01/06/2012									2,410.39		
85	02/06/2012									-		
86	03/06/2012											
87	04/06/2012											
88	05/06/2012									Sum	**120,454.00**	
89	06/06/2012											
90												
91												



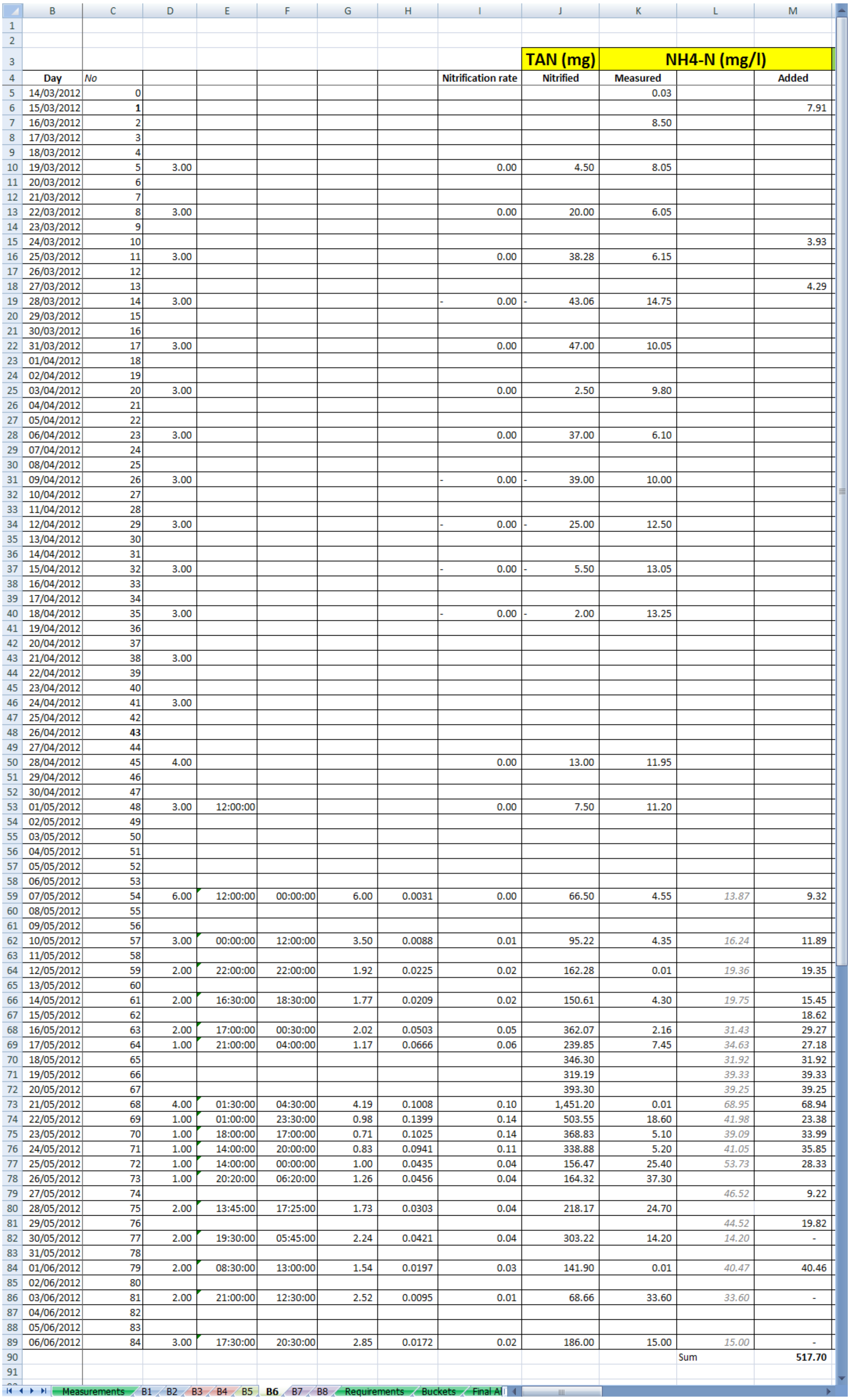
	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									**TAN (mg)**	**NH4-N (mg/l)**		
4	**Day**	*No*						**Nitrification rate**	**Nitrified**	**Measured**		**Added**
5	14/03/2012	0								0.03		
6	15/03/2012	**1**										7.91
7	16/03/2012	2								8.25		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					0.00	14.00	6.85		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	13.50	5.50		
14	23/03/2012	9										
15	24/03/2012	10										3.93
16	25/03/2012	11	3.00					0.00	28.28	6.60		
17	26/03/2012	12										
18	27/03/2012	13										3.67
19	28/03/2012	14	3.00					- 0.00	- 20.34	12.30		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	27.50	9.55		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 15.50	11.10		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	48.50	6.25		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 37.00	9.95		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 21.00	12.05		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					- 0.00	- 9.50	13.00		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					-	-	13.00		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00									
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00									
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					0.00	18.00	11.20		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.00	1.50	11.05		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0019	0.00	40.50	7.00	*11.19*	4.19
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0042	0.00	45.90	6.60	*17.39*	10.79
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0145	0.02	104.38	6.95	*17.95*	11.00
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0245	0.03	176.48	0.30	*18.63*	18.33
67	15/05/2012	62										19.04
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0394	0.04	283.66	9.30	*28.05*	18.75
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0511	0.04	183.98	9.65	*30.73*	21.08
70	18/05/2012	65							307.29		*31.50*	31.50
71	19/05/2012	66							315.00		*39.04*	39.04
72	20/05/2012	67							390.42		*39.28*	39.28
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.0885	0.08	1,274.48	13.10	*65.91*	52.81
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.1031	0.11	371.15	28.80	*41.87*	13.07
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.0732	0.10	263.66	15.50	*41.89*	26.39
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0633	0.08	227.94	19.10	*40.34*	21.24
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0734	0.07	264.36	13.90	*53.62*	39.72
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0842	0.07	303.23	23.30		
79	27/05/2012	74									*52.08*	28.78
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0458	0.05	329.77	19.10		
81	29/05/2012	76									*47.25*	28.15
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0431	0.04	310.49	16.20	*16.20*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0225	0.03	161.90	0.01	*40.15*	40.14
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	0.0019	0.00	13.51	38.80	*38.80*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0024	0.00	26.00	36.20	*36.20*	-
90											Sum	**478.79**
91												



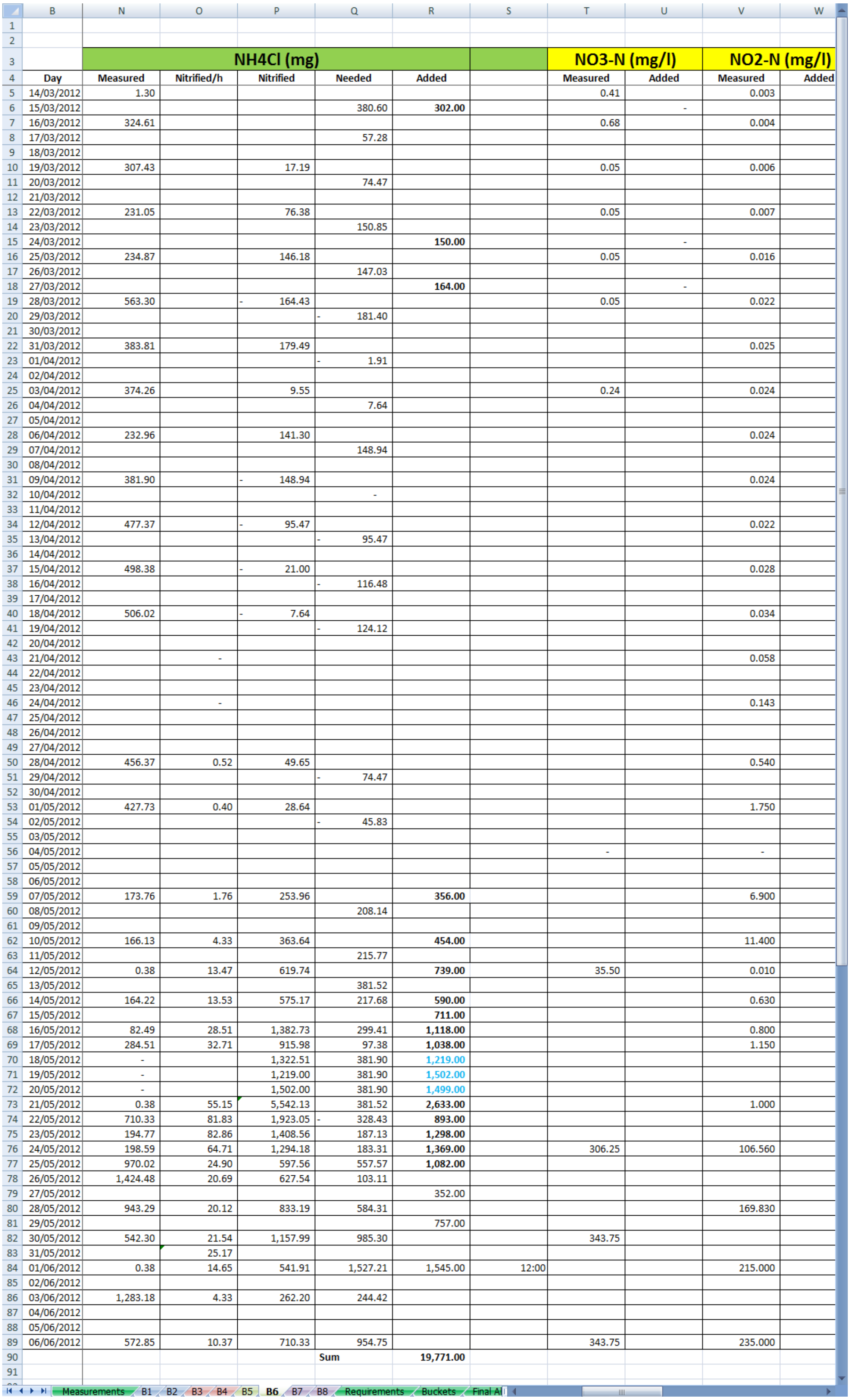
	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		NH4Cl (mg)						NO3-N (mg/l)		NO2-N (mg/l)	
4	Day	Measured	Nitrified/h	Nitrified	Needed	Added		Measured	Added	Measured	Added
5	14/03/2012	1.30						0.41		0.003	
6	15/03/2012				380.60	**302.00**			-		
7	16/03/2012	315.07						0.50		0.004	
8	17/03/2012				66.83						
9	18/03/2012										
10	19/03/2012	261.60		53.47				0.05		0.006	
11	20/03/2012				120.30						
12	21/03/2012										
13	22/03/2012	210.04		51.56				0.05		0.005	
14	23/03/2012				171.85						
15	24/03/2012					**150.00**			-		
16	25/03/2012	252.05		107.99				0.05		0.014	
17	26/03/2012				129.85						
18	27/03/2012					**140.00**			-		
19	28/03/2012	469.74		- 77.68				0.05		0.023	
20	29/03/2012				- 87.84						
21	30/03/2012										
22	31/03/2012	364.71		105.02						0.023	
23	01/04/2012				17.19						
24	02/04/2012										
25	03/04/2012	423.91		- 59.19				0.35		0.018	
26	04/04/2012				- 42.01						
27	05/04/2012										
28	06/04/2012	238.69		185.22						0.019	
29	07/04/2012				143.21						
30	08/04/2012										
31	09/04/2012	379.99		- 141.30						0.019	
32	10/04/2012				1.91						
33	11/04/2012										
34	12/04/2012	460.19		- 80.20						0.021	
35	13/04/2012				- 78.29						
36	14/04/2012										
37	15/04/2012	496.47		- 36.28						0.027	
38	16/04/2012				- 114.57						
39	17/04/2012										
40	18/04/2012	496.47		-						0.035	
41	19/04/2012				- 114.57						
42	20/04/2012										
43	21/04/2012		-							0.058	
44	22/04/2012										
45	23/04/2012										
46	24/04/2012		-							0.140	
47	25/04/2012										
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	427.73	0.72	68.74						0.540	
51	29/04/2012				- 45.83						
52	30/04/2012										
53	01/05/2012	422.00	0.08	5.73						1.800	
54	02/05/2012				- 40.10						
55	03/05/2012										
56	04/05/2012							-		-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	267.33	1.07	154.67		**160.00**				4.200	
60	08/05/2012				114.57						
61	09/05/2012										
62	10/05/2012	252.05	2.09	175.28		**412.00**				2.000	
63	11/05/2012				129.85						
64	12/05/2012	265.42	8.67	398.63		**420.00**		24.50		0.500	
65	13/05/2012				116.48						
66	14/05/2012	11.46	15.86	673.96	370.44	**700.00**				0.080	
67	15/05/2012					**727.00**					
68	16/05/2012	355.17	22.34	1,083.29	26.73	**716.00**				0.930	
69	17/05/2012	368.53	25.09	702.63	13.37	**805.00**				1.650	
70	18/05/2012	-		1,173.53	381.90	1,203.00					
71	19/05/2012	-		1,203.00	381.90	1,491.00					
72	20/05/2012	-		1,491.00	381.90	1,500.00					
73	21/05/2012	500.29	48.43	4,867.24	- 118.39	**2,017.00**				40.000	
74	22/05/2012	1,099.87	60.32	1,417.42	- 717.97	**499.00**					
75	23/05/2012	591.94	59.23	1,006.93	- 210.04	**1,008.00**					
76	24/05/2012	729.43	43.53	870.52	- 347.53	**811.00**		240.63		119.880	
77	25/05/2012	530.84	42.07	1,009.59	996.76	**1,517.00**					
78	26/05/2012	889.82	38.18	1,158.01	637.77						
79	27/05/2012					1,099.00					
80	28/05/2012	729.43	30.41	1,259.40	798.17					239.760	
81	29/05/2012					1,075.00					
82	30/05/2012	618.68	22.06	1,185.75	908.92			281.25			
83	31/05/2012		28.04								
84	01/06/2012	0.38	16.71	618.29	1,527.21	1,533.00	12:00			260.000	
85	02/06/2012										
86	03/06/2012	1,481.77	0.85	51.61	45.83						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	1,382.47	1.45	99.29	145.12			300.00		255.000	
90					**Sum**	**18,285.00**					
91											



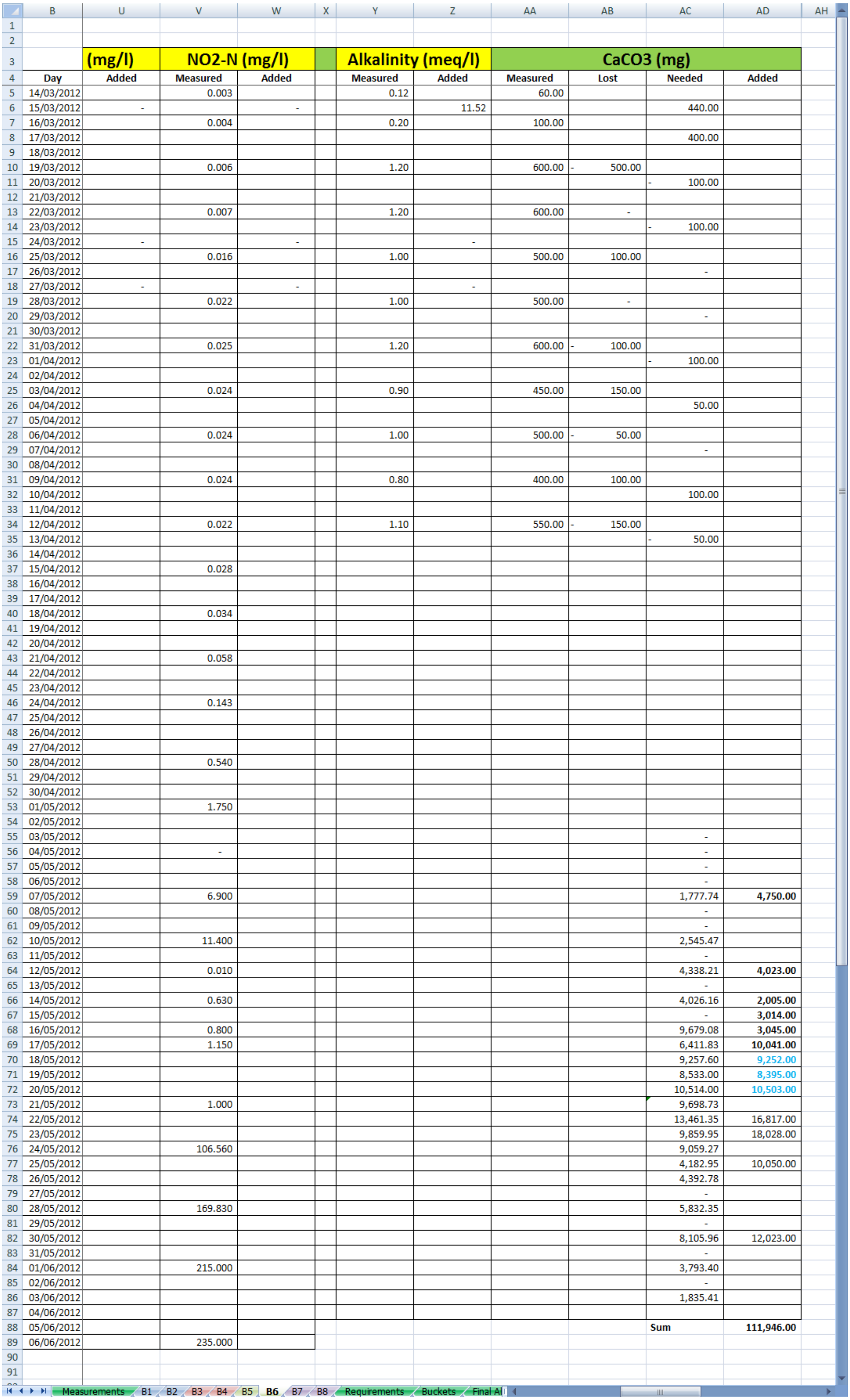
	B	U	V	W	X	Y	Z	AA	AB	AC	AD	AH
1												
2												
3		(mg/l)	NO2-N (mg/l)			Alkalinity (meq/l)		CaCO3 (mg)				
4	Day	Added	Measured	Added		Measured	Added	Measured	Lost	Needed	Added	
5	14/03/2012		0.003			0.12		60.00				
6	15/03/2012	-		-			11.52			440.00		
7	16/03/2012		0.004			0.20		100.00				
8	17/03/2012									400.00		
9	18/03/2012											
10	19/03/2012		0.006			1.20		600.00	- 500.00			
11	20/03/2012									- 100.00		
12	21/03/2012											
13	22/03/2012		0.005			1.20		600.00	-			
14	23/03/2012									- 100.00		
15	24/03/2012	-		-			-					
16	25/03/2012		0.014			1.00		500.00	100.00			
17	26/03/2012									-		
18	27/03/2012	-		-			-					
19	28/03/2012		0.023			1.00		500.00	-			
20	29/03/2012									-		
21	30/03/2012											
22	31/03/2012		0.023			1.20		600.00	- 100.00			
23	01/04/2012									- 100.00		
24	02/04/2012											
25	03/04/2012		0.018			0.90		450.00	150.00			
26	04/04/2012									50.00		
27	05/04/2012											
28	06/04/2012		0.019			1.00		500.00	- 50.00			
29	07/04/2012									-		
30	08/04/2012											
31	09/04/2012		0.019			0.80		400.00	100.00			
32	10/04/2012									100.00		
33	11/04/2012											
34	12/04/2012		0.021			1.10		550.00	- 150.00			
35	13/04/2012									- 50.00		
36	14/04/2012											
37	15/04/2012		0.027									
38	16/04/2012											
39	17/04/2012											
40	18/04/2012		0.035									
41	19/04/2012											
42	20/04/2012											
43	21/04/2012		0.058									
44	22/04/2012											
45	23/04/2012											
46	24/04/2012		0.140									
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		0.540									
51	29/04/2012											
52	30/04/2012											
53	01/05/2012		1.800									
54	02/05/2012											
55	03/05/2012									-		
56	04/05/2012		-							-		
57	05/05/2012									-		
58	06/05/2012									-		
59	07/05/2012		4.200							1,082.68	**4,250.00**	
60	08/05/2012									-		
61	09/05/2012									-		
62	10/05/2012		2.000							1,226.93		
63	11/05/2012									-		
64	12/05/2012		0.500							2,790.43	**3,064.00**	
65	13/05/2012									-		
66	14/05/2012		0.080							4,717.74	**2,080.00**	
67	15/05/2012									-	**3,056.00**	
68	16/05/2012		0.930							7,583.04	**3,025.00**	
69	17/05/2012		1.650							4,918.43	**7,011.00**	
70	18/05/2012									8,214.73	8,206.00	
71	19/05/2012									8,421.00	8,420.00	
72	20/05/2012									10,437.00	10,507.00	
73	21/05/2012		40.000							8,517.68	**9,995.00**	
74	22/05/2012									9,921.93	**16,848.00**	
75	23/05/2012									7,048.48	10,022.00	
76	24/05/2012		119.880							6,093.61		
77	25/05/2012									7,067.11	10,092.00	
78	26/05/2012									8,106.10	10,172.00	
79	27/05/2012									-		
80	28/05/2012		239.760							8,815.78		
81	29/05/2012									-		
82	30/05/2012									8,300.26	12,013.00	
83	31/05/2012									-		
84	01/06/2012		260.000							4,328.06		
85	02/06/2012									-		
86	03/06/2012											
87	04/06/2012											
88	05/06/2012									**Sum**	**118,761.00**	
89	06/06/2012		255.000									
90												
91												



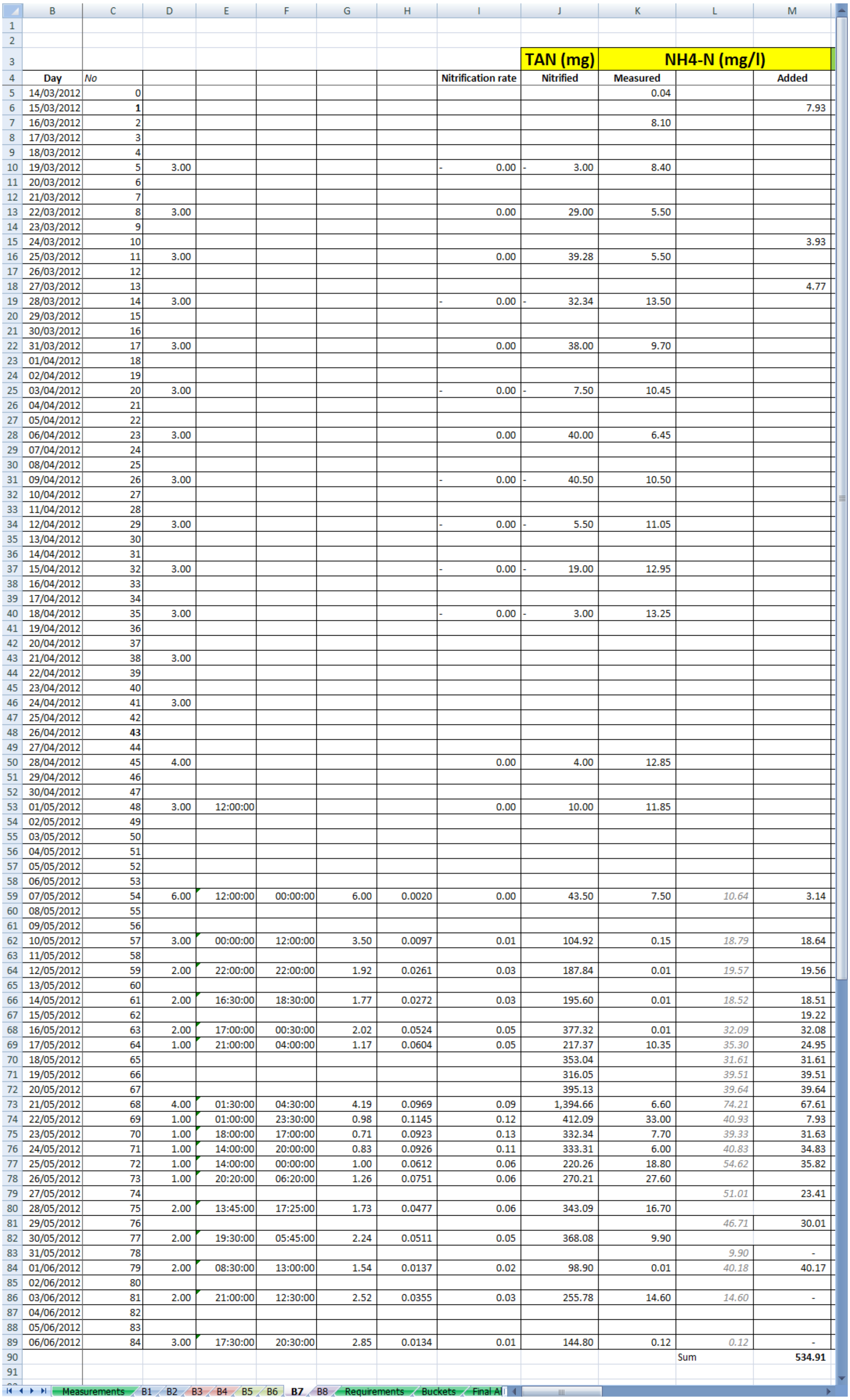
	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									TAN (mg)	NH4-N (mg/l)		
4	Day	*No*						Nitrification rate	Nitrified	Measured		Added
5	14/03/2012	0								0.03		
6	15/03/2012	**1**										7.91
7	16/03/2012	2								8.50		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					0.00	4.50	8.05		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	20.00	6.05		
14	23/03/2012	9										
15	24/03/2012	10										3.93
16	25/03/2012	11	3.00					0.00	38.28	6.15		
17	26/03/2012	12										
18	27/03/2012	13										4.29
19	28/03/2012	14	3.00					- 0.00	- 43.06	14.75		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	47.00	10.05		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					0.00	2.50	9.80		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	37.00	6.10		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 39.00	10.00		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 25.00	12.50		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					- 0.00	- 5.50	13.05		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					- 0.00	- 2.00	13.25		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00									
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00									
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					0.00	13.00	11.95		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.00	7.50	11.20		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0031	0.00	66.50	4.55	*13.87*	9.32
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0088	0.01	95.22	4.35	*16.24*	11.89
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0225	0.02	162.28	0.01	*19.36*	19.35
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0209	0.02	150.61	4.30	*19.75*	15.45
67	15/05/2012	62										18.62
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0503	0.05	362.07	2.16	*31.43*	29.27
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0666	0.06	239.85	7.45	*34.63*	27.18
70	18/05/2012	65							346.30		*31.92*	31.92
71	19/05/2012	66							319.19		*39.33*	39.33
72	20/05/2012	67							393.30		*39.25*	39.25
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.1008	0.10	1,451.20	0.01	*68.95*	68.94
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.1399	0.14	503.55	18.60	*41.98*	23.38
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.1025	0.14	368.83	5.10	*39.09*	33.99
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0941	0.11	338.88	5.20	*41.05*	35.85
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0435	0.04	156.47	25.40	*53.73*	28.33
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0456	0.04	164.32	37.30		
79	27/05/2012	74									*46.52*	9.22
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0303	0.04	218.17	24.70		
81	29/05/2012	76									*44.52*	19.82
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0421	0.04	303.22	14.20	*14.20*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0197	0.03	141.90	0.01	*40.47*	40.46
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	0.0095	0.01	68.66	33.60	*33.60*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0172	0.02	186.00	15.00	*15.00*	-
90											Sum	**517.70**
91												



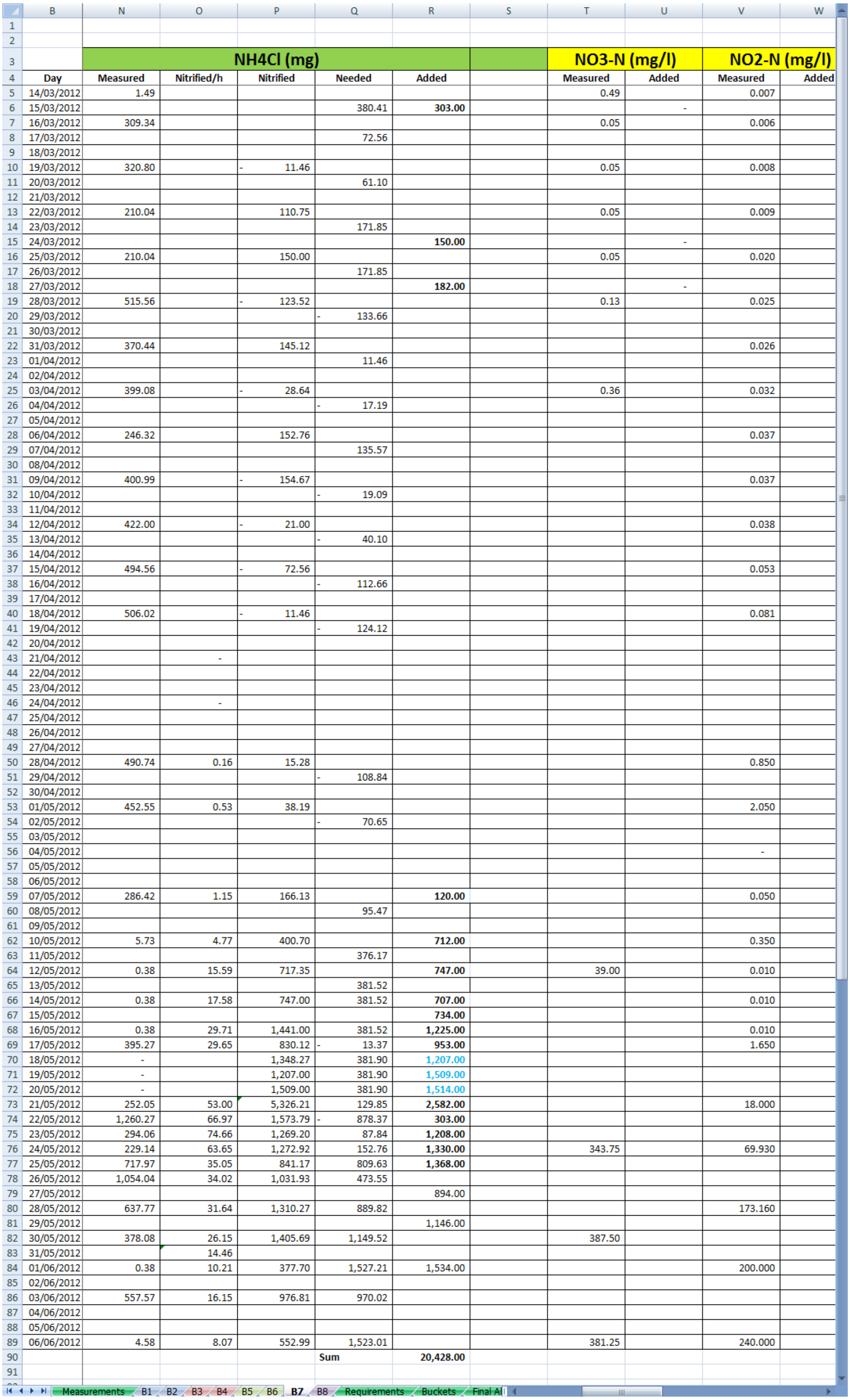
	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		NH4Cl (mg)						NO3-N (mg/l)		NO2-N (mg/l)	
4	Day	Measured	Nitrified/h	Nitrified	Needed	Added		Measured	Added	Measured	Added
5	14/03/2012	1.30						0.41		0.003	
6	15/03/2012				380.60	**302.00**			-		
7	16/03/2012	324.61						0.68		0.004	
8	17/03/2012				57.28						
9	18/03/2012										
10	19/03/2012	307.43		17.19				0.05		0.006	
11	20/03/2012				74.47						
12	21/03/2012										
13	22/03/2012	231.05		76.38				0.05		0.007	
14	23/03/2012				150.85						
15	24/03/2012					**150.00**			-		
16	25/03/2012	234.87		146.18				0.05		0.016	
17	26/03/2012				147.03						
18	27/03/2012					**164.00**			-		
19	28/03/2012	563.30		- 164.43				0.05		0.022	
20	29/03/2012				- 181.40						
21	30/03/2012										
22	31/03/2012	383.81		179.49						0.025	
23	01/04/2012				- 1.91						
24	02/04/2012										
25	03/04/2012	374.26		9.55				0.24		0.024	
26	04/04/2012				7.64						
27	05/04/2012										
28	06/04/2012	232.96		141.30						0.024	
29	07/04/2012				148.94						
30	08/04/2012										
31	09/04/2012	381.90		- 148.94						0.024	
32	10/04/2012				-						
33	11/04/2012										
34	12/04/2012	477.37		- 95.47						0.022	
35	13/04/2012				- 95.47						
36	14/04/2012										
37	15/04/2012	498.38		- 21.00						0.028	
38	16/04/2012				- 116.48						
39	17/04/2012										
40	18/04/2012	506.02		- 7.64						0.034	
41	19/04/2012				- 124.12						
42	20/04/2012										
43	21/04/2012		-							0.058	
44	22/04/2012										
45	23/04/2012										
46	24/04/2012		-							0.143	
47	25/04/2012										
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	456.37	0.52	49.65						0.540	
51	29/04/2012				- 74.47						
52	30/04/2012										
53	01/05/2012	427.73	0.40	28.64						1.750	
54	02/05/2012				- 45.83						
55	03/05/2012										
56	04/05/2012							-		-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	173.76	1.76	253.96		**356.00**				6.900	
60	08/05/2012				208.14						
61	09/05/2012										
62	10/05/2012	166.13	4.33	363.64		**454.00**				11.400	
63	11/05/2012				215.77						
64	12/05/2012	0.38	13.47	619.74		**739.00**		35.50		0.010	
65	13/05/2012				381.52						
66	14/05/2012	164.22	13.53	575.17	217.68	**590.00**				0.630	
67	15/05/2012					**711.00**					
68	16/05/2012	82.49	28.51	1,382.73	299.41	**1,118.00**				0.800	
69	17/05/2012	284.51	32.71	915.98	97.38	**1,038.00**				1.150	
70	18/05/2012	-		1,322.51	381.90	**1,219.00**					
71	19/05/2012	-		1,219.00	381.90	**1,502.00**					
72	20/05/2012	-		1,502.00	381.90	**1,499.00**					
73	21/05/2012	0.38	55.15	5,542.13	381.52	**2,633.00**				1.000	
74	22/05/2012	710.33	81.83	1,923.05	- 328.43	**893.00**					
75	23/05/2012	194.77	82.86	1,408.56	187.13	**1,298.00**					
76	24/05/2012	198.59	64.71	1,294.18	183.31	**1,369.00**		306.25		106.560	
77	25/05/2012	970.02	24.90	597.56	557.57	**1,082.00**					
78	26/05/2012	1,424.48	20.69	627.54	103.11						
79	27/05/2012					352.00					
80	28/05/2012	943.29	20.12	833.19	584.31					169.830	
81	29/05/2012					757.00					
82	30/05/2012	542.30	21.54	1,157.99	985.30			343.75			
83	31/05/2012		25.17								
84	01/06/2012	0.38	14.65	541.91	1,527.21	1,545.00	12:00			215.000	
85	02/06/2012										
86	03/06/2012	1,283.18	4.33	262.20	244.42						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	572.85	10.37	710.33	954.75			343.75		235.000	
90					**Sum**	**19,771.00**					
91											

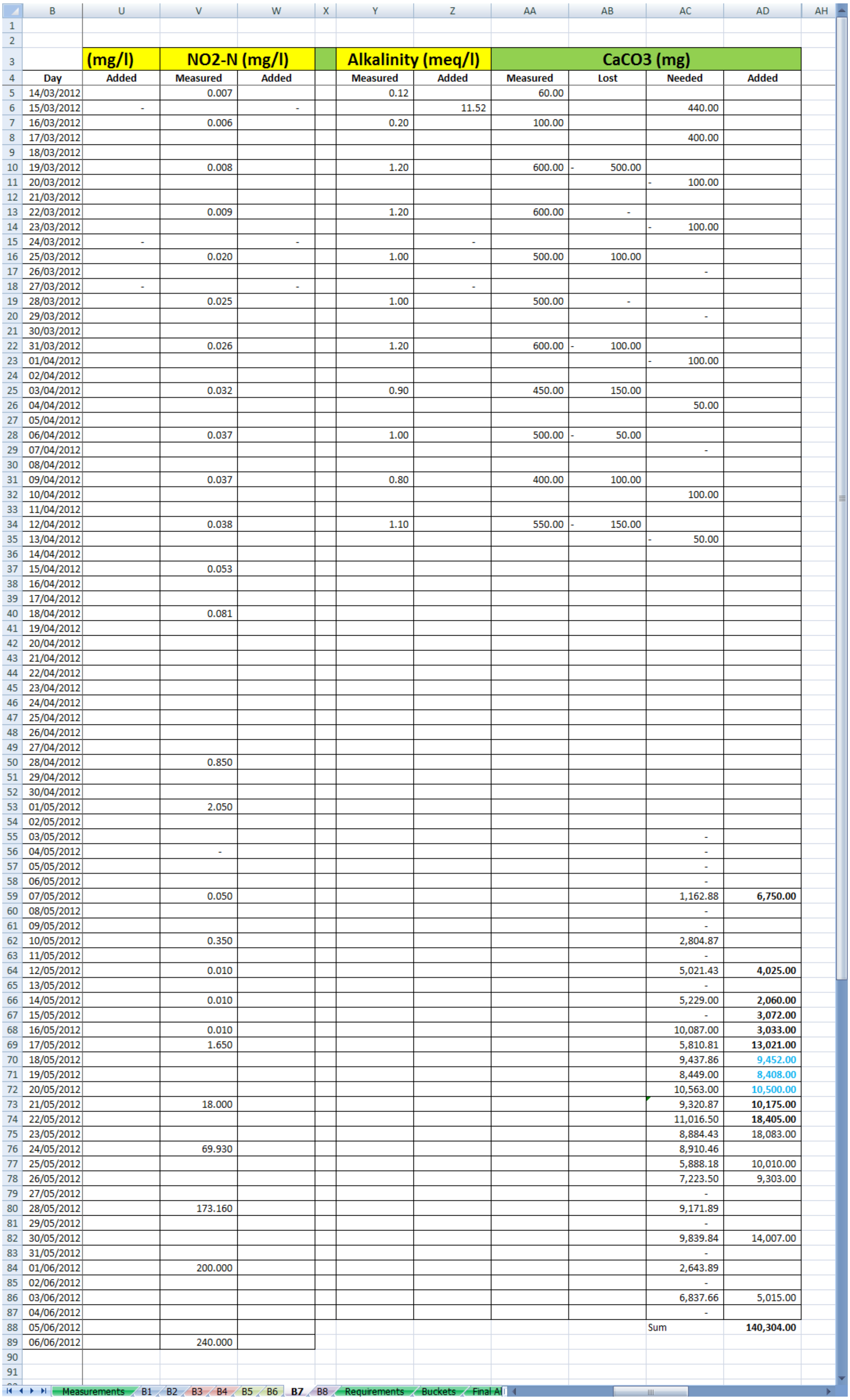


	B	U	V	W	X	Y	Z	AA	AB	AC	AD	AH
1												
2												
3		**(mg/l)**	**NO2-N (mg/l)**			**Alkalinity (meq/l)**		**CaCO3 (mg)**				
4	**Day**	**Added**	**Measured**	**Added**		**Measured**	**Added**	**Measured**	**Lost**	**Needed**	**Added**	
5	14/03/2012		0.003			0.12		60.00				
6	15/03/2012	-		-			11.52			440.00		
7	16/03/2012		0.004			0.20		100.00				
8	17/03/2012									400.00		
9	18/03/2012											
10	19/03/2012		0.006			1.20		600.00	- 500.00			
11	20/03/2012									- 100.00		
12	21/03/2012											
13	22/03/2012		0.007			1.20		600.00	-			
14	23/03/2012									- 100.00		
15	24/03/2012	-		-			-					
16	25/03/2012		0.016			1.00		500.00	100.00			
17	26/03/2012									-		
18	27/03/2012	-		-			-					
19	28/03/2012		0.022			1.00		500.00	-			
20	29/03/2012									-		
21	30/03/2012											
22	31/03/2012		0.025			1.20		600.00	- 100.00			
23	01/04/2012									- 100.00		
24	02/04/2012											
25	03/04/2012		0.024			0.90		450.00	150.00			
26	04/04/2012									50.00		
27	05/04/2012											
28	06/04/2012		0.024			1.00		500.00	- 50.00			
29	07/04/2012									-		
30	08/04/2012											
31	09/04/2012		0.024			0.80		400.00	100.00			
32	10/04/2012									100.00		
33	11/04/2012											
34	12/04/2012		0.022			1.10		550.00	- 150.00			
35	13/04/2012									- 50.00		
36	14/04/2012											
37	15/04/2012		0.028									
38	16/04/2012											
39	17/04/2012											
40	18/04/2012		0.034									
41	19/04/2012											
42	20/04/2012											
43	21/04/2012		0.058									
44	22/04/2012											
45	23/04/2012											
46	24/04/2012		0.143									
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		0.540									
51	29/04/2012											
52	30/04/2012											
53	01/05/2012		1.750									
54	02/05/2012											
55	03/05/2012									-		
56	04/05/2012		-							-		
57	05/05/2012									-		
58	06/05/2012									-		
59	07/05/2012		6.900							1,777.74	**4,750.00**	
60	08/05/2012									-		
61	09/05/2012									-		
62	10/05/2012		11.400							2,545.47		
63	11/05/2012									-		
64	12/05/2012		0.010							4,338.21	**4,023.00**	
65	13/05/2012									-		
66	14/05/2012		0.630							4,026.16	**2,005.00**	
67	15/05/2012									-	**3,014.00**	
68	16/05/2012		0.800							9,679.08	**3,045.00**	
69	17/05/2012		1.150							6,411.83	**10,041.00**	
70	18/05/2012									9,257.60	9,252.00	
71	19/05/2012									8,533.00	8,395.00	
72	20/05/2012									10,514.00	10,503.00	
73	21/05/2012		1.000							9,698.73		
74	22/05/2012									13,461.35	16,817.00	
75	23/05/2012									9,859.95	18,028.00	
76	24/05/2012		106.560							9,059.27		
77	25/05/2012									4,182.95	10,050.00	
78	26/05/2012									4,392.78		
79	27/05/2012									-		
80	28/05/2012		169.830							5,832.35		
81	29/05/2012									-		
82	30/05/2012									8,105.96	12,023.00	
83	31/05/2012									-		
84	01/06/2012		215.000							3,793.40		
85	02/06/2012									-		
86	03/06/2012									1,835.41		
87	04/06/2012											
88	05/06/2012									**Sum**	**111,946.00**	
89	06/06/2012		235.000									
90												
91												

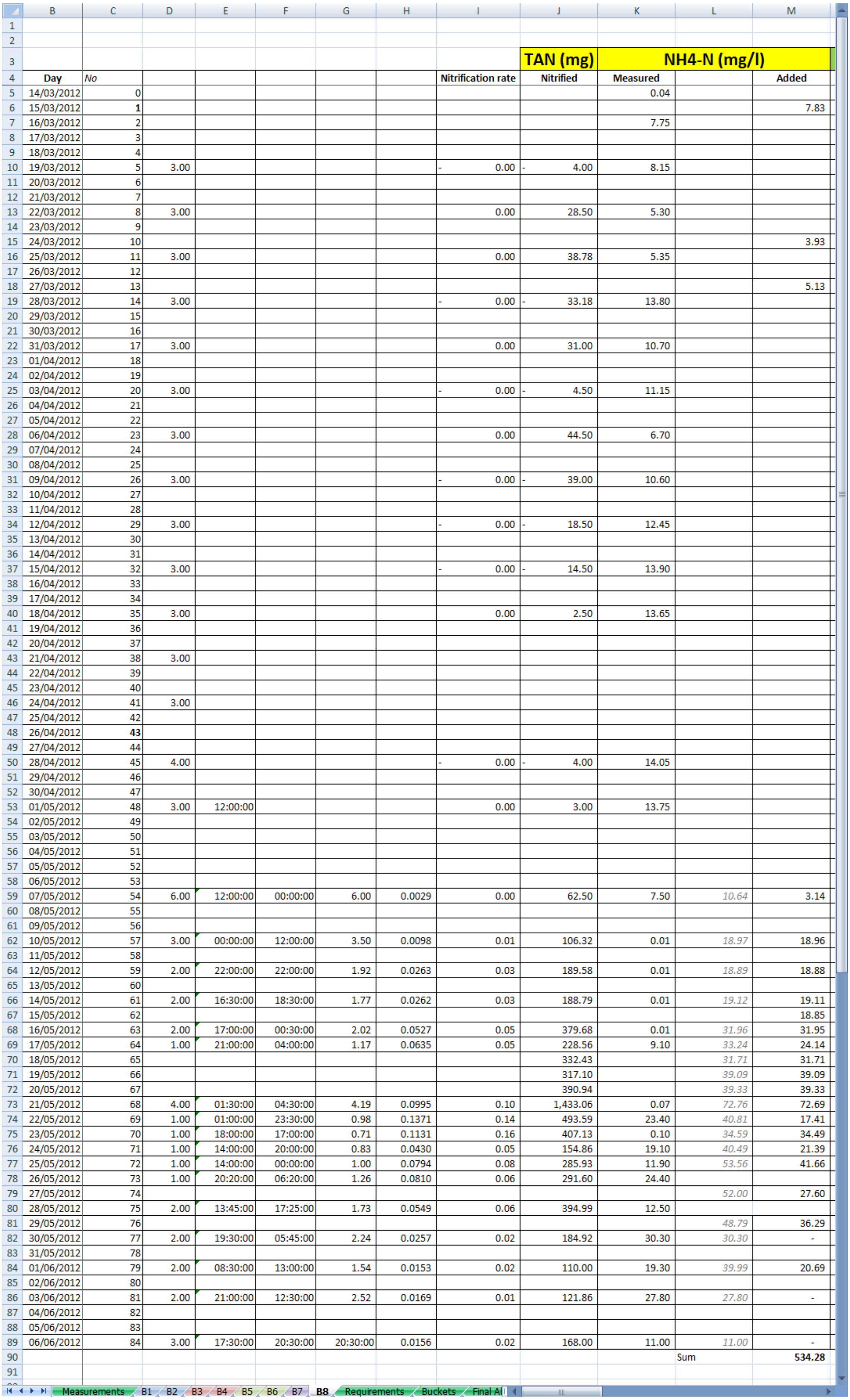


	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									TAN (mg)	NH4-N (mg/l)		
4	Day	*No*						Nitrification rate	Nitrified	Measured		Added
5	14/03/2012	0								0.04		
6	15/03/2012	**1**										7.93
7	16/03/2012	2								8.10		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					- 0.00	- 3.00	8.40		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	29.00	5.50		
14	23/03/2012	9										
15	24/03/2012	10										3.93
16	25/03/2012	11	3.00					0.00	39.28	5.50		
17	26/03/2012	12										
18	27/03/2012	13										4.77
19	28/03/2012	14	3.00					- 0.00	- 32.34	13.50		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	38.00	9.70		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 7.50	10.45		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	40.00	6.45		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 40.50	10.50		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 5.50	11.05		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					- 0.00	- 19.00	12.95		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					- 0.00	- 3.00	13.25		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00									
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00									
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					0.00	4.00	12.85		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.00	10.00	11.85		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0020	0.00	43.50	7.50	*10.64*	3.14
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0097	0.01	104.92	0.15	*18.79*	18.64
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0261	0.03	187.84	0.01	*19.57*	19.56
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0272	0.03	195.60	0.01	*18.52*	18.51
67	15/05/2012	62										19.22
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0524	0.05	377.32	0.01	*32.09*	32.08
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0604	0.05	217.37	10.35	*35.30*	24.95
70	18/05/2012	65							353.04		*31.61*	31.61
71	19/05/2012	66							316.05		*39.51*	39.51
72	20/05/2012	67							395.13		*39.64*	39.64
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.0969	0.09	1,394.66	6.60	*74.21*	67.61
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.1145	0.12	412.09	33.00	*40.93*	7.93
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.0923	0.13	332.34	7.70	*39.33*	31.63
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0926	0.11	333.31	6.00	*40.83*	34.83
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0612	0.06	220.26	18.80	*54.62*	35.82
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0751	0.06	270.21	27.60		
79	27/05/2012	74									*51.01*	23.41
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0477	0.06	343.09	16.70		
81	29/05/2012	76									*46.71*	30.01
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0511	0.05	368.08	9.90		
83	31/05/2012	78									*9.90*	-
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0137	0.02	98.90	0.01	*40.18*	40.17
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	0.0355	0.03	255.78	14.60	*14.60*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	2.85	0.0134	0.01	144.80	0.12	*0.12*	-
90											Sum	**534.91**
91												

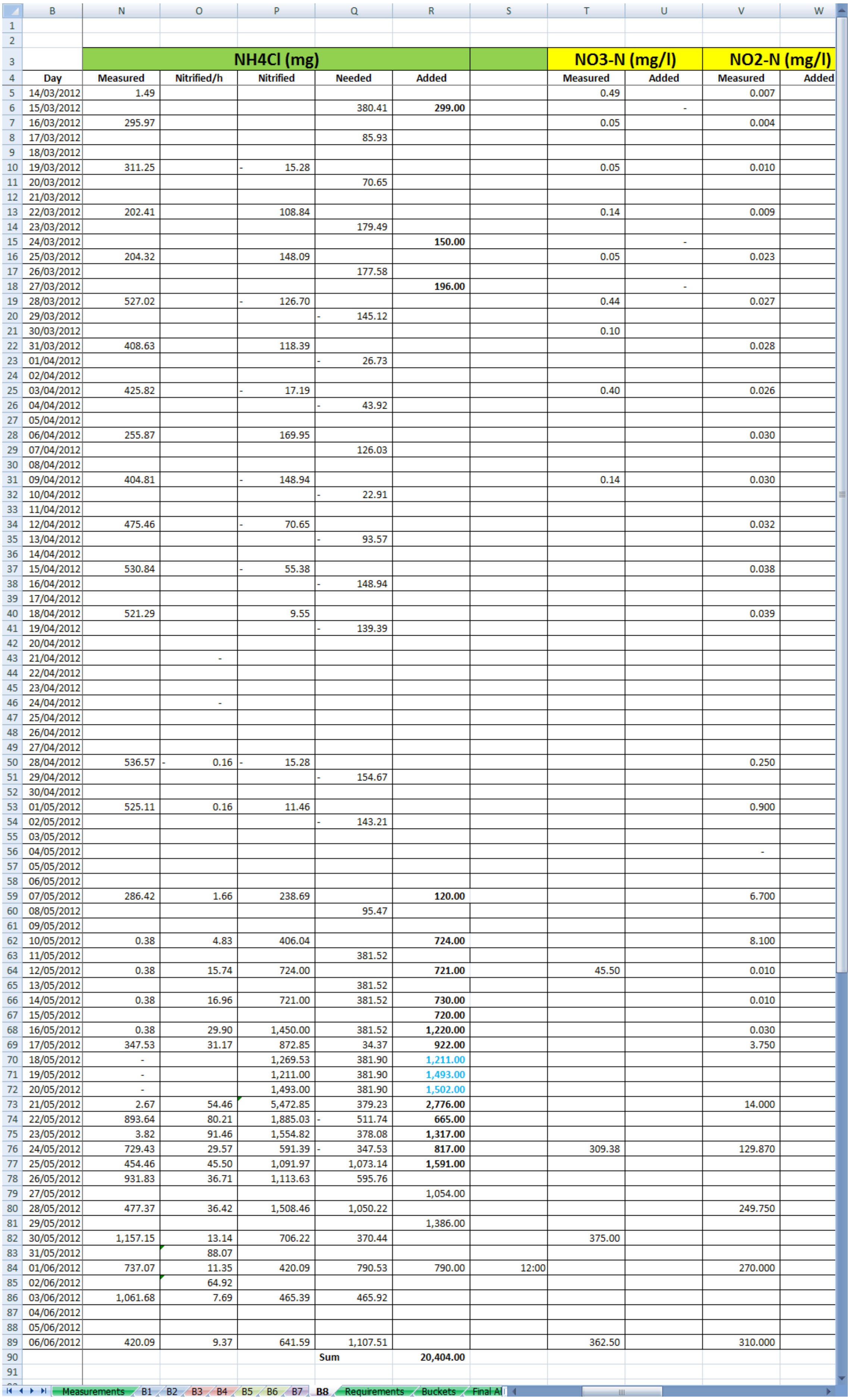




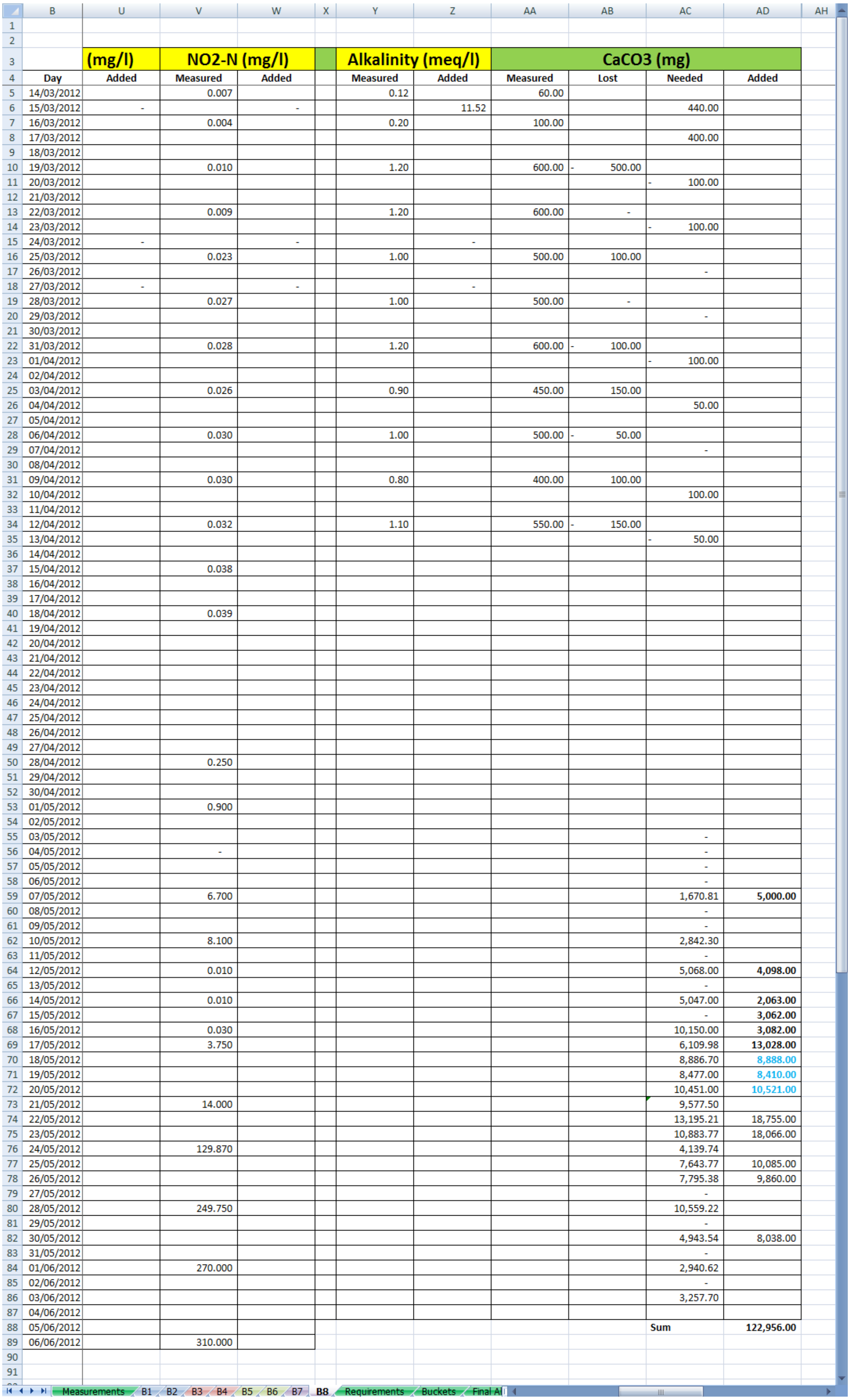
	B	U	V	W	X	Y	Z	AA	AB	AC	AD	AH
1												
2												
3		(mg/l)	NO2-N (mg/l)			Alkalinity (meq/l)		CaCO3 (mg)				
4	Day	Added	Measured	Added		Measured	Added	Measured	Lost	Needed	Added	
5	14/03/2012		0.007			0.12		60.00				
6	15/03/2012	-		-			11.52			440.00		
7	16/03/2012		0.006			0.20		100.00				
8	17/03/2012									400.00		
9	18/03/2012											
10	19/03/2012		0.008			1.20		600.00	- 500.00			
11	20/03/2012									- 100.00		
12	21/03/2012											
13	22/03/2012		0.009			1.20		600.00	-			
14	23/03/2012									- 100.00		
15	24/03/2012	-		-			-					
16	25/03/2012		0.020			1.00		500.00	100.00			
17	26/03/2012									-		
18	27/03/2012	-		-			-					
19	28/03/2012		0.025			1.00		500.00	-			
20	29/03/2012									-		
21	30/03/2012											
22	31/03/2012		0.026			1.20		600.00	- 100.00			
23	01/04/2012									- 100.00		
24	02/04/2012											
25	03/04/2012		0.032			0.90		450.00	150.00			
26	04/04/2012									50.00		
27	05/04/2012											
28	06/04/2012		0.037			1.00		500.00	- 50.00			
29	07/04/2012									-		
30	08/04/2012											
31	09/04/2012		0.037			0.80		400.00	100.00			
32	10/04/2012									100.00		
33	11/04/2012											
34	12/04/2012		0.038			1.10		550.00	- 150.00			
35	13/04/2012									- 50.00		
36	14/04/2012											
37	15/04/2012		0.053									
38	16/04/2012											
39	17/04/2012											
40	18/04/2012		0.081									
41	19/04/2012											
42	20/04/2012											
43	21/04/2012											
44	22/04/2012											
45	23/04/2012											
46	24/04/2012											
47	25/04/2012											
48	26/04/2012											
49	27/04/2012											
50	28/04/2012		0.850									
51	29/04/2012											
52	30/04/2012											
53	01/05/2012		2.050									
54	02/05/2012											
55	03/05/2012									-		
56	04/05/2012		-							-		
57	05/05/2012									-		
58	06/05/2012									-		
59	07/05/2012		0.050							1,162.88	**6,750.00**	
60	08/05/2012									-		
61	09/05/2012									-		
62	10/05/2012		0.350							2,804.87		
63	11/05/2012									-		
64	12/05/2012		0.010							5,021.43	**4,025.00**	
65	13/05/2012									-		
66	14/05/2012		0.010							5,229.00	**2,060.00**	
67	15/05/2012									-	**3,072.00**	
68	16/05/2012		0.010							10,087.00	**3,033.00**	
69	17/05/2012		1.650							5,810.81	**13,021.00**	
70	18/05/2012									9,437.86	9,452.00	
71	19/05/2012									8,449.00	8,408.00	
72	20/05/2012									10,563.00	10,500.00	
73	21/05/2012		18.000							9,320.87	**10,175.00**	
74	22/05/2012									11,016.50	**18,405.00**	
75	23/05/2012									8,884.43	18,083.00	
76	24/05/2012		69.930							8,910.46		
77	25/05/2012									5,888.18	10,010.00	
78	26/05/2012									7,223.50	9,303.00	
79	27/05/2012									-		
80	28/05/2012		173.160							9,171.89		
81	29/05/2012									-		
82	30/05/2012									9,839.84	14,007.00	
83	31/05/2012									-		
84	01/06/2012		200.000							2,643.89		
85	02/06/2012									-		
86	03/06/2012									6,837.66	5,015.00	
87	04/06/2012									-		
88	05/06/2012									Sum	**140,304.00**	
89	06/06/2012		240.000									
90												
91												



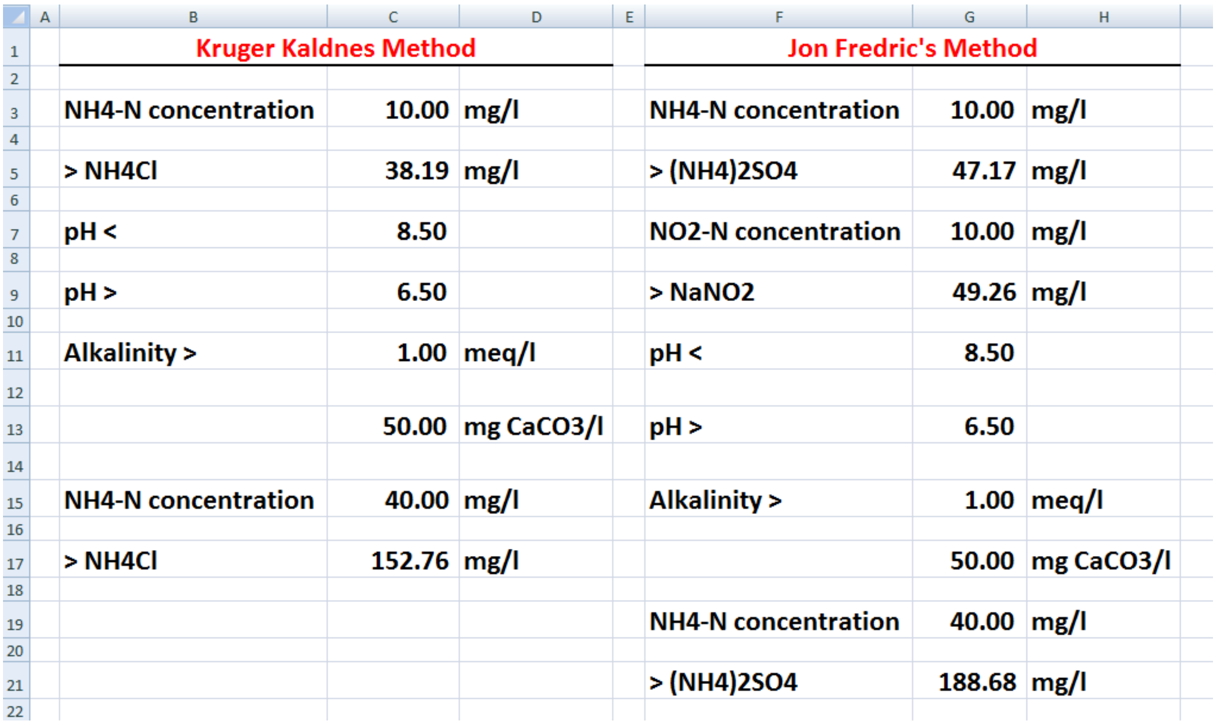
	B	C	D	E	F	G	H	I	J	K	L	M
1												
2												
3									**TAN (mg)**	**NH4-N (mg/l)**		
4	**Day**	*No*						**Nitrification rate**	**Nitrified**	**Measured**		**Added**
5	14/03/2012	0								0.04		
6	15/03/2012	**1**										7.83
7	16/03/2012	2								7.75		
8	17/03/2012	3										
9	18/03/2012	4										
10	19/03/2012	5	3.00					- 0.00	- 4.00	8.15		
11	20/03/2012	6										
12	21/03/2012	7										
13	22/03/2012	8	3.00					0.00	28.50	5.30		
14	23/03/2012	9										
15	24/03/2012	10										3.93
16	25/03/2012	11	3.00					0.00	38.78	5.35		
17	26/03/2012	12										
18	27/03/2012	13										5.13
19	28/03/2012	14	3.00					- 0.00	- 33.18	13.80		
20	29/03/2012	15										
21	30/03/2012	16										
22	31/03/2012	17	3.00					0.00	31.00	10.70		
23	01/04/2012	18										
24	02/04/2012	19										
25	03/04/2012	20	3.00					- 0.00	- 4.50	11.15		
26	04/04/2012	21										
27	05/04/2012	22										
28	06/04/2012	23	3.00					0.00	44.50	6.70		
29	07/04/2012	24										
30	08/04/2012	25										
31	09/04/2012	26	3.00					- 0.00	- 39.00	10.60		
32	10/04/2012	27										
33	11/04/2012	28										
34	12/04/2012	29	3.00					- 0.00	- 18.50	12.45		
35	13/04/2012	30										
36	14/04/2012	31										
37	15/04/2012	32	3.00					- 0.00	- 14.50	13.90		
38	16/04/2012	33										
39	17/04/2012	34										
40	18/04/2012	35	3.00					0.00	2.50	13.65		
41	19/04/2012	36										
42	20/04/2012	37										
43	21/04/2012	38	3.00									
44	22/04/2012	39										
45	23/04/2012	40										
46	24/04/2012	41	3.00									
47	25/04/2012	42										
48	26/04/2012	**43**										
49	27/04/2012	44										
50	28/04/2012	45	4.00					- 0.00	- 4.00	14.05		
51	29/04/2012	46										
52	30/04/2012	47										
53	01/05/2012	48	3.00	12:00:00				0.00	3.00	13.75		
54	02/05/2012	49										
55	03/05/2012	50										
56	04/05/2012	51										
57	05/05/2012	52										
58	06/05/2012	53										
59	07/05/2012	54	6.00	12:00:00	00:00:00	6.00	0.0029	0.00	62.50	7.50	*10.64*	3.14
60	08/05/2012	55										
61	09/05/2012	56										
62	10/05/2012	57	3.00	00:00:00	12:00:00	3.50	0.0098	0.01	106.32	0.01	*18.97*	18.96
63	11/05/2012	58										
64	12/05/2012	59	2.00	22:00:00	22:00:00	1.92	0.0263	0.03	189.58	0.01	*18.89*	18.88
65	13/05/2012	60										
66	14/05/2012	61	2.00	16:30:00	18:30:00	1.77	0.0262	0.03	188.79	0.01	*19.12*	19.11
67	15/05/2012	62										18.85
68	16/05/2012	63	2.00	17:00:00	00:30:00	2.02	0.0527	0.05	379.68	0.01	*31.96*	31.95
69	17/05/2012	64	1.00	21:00:00	04:00:00	1.17	0.0635	0.05	228.56	9.10	*33.24*	24.14
70	18/05/2012	65							332.43		*31.71*	31.71
71	19/05/2012	66							317.10		*39.09*	39.09
72	20/05/2012	67							390.94		*39.33*	39.33
73	21/05/2012	68	4.00	01:30:00	04:30:00	4.19	0.0995	0.10	1,433.06	0.07	*72.76*	72.69
74	22/05/2012	69	1.00	01:00:00	23:30:00	0.98	0.1371	0.14	493.59	23.40	*40.81*	17.41
75	23/05/2012	70	1.00	18:00:00	17:00:00	0.71	0.1131	0.16	407.13	0.10	*34.59*	34.49
76	24/05/2012	71	1.00	14:00:00	20:00:00	0.83	0.0430	0.05	154.86	19.10	*40.49*	21.39
77	25/05/2012	72	1.00	14:00:00	00:00:00	1.00	0.0794	0.08	285.93	11.90	*53.56*	41.66
78	26/05/2012	73	1.00	20:20:00	06:20:00	1.26	0.0810	0.06	291.60	24.40		
79	27/05/2012	74									*52.00*	27.60
80	28/05/2012	75	2.00	13:45:00	17:25:00	1.73	0.0549	0.06	394.99	12.50		
81	29/05/2012	76									*48.79*	36.29
82	30/05/2012	77	2.00	19:30:00	05:45:00	2.24	0.0257	0.02	184.92	30.30	*30.30*	-
83	31/05/2012	78										
84	01/06/2012	79	2.00	08:30:00	13:00:00	1.54	0.0153	0.02	110.00	19.30	*39.99*	20.69
85	02/06/2012	80										
86	03/06/2012	81	2.00	21:00:00	12:30:00	2.52	0.0169	0.01	121.86	27.80	*27.80*	-
87	04/06/2012	82										
88	05/06/2012	83										
89	06/06/2012	84	3.00	17:30:00	20:30:00	20:30:00	0.0156	0.02	168.00	11.00	*11.00*	-
90											Sum	**534.28**
91												



	B	N	O	P	Q	R	S	T	U	V	W
1											
2											
3		NH4Cl (mg)						NO3-N (mg/l)		NO2-N (mg/l)	
4	Day	Measured	Nitrified/h	Nitrified	Needed	Added		Measured	Added	Measured	Added
5	14/03/2012	1.49						0.49		0.007	
6	15/03/2012				380.41	**299.00**			-		
7	16/03/2012	295.97						0.05		0.004	
8	17/03/2012				85.93						
9	18/03/2012										
10	19/03/2012	311.25		- 15.28				0.05		0.010	
11	20/03/2012				70.65						
12	21/03/2012										
13	22/03/2012	202.41		108.84				0.14		0.009	
14	23/03/2012				179.49						
15	24/03/2012					**150.00**			-		
16	25/03/2012	204.32		148.09				0.05		0.023	
17	26/03/2012				177.58						
18	27/03/2012					**196.00**			-		
19	28/03/2012	527.02		- 126.70				0.44		0.027	
20	29/03/2012				- 145.12						
21	30/03/2012							0.10			
22	31/03/2012	408.63		118.39						0.028	
23	01/04/2012				- 26.73						
24	02/04/2012										
25	03/04/2012	425.82		- 17.19				0.40		0.026	
26	04/04/2012				- 43.92						
27	05/04/2012										
28	06/04/2012	255.87		169.95						0.030	
29	07/04/2012				126.03						
30	08/04/2012										
31	09/04/2012	404.81		- 148.94				0.14		0.030	
32	10/04/2012				- 22.91						
33	11/04/2012										
34	12/04/2012	475.46		- 70.65						0.032	
35	13/04/2012				- 93.57						
36	14/04/2012										
37	15/04/2012	530.84		- 55.38						0.038	
38	16/04/2012				- 148.94						
39	17/04/2012										
40	18/04/2012	521.29		9.55						0.039	
41	19/04/2012				- 139.39						
42	20/04/2012										
43	21/04/2012		-								
44	22/04/2012										
45	23/04/2012										
46	24/04/2012		-								
47	25/04/2012										
48	26/04/2012										
49	27/04/2012										
50	28/04/2012	536.57	- 0.16	- 15.28						0.250	
51	29/04/2012				- 154.67						
52	30/04/2012										
53	01/05/2012	525.11	0.16	11.46						0.900	
54	02/05/2012				- 143.21						
55	03/05/2012										
56	04/05/2012									-	
57	05/05/2012										
58	06/05/2012										
59	07/05/2012	286.42	1.66	238.69		**120.00**				6.700	
60	08/05/2012				95.47						
61	09/05/2012										
62	10/05/2012	0.38	4.83	406.04		**724.00**				8.100	
63	11/05/2012				381.52						
64	12/05/2012	0.38	15.74	724.00		**721.00**		45.50		0.010	
65	13/05/2012				381.52						
66	14/05/2012	0.38	16.96	721.00	381.52	**730.00**				0.010	
67	15/05/2012					**720.00**					
68	16/05/2012	0.38	29.90	1,450.00	381.52	**1,220.00**				0.030	
69	17/05/2012	347.53	31.17	872.85	34.37	**922.00**				3.750	
70	18/05/2012	-		1,269.53	381.90	**1,211.00**					
71	19/05/2012	-		1,211.00	381.90	**1,493.00**					
72	20/05/2012	-		1,493.00	381.90	**1,502.00**					
73	21/05/2012	2.67	54.46	5,472.85	379.23	**2,776.00**				14.000	
74	22/05/2012	893.64	80.21	1,885.03	- 511.74	**665.00**					
75	23/05/2012	3.82	91.46	1,554.82	378.08	**1,317.00**					
76	24/05/2012	729.43	29.57	591.39	- 347.53	**817.00**		309.38		129.870	
77	25/05/2012	454.46	45.50	1,091.97	1,073.14	**1,591.00**					
78	26/05/2012	931.83	36.71	1,113.63	595.76						
79	27/05/2012					1,054.00					
80	28/05/2012	477.37	36.42	1,508.46	1,050.22					249.750	
81	29/05/2012					1,386.00					
82	30/05/2012	1,157.15	13.14	706.22	370.44			375.00			
83	31/05/2012		88.07								
84	01/06/2012	737.07	11.35	420.09	790.53	790.00	12:00			270.000	
85	02/06/2012		64.92								
86	03/06/2012	1,061.68	7.69	465.39	465.92						
87	04/06/2012										
88	05/06/2012										
89	06/06/2012	420.09	9.37	641.59	1,107.51			362.50		310.000	
90					**Sum**	**20,404.00**					
91											



	B	U	V	W	X	Y	Z	AA	AB	AC	AD
1											
2											
3		(mg/l)	NO2-N (mg/l)			Alkalinity (meq/l)		CaCO3 (mg)			
4	Day	Added	Measured	Added		Measured	Added	Measured	Lost	Needed	Added
5	14/03/2012		0.007			0.12		60.00			
6	15/03/2012	-		-			11.52			440.00	
7	16/03/2012		0.004			0.20		100.00			
8	17/03/2012									400.00	
9	18/03/2012										
10	19/03/2012		0.010			1.20		600.00	- 500.00		
11	20/03/2012									- 100.00	
12	21/03/2012										
13	22/03/2012		0.009			1.20		600.00	-		
14	23/03/2012									- 100.00	
15	24/03/2012	-		-			-				
16	25/03/2012		0.023			1.00		500.00	100.00		
17	26/03/2012									-	
18	27/03/2012	-		-			-				
19	28/03/2012		0.027			1.00		500.00	-		
20	29/03/2012									-	
21	30/03/2012										
22	31/03/2012		0.028			1.20		600.00	- 100.00		
23	01/04/2012									- 100.00	
24	02/04/2012										
25	03/04/2012		0.026			0.90		450.00	150.00		
26	04/04/2012									50.00	
27	05/04/2012										
28	06/04/2012		0.030			1.00		500.00	- 50.00		
29	07/04/2012									-	
30	08/04/2012										
31	09/04/2012		0.030			0.80		400.00	100.00		
32	10/04/2012									100.00	
33	11/04/2012										
34	12/04/2012		0.032			1.10		550.00	- 150.00		
35	13/04/2012									- 50.00	
36	14/04/2012										
37	15/04/2012		0.038								
38	16/04/2012										
39	17/04/2012										
40	18/04/2012		0.039								
41	19/04/2012										
42	20/04/2012										
43	21/04/2012										
44	22/04/2012										
45	23/04/2012										
46	24/04/2012										
47	25/04/2012										
48	26/04/2012										
49	27/04/2012										
50	28/04/2012		0.250								
51	29/04/2012										
52	30/04/2012										
53	01/05/2012		0.900								
54	02/05/2012										
55	03/05/2012									-	
56	04/05/2012		-							-	
57	05/05/2012									-	
58	06/05/2012									-	
59	07/05/2012		6.700							1,670.81	**5,000.00**
60	08/05/2012									-	
61	09/05/2012									-	
62	10/05/2012		8.100							2,842.30	
63	11/05/2012									-	
64	12/05/2012		0.010							5,068.00	**4,098.00**
65	13/05/2012									-	
66	14/05/2012		0.010							5,047.00	**2,063.00**
67	15/05/2012									-	**3,062.00**
68	16/05/2012		0.030							10,150.00	**3,082.00**
69	17/05/2012		3.750							6,109.98	**13,028.00**
70	18/05/2012									8,886.70	**8,888.00**
71	19/05/2012									8,477.00	**8,410.00**
72	20/05/2012									10,451.00	**10,521.00**
73	21/05/2012		14.000							9,577.50	
74	22/05/2012									13,195.21	18,755.00
75	23/05/2012									10,883.77	18,066.00
76	24/05/2012		129.870							4,139.74	
77	25/05/2012									7,643.77	10,085.00
78	26/05/2012									7,795.38	9,860.00
79	27/05/2012									-	
80	28/05/2012		249.750							10,559.22	
81	29/05/2012									-	
82	30/05/2012									4,943.54	8,038.00
83	31/05/2012									-	
84	01/06/2012		270.000							2,940.62	
85	02/06/2012									-	
86	03/06/2012									3,257.70	
87	04/06/2012										
88	05/06/2012									**Sum**	**122,956.00**
89	06/06/2012		310.000								
90											
91											



	A	B	C	D	E	F	G	H
1		Kruger Kaldnes Method				Jon Fredric's Method		
2								
3		NH4-N concentration	10.00	mg/l		NH4-N concentration	10.00	mg/l
4								
5		> NH4Cl	38.19	mg/l		> (NH4)2SO4	47.17	mg/l
6								
7		pH <	8.50			NO2-N concentration	10.00	mg/l
8								
9		pH >	6.50			> NaNO2	49.26	mg/l
10								
11		Alkalinity >	1.00	meq/l		pH <	8.50	
12								
13			50.00	mg CaCO3/l		pH >	6.50	
14								
15		NH4-N concentration	40.00	mg/l		Alkalinity >	1.00	meq/l
16								
17		> NH4Cl	152.76	mg/l			50.00	mg CaCO3/l
18								
19						NH4-N concentration	40.00	mg/l
20								
21						> (NH4)2SO4	188.68	mg/l
22								