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Pollution Loads on Sewer

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Preface

This study is intended for the completion of two years Master's Degree (30 credits) in specialization program "Sustainable Water and Sanitation, Health and Development" at the Faculty of Sciences and Technology in Norwegian University of Life Sciences (NMBU), Norway. The research for this study is in cooperation with Asker Municipality and Rosim AS.

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For the gained experience during the study period, I would be forever thankful to my supervisor and co-supervisor along with all the supporting and encouraging people. My special thanks to my parents and my husband Er Asim Lamsal for the help, support and encouragement during the study period and thesis.

Somita Giri

Abstract

The increasing water problems and environmental pollutions have been a crucial matter of interest due to its adverse impact on the human life and environment. The stringent environmental regulations thereby, are enforced by the concern authorities as a measure of environmental protection and sustainability. The objectives of this study are to analyze various sewer parameters manually using online and offline measurements, identify the correlation between sewer parameters from multivariate statistical tool (Unscrambler X), search for the innovative measurement concept based on time and cost effective correlated sewer parameters to estimate some expensive and slow responding sewer parameters. In addition, quantifying the pollutant loads in the sanitary sewage influent. Therefore, effective, efficient and optimal treatment of the wastewater along with the proper regulation of the environmental laws can be achieved.

A total 9 days 24-hour sewage sample series with the time interval of 1 hour, were collected by autosampler from January to April 2018. The sampling was done from the upstream separate sanitary sewer line at Våkas in Asker municipality. The global wastewater parameters pH, conductivity, total suspended solids, turbidity, Nitrate (NO_3), Ammonium (NH_4), Orthophosphate (PO_4), Total phosphorus and COD were measured in the Laboratory at NMBU. The nutrients were measured from automated colorimeter, Systea EasyChem Plus. The flow data collected from the Regnbyge.no indicated 3 times increment in the average sewage flow rate during WWF (sewage flow rate higher than $0.02 m^3/s$) in comparison to DWF. The high degree of infiltration into the sewer networks possibly from the nearby water stream and surface runoffs during rainfall and snowmelt events were observed. The pollutants concentration significantly reduced during wet weather due to the dilution of the dry weather sanitary sewage from infiltrated groundwater and surface runoffs. It was observed that the characteristics of influent wastewater varies temporally and are highly influenced by the characteristics and environmental exposures of the catchment area such as average rate of water supply (lpcd), population size and living style, climatic condition, seasonal variation and peak hours of day (morning and evening). With the average sewage flow rate of $0.027 \pm 0.020 m^3/s$, average pollutant concentration in overall samples were found to be 8.399 ± 7.112 mg/l for ammonium, 1.275 ± 1.030 mg/l for nitrate, 165.340 ± 150.072mg/l for COD, 1.126 ± 1.069 mg/l for orthophosphate and 2.02 ± 1.882 mg/l for total phosphorus. The average pH, conductivity, turbidity and TSS measured in the laboratory were found to be 7.52 ± 0.534, 496.58 ± 65.5 µS/cm, 38.83 ± 37.57 NTU and 89.54 ± 79.31 mg/l respectively.

There is an urgent need of proper maintenance of the leaky sewer network system to prevent possible sewage overflow during wet weathers and high environmental contamination risks. From PCA, strong correlation between atmospheric temperature and sewage flow rate was observed which has inverse relation with another correlated group of parameters namely turbidity, TSS, nitrate, ammonium, orthophosphate, total phosphorus and conductivity. The highly correlated parameters that are easy, simple and fast to measure can be used to estimate slow responding and costly parameters such as COD, total phosphorus. This can save the energy and resources up to a great extent. Additionally, new innovative ideas for the virtual sensor development can be obtained from further multivariate statistical analysis.

Abbreviations

H	: Hydrogen
O	: Oxygen
WHO	: World Health Organization
DWF	: Dry Weather Flow
WWF	: Wet Weather Flow
MS Excel	: Microsoft office Excel
pe	: Population equivalent
sq	: Square
VAT	: Value Added Tax
NOK	: Norwegian Krone
Lab	: Laboratory
SCADA	: Supervisory Control and Data Acquisition
N	: North
E	: East
GIS	: Geographic Information System
Kg	: Kilogram
g	: gram
WWTP	: Wastewater Treatment Plant
CSO	: Combined Sewer Overflow
mg/l	: milligram per liter
mg/hr	: milligram per hour
µS/cm	: microsiemens per centimeter
ISO standard	: International Organization for Standardization
NTU	: Nephelometric Turbidity Unit
FNU	: Formazin Nephelometric Unit
NO_3	: Nitrate
NH_3	: Ammonia
NH_4	: Ammonium
nm	: nanometer

COD	: Chemical Oxygen Demand
Ortho-P/ O-P/ /ORTHOp/PO_4	: Orthophosphate
T-P /TP/Tot-PP	: Total phosphorus
BOD_5	: Biological Oxygen Demand after 5 days incubation
CR_3^+	: Chromium ion
PCA	: Principal Component Analysis
TSS	: Total Suspended Solids
RPM	: Revolutions per minute
ml	: milliliter
mm	: millimeter
km	: kilometer
m.a.s.l	: meters above sea level
HDPE	: High-density polyethylene
μm	: micrometer
O. D	: Optical Density
UV	: Ultraviolet
mV	: millivolt
KCL	: Potassium Chloride
AgCl	: Silver Chloride
am	: anti meridiem
pm	: post meridiem
HCO_3	: bicarbonate
lpcd	: liters per capita per day
DI water	: Deionized water

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1. Introduction

1.1 Background

Water covers about 71 % of the Earth surface in different forms like seas, oceans, rivers, lakes, glaciers, and in air vapor (Perlman). Out of it only 2.5 % is fresh water that is required to sustain lives. The remaining 96.5% is ocean water and 0.9 % is in other saline water form (Perlman). Water is a universal solvent with two atoms of hydrogen (H_2) and one atom of oxygen (O). Water is good at dissolving polar molecules, but it is not that good for non-polar such as oils and fats. It is an very essential basis of any life without which lives cannot be imagined. Water is used for numerous purposes in our daily life as such drinking, cooking, bathing, gardening, cleaning and so on. According to *Water sanitation hygiene* by WHO," *A higher quantity of about 20 litres per capita per day should be assured to take care of basic hygiene needs and basic food hygiene. Laundry/bathing might require higher amounts unless carried out at source*.". However, water consumption rate varies with the development of the nations and the available resources. In Norway, average household consumption per capita per day (liter) was 190 in 2016 (sentralbyrå). Safe, secure and sufficient water is necessary for a healthy life and environment. Being a universal solvent, it is more susceptible for carrying contaminants and pollutants during the water cycle process (flow of water from atmosphere to the ground surface and vice versa). The present substances that has negative impact to the living creatures and deteriorates the water quality, are called pollutants. Such as pathogens, particles, harmful and toxic chemicals, heavy metals, nitrogen, phosphorus etc. These pollutants are detrimental for human health because it causes catastrophic diseases such as typhoid, diarrhea, dysentery, polio and so on. The water containing nutrients and heavy metals indicate potential threats to human health (Korostynska et al., 2012). In 2010, every day 2,200 children died from diarrheal diseases along (Liu et al., 2012). However, many efforts are continuously carried out to control and prevent these hazards but are not still sufficient till date specially in the developing countries. Not only to the human health, contaminated water also harms the other living creatures and environment causing eutrophication of water bodies, pollution of the environmental elements such as air, water and soil, loss of aquatic lives, reduces aesthetic beauty of the environment. Infiltrated contaminated water pollutes groundwater and reduces the soil fertility which effects food crop productions and so on.

The rising water problems and environmental pollutions has been a crucial matter of interest. The quantity and quality of the water prior and after the use as a drinking water and wastewater respectively, is a very important matter which directly affects human lives and environment. From this, emerges the need of proper documentation of pollutant loads in the effluent as well as in influent wastewater of the treatment plant. There are various factors which affect the water quality and quantity such as climate change, global warming, rapid population growth, over-exploitation of natural resources, unplanned urbanization and industrialization, improper disposal of solid and liquid waste, leakage of sewer pipelines and pollutions. One of the effective way for environmental protection is proper collection, treatment and disposal of wastewater. As the untreated wastewater has higher potential for environmental pollutions, proper sewer network system and their monitoring and maintenance is of utmost necessity. The factors like, quality and quantity of the incoming wastewater in a sewer network, required effluent quality, available resources and fundings, environmental sustainability, prevalent environmental regulations at site and for recipient water and so on governs the type of treatment system to be used. But proper treatment of wastewater and disposal is not an easy task because using sophisticated or high-tech technologies and resources does not necessarily lead to proper treatment from the context of sustainability. Such as investing more cost, using more chemicals and energy, installation of additional or bigger treatment units and others. Therefore, one should always think about the optimization, effectiveness, sustainability and economy of the project. Nowadays, there is an increasing trend of using online, offline and real time sensors for the measurement of the water and wastewater parameters in a continuous and automated way. These advanced systems are highly efficient and effective but at the meantime they are costly, complex system which are sensitive to the working environment.

2. Thesis Description

This is a 30credits thesis written in a final year of the master's Degree in "Sustainable Water and Sanitation, Health and Development" from Norwegian University of Life Sciences, Norway. In this Master Thesis, the quality of incoming wastewater in the sewer was studied to understand and quantify the various pollution loads encountered in it. In context, an experiment was performed on upstream sewer samples from Asker municipality, Norway. With the aim of collecting true representative samples including possible variations, a total of 9 days samples was collected from autosampler. The sampler collected one sample every hour for 24 hours to catch daily variations. Those 9 days samples include 5 Dry Weather Flow (DWF) samples of 3 weekdays and 2 weekends and 4 Wet Weather Flow (WWF) samples of 2 weekdays and 2 weekends. Therefore, a total of 216 upstream sewer samples were analyzed in University's laboratory, NMBU Ås. Different parameters like pH, conductivity, turbidity, total suspended solids, Nitrate, Ammonium, Orthophosphate, Total Phosphorus and Chemical Oxygen Demand (COD) were measured using different available instruments and chemicals in the lab. Sample's online sensor datas available from Asker municipality wastewater treatment plant were also collected for analyzing pollutant loads in the sewer. The data analysis was done using MS-Excel and the statistical tool Unscrambler X.

2.1. Objectives of the study:

a. Analyze various sewer parameters manually using online and offline measurements to find statistical relationships which that can be used for virtual sensor development.

b. Assess potential innovative measurement concepts suitable for sewers primarily as a combination of simple online measurements and virtual sensors.

c. Quantify the sewer pollutants.

2.2. Significance of the study:

In Norway, every year there is increment in the percentage of the population connecting to the municipal wastewater facilities (Berge et al., 2017). In 2016, wastewater facilities(plants) serving 86% of Norway's population were 2,685. The rest 14% of the population were connected to small wastewater facilities. In 2016 among 4.5 million people linked with wastewater facility, only 55 % were bound by their treatment permits whereas other 33% were not in compliance with any treatment permits. Moreover, compliance data were unknown for rest of the 12 %. This creates a huge hinder in the wastewater management for the concerned authorities and increases liabilities for environmental pollution and health risks. In 2016 municipal wastewater sector including small wastewater facilities (less than 50 pe) discharge the total phosphorus and nitrogen including estimated leakage was approximately 1,530 tonnes and 19,880 tonnes respectively (Berge et al., 2017). The main target is to reduce the potential polluting agents from the wastewater by treating it up to the safe limit before discharging into the environment. With the high treatment efficiency of 57%, Oslo and Akershus have 2.09 kg of low per capita discharge of nitrogen. An average municipal wastewater connection fee excluding VAT was NOK 15,200 and an annual fee of NOK 3,832 in 2017. The total annual cost of municipalities in 2016 was found to be NOK 7.3 billion including capital costs and operating expenditures. This value represents an increase of 4.8 % over the previous year 2015 (Berge et al., 2017).

Therefore, a huge flow of capital is invested annually in this sector which seems to be increasing due to increases in both capital costs, operating costs and more stringent environmental regulations. There is an evolutionary change in water and wastewater treatment techniques and process control mechanisms in present days. The market is full of different technologies for measuring water quality with varying degrees of efficiency and effectiveness with the aim of achieving adequate treatment with good process control facilities. Examples of such systems include online and offline sensors, virtual sensors, DOSCON, SCADA and so on. They are, however, expensive in operation and maintenance, requires special working environments, have high energy demands and needs skilled manpower. Sensors are highly sensitive to the exposed environment, even a minor deviation can alter data greatly so frequent monitoring and maintenance is a must, especially for the use in sewer lines due to more wastes, pollutants and dynamic process of them. For example, deviation of turbidity sensor reading due to waste accumulation in or on the sensor, variation in coagulation dosing affects performances of the whole treatment system. As a result, the use of modern techniques and sensors are definitely a very useful tool for continuous data collection and process control in any treatment system but these do need a special attention to care, maintenance, resources and economy. Bourgeois et al. (2001) stated "Real-time monitoring of wastewater quality remains an unresolved problem to the wastewater treatment industry" and also enlightened the fact that for the monitoring of wastewater quality especially for the nutrients and phosphates measurements there is a need of automated cost-effective method development. Therefore, any alternative method which could replace the use of complex, time consuming and costly wastewater quality measurement will be of great advantage. Some major parameters of the sewer samples were analyzed in the lab from which behavior of the incoming pollutants under different circumstances were studied. With the use of statistical tool, relationships between the parameters were investigated. From this a better understanding can be gained for the development of innovative ideas that can be used for virtual sensor development in the future. The quantification of the potential pollutants in the incoming sewer flow under various condition (hourly variation, seasonal variation and climatic influence (rainfall and snowmelt)) will aid in proper documentation of the incoming pollutants concentrations. This will ultimately assist to optimize the cost and performance of the treatment process effectively and efficiently, document compliance with proper regulation and environmental laws and up to some extent sewer networks performance can also be known.

3. Study Area

Asker is a municipality in Akershus county, Norway with 61,065 inhabitants (sentralbyrå). At latitude 59°50'7''N and longitude 10°26'6''E it covers 101sq kilometers area. Figure 1 shows the catchment area of the incoming wastewater and network distributions of the private sewer lines and public sewer lines. Only the public sewer pipes are connected to the municipal sewers mains whereas private sewer networks are the one with their own treatment facility.

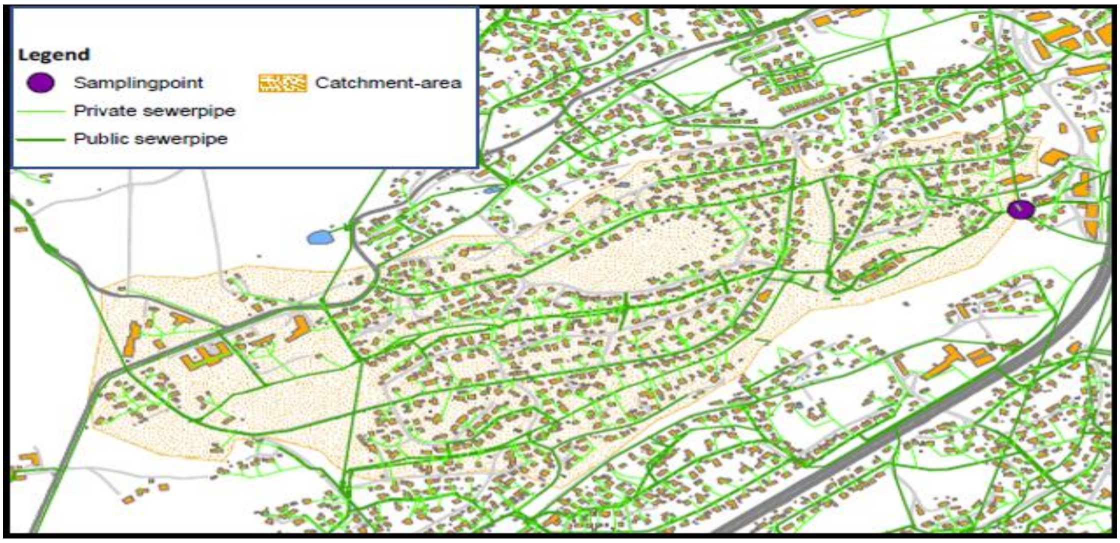

Figure 1 Wastewater Catchment Area, Våkas (Sola, 2018).

3.1. Catchment description

The catchment area contributing for the incoming wastewater at Våkas is approximately 1,155,600 sq. meters with a population around 1900 (Sola, 2018). The catchment area mainly comprises of residential and commercial buildings, some forest area and agriculture fields as shown in Figure 2. The map is only the tentative representation of the catchment boundary made in GIS to see the land use properties of the catchment area so that the potential sources of pollutions can be predicted roughly. The sewer network connections between the users to the inlet of the wastewater treatment plant is a separate system hence storm water and sanitary sewage water flows in different pipelines.

Figure 2 GIS Map showing approximate area of the Catchment, Våkas.

4. Theoretical Background

4.1. Sewage

Sewage is wastewater coming from different industries and domestic households. The structures and appurtenances like pipes, manhole, outlets, screens and many others, for the conveyance of the sewage from source to the WWTP are called sewer or sewerage system. The separate sewer system has two different pipe systems where sanitary sewage (domestic and industrial wastewater) and stormwater flows separately. In the case of a combined sewer system, both storm water and sanitary sewage flows together. The typical arrangement for the collection and disposal of the sewage in both the sewer systems are shown in Figure 3.

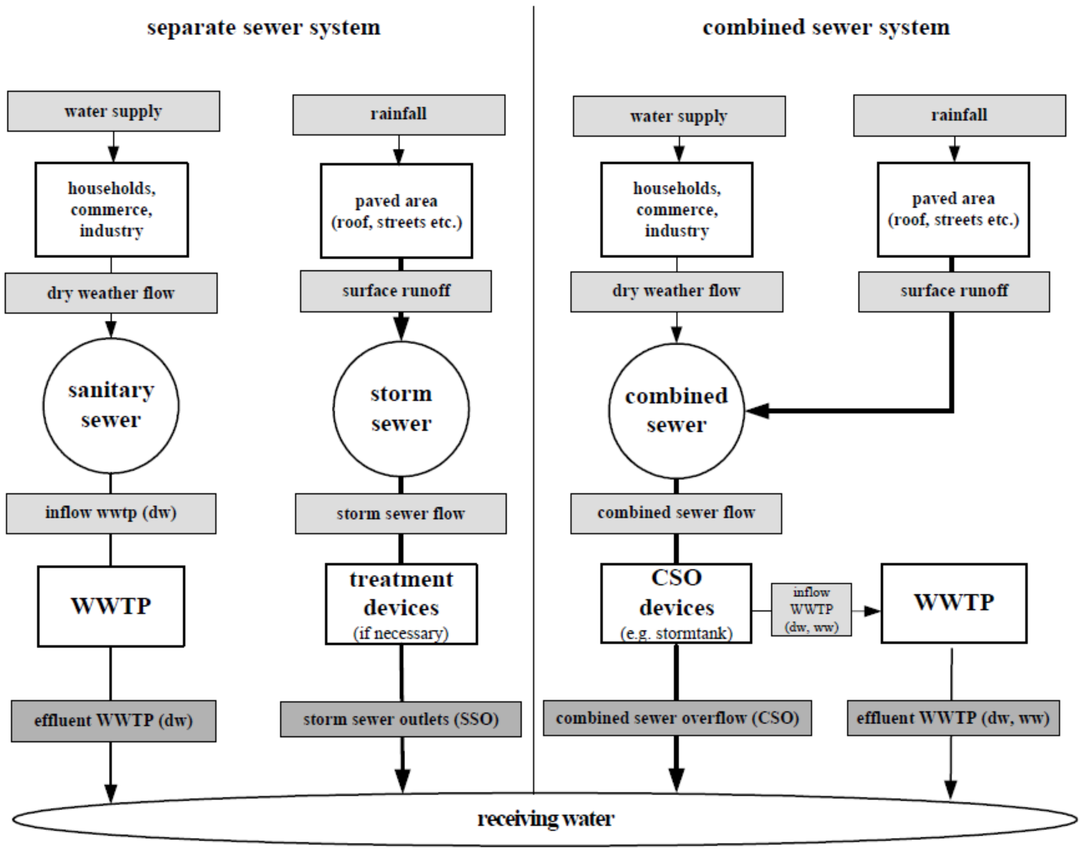

Figure 3 Typical flow diagram of Separate Sewer System and Combined Sewer System (Welker, 2008).

The domestic sewage comprises approximately 99.9% water and the remaining part contains organic and inorganic matters, solids in suspended or dissolved form, nutrients, greasy biomass or oils and microorganisms (Von Sperling, 2007). Basically, the domestic sewage constituents are grey water and black water. The term grey water refers to wastewater from bathing, wash-basins, gardening, kitchen except for urine and feces or toilet flush. The urine and feces wastes are called black water which is full of harmful pathogens and nutrients such as nitrogen, phosphorus and potassium. In a day, most adult produces 1 to 1.3kg of urine which contains a high amount of nitrogen. In urine, approximately 550 mg/l of ammonia and 24,000mg/l urea which readily hydrolyzed into ammonia is present (Droste, 1997). The excreta from infected or sick people can spread the harmful pathogens in the environment increasing the health risk for the people. In contrast, wastes from industries contain chemicals, heavy metals and toxins which are comparatively harder to remove during the treatment process so may require some specific treatment technology or method for this purpose. Depending upon sewer design it may contain rainwater as a surface runoff in a certain amount, usually high in wet weather periods. This introduces a high volume of particles and various contaminations in the wastewater which ultimately adds more pollutants in the sewer and increases the treatment burden in the WWTP. Therefore, the characteristics or composition of the incoming sewer water or wastewater plays a key role for the proper conveyance, management, treatment and disposal of the wastewater which is a must for a clean, safe, pollution free and healthy livable environment for all the living begins. Wastewater characteristics and contaminants are important to municipalities as a way of quantifying pollutants released into the environment. Some of important characteristics of the wastewater with their sources are illustrated in Table 1 Wastewater characteristics and their sources (Muttamara, 1996). and important contaminates are listed in Table 2.

Wastewater Characteristics and their Sources:

Table 1 Wastewater characteristics and their sources (Muttamara, 1996).

Physical Characteristics	Sources
Color	Domestic and industrial wastes, natural decay of organic materials
Odor	Decomposing wastewater, industrial wastes
Solids	Domestic water supply, domestic and industrial wastes, soil erosion, inflow- infiltration
Temperature	Domestic and industrial wastes
Chemical Constituents:	
Organic:	
Carbohydrates	Domestic, commercial and industrial wastes
Fats, oils and grease	Domestic, commercial and industrial wastes
Pesticides	Agricultural wastes
Phenols	Industrial wastes
Proteins	Domestic and commercial wastes
Surfactants	Domestic and industrial wastes
others	Natural decay of organic materials
Inorganic:	
Alkalinity	Domestic water supply and wastes, groundwater infiltration
Chlorides	Domestic water supply and wastes, groundwater infiltration, water softeners

Heavy metals	Industrial wastes
Nitrogen	Domestic and agricultural wastes
pH	Industrial wastes
Phosphorus	Domestic and industrial wastes, natural runoff
Sulfur	Domestic water supply and wastes, industrial wastes
Toxic compounds	Industrial wastes
Gases:	
Hydrogen Sulfide	Decomposition of domestic wastes
Methane	Decomposition of domestic wastes
Oxygen	Domestic water supply, surface-water infiltration
Biological Constituents:	
Animals	Open watercourses and treatment plants
Plants	Open watercourses and treatment plants
Protista	Domestic wastes, treatment plants
Viruses	Domestic wastes

The source and effect of some important contaminants in wastewater:

Table 2 Source of important Contaminants in Wastewater and their effects (Von Sperling, 2007)

Pollutant	Main representative parameters	Source: Wastewater – Domestic	Source: Wastewater – Industrial	Source: Stormwater – Urban	Source: Stormwater – Agricultural and pasture	Possible effect of the pollutant
Suspended solids	Total suspended solids	XXX	←→	XX	X	• Aesthetic problems • Sludge deposits • Pollutants adsorption • Protection of pathogens
Biodegradable organic matter	Biochemical oxygen demand	XXX	←→	XX	X	• Oxygen consumption • Death of fish • Septic conditions
Nutrients	Nitrogen Phosphorus	XXX	←→	XX	X	• Excessive algae growth • Toxicity to fish (ammonia) • Illnesses in new-born infants (nitrate) • Pollution of groundwater
Pathogens	Coliforms	XXX	←→	XX	X	• Water-borne diseases
Non-biodegradable organic matter	Pesticides Some detergents Others	X	←→	X	XX	• Toxicity (various) • Foam (detergents) • Reduction of oxygen transfer (detergents) • Non-biodegradability • Bad odours (e.g.: phenols)
Metals	Specific elements (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, etc.)	X	←→	X		• Toxicity • Inhibition of biological sewage treatment • Problems in agriculture use of sludge • Contamination of groundwater
Inorganic dissolved solids	Total dissolved solids Conductivity	XX	←→		X	• Excessive salinity – harm to plantations (irrigation) • Toxicity to plants (some ions) • Problems with soil permeability (sodium)

x: *small* xx: *medium* xxx: *high* ←→: variable *empty*: usually not important

There are two possible ways that pollutants enter and reach the receiving body, either as point-source pollution or diffuse pollution (Von Sperling, 2007). As shown in Table 2, domestic and industrial wastewater discharge is a point-source pollution as the pollutants enters from the point sources or outfalls whereas, a storm water is a diffuse pollution where the pollutants enter from different points throughout the length.

The compositions of the untreated domestic wastewater of medium strength shown in Table 3 can be useful to compare the concentration of constituents of the samples. Since the population is approximately 1,900 people the comparison of the findings from this study with medium strength domestic wastewater can be justifiable.

<u>Composition of Medium Strength Untreated Domestic Wastewater:</u>

Table 3 Medium strength untreated composition of Domestic Wastewater (Droste, 1997).

Constituent	Concentration(mg/l)
Bacteria	10^7 to 2×10^8
Total Solids	450
Suspended solids	250 mg/l
Volatile suspended solids	200
Total dissolved solids	200
BOD_5	150-250
Nitrate and Nitrite nitrogen as N	< 0.6
Organic nitrogen as N	25-85
Ammonia nitrogen as N	15-50
Total phosphorus	6-12
Soluble phosphorus	4-6

4.2. Parameters

4.2.1. Quantity of flow:

The total quantity of the incoming wastewater in the pipe measured as discharge 'Q' is obtained by the equation Q = A× v where, A is the cross-sectional area of the pipe (m^2)

v is the velocity of flow (m/s)

The amount of incoming pollutants in the wastewater may vary with the velocity and volume of the flow. So accurate measurement of the sewage flow as discharge 'Q' is necessary for keeping the track of incoming pollutants in the sewer.

4.2.2. pH:

The logarithmic scale to determine quantitatively the acidity or basicity of any solution is called pH. Mathematically expressed as pH = - log [H+], the negative logarithm of hydrogen ion [H^+]

concentration in moles per liter present in the solution. In the scale of 0 to 14, pH value less than 7 indicates the acidity of the solution and greater than 7 indicates basic nature, whereas 7 indicates the neutral solution. Since the scale is in logarithmic, 1 unit increase or decrease in the pH scale is actually 10 times more basic or acidic than the previous value. For example, pH 3 is 10 times more acidic than pH 4 and 100 times (10 times 10) than pH 5.

Sewer pH has several effects in the wastewater transport and treatment system such as odor formation due to the transfer of Hydrogen Sulfide (H_2S) from sewage to the surroundings, sewer biofilm biochemical processes rate affecting the production rate of sulfide, corrosion of the sewer appurtenance and chemical dosing during treatment (Sharma et al., 2013). Therefore, it is of the utmost necessity to keep track of the pH variation and maintain the required or designed pH throughout the treatment process. During the biological removal process in a treatment plant, the biological activities of the microorganisms are affected by pH especially for those which have an optimal pH range and exceeding the pH range will critically limit the biological activities or may even cause the death of microbes (Gray, 2012). The chemical removal process is also affected by pH range because variation in pH range will affect rates of chemical precipitation reactions (Gray, 2012). The extreme pH of wastewater in a sewer network can corrode the pipes and damage sewer appurtenance which cause or worsen the infiltration problems in the network. Therefore, to avoid such unfavorable conditions which can ultimately reduce the treatment efficiency of the plant, increase the operation and maintenance cost and also increase the environmental pollution risk, pH of the influent till the effluent must be measured on a regular basis. Sewer pH depends mainly on the sewage constituents, source and in-sewer processes (Sharma et al., 2013) which causes variation in pH value. The pH variation of 7.7 to 9.8 was reported by Houhou et al. (2009) from the study on Greater Nancy (France).

4.2.3. Conductivity:

The capacity to carry an electric current by an aqueous solution due to the presences of ions is called conductivity, represented here with the symbol ‘k’. The valency, total concentration and mobility of the ions of the aqueous solution, influence the conductivity. In International System of Units (SI), it is measured in millisiemens per meter ‘mS/m’ where, S is Siemens (reciprocal of ohm ‘Ω’). The conductivity of distilled water generated in the laboratory varies from 0.5 to 3 µS/cm which increases when exposed to air and water container (Association et al., 2012).

Electrical conductivity is generally used to measure the salinity of the solution and have a linear dependency on the metal ions present in solution (Prieto et al., 2001). The measurement of conductivity shows water quality as a function of dissolved salt hence can be used in process control during wastewater treatment. The conductivity of the wastewater is distinctly reduced during the biological nutrient removal mechanism such as phosphorus and nitrogen (Levlin, 2010). Conductivity depends upon the temperature of the solution since the increase in temperature reduces viscosity which in turn increases the mobility of the ion. This ultimately increases the conductivity of the solution (Barron & Ashton, 2005). High conductivity in water or wastewater distribution network causes corrosion of pipelines.

4.2.4. Turbidity:

Turbidity is the degree of clearness of the water. The presence of more suspended and colloidal matter such as silt, clay, fined organic and inorganic matters and other microscopic organisms in water increase the turbidity hence reduces the water quality. Turbidity is measured based on the intensity of light scattered and absorbed instead of transmitted without change in direction in a sample (Association et al., 2012). So, more intensity of light scattered, the higher the turbidity. As per ISO standards, it is measured in unit Formazin Turbidity Units (FTU) which equals to Nephelometric Turbidity Units (NTU).

4.2.5. Total suspended solids:

The suspended or dissolved matters present in water or wastewater is called solids which have the tendency to deteriorate the water quality and appearance of water by the physical and chemical reaction with the constituents of the water. It causes turbidity, when present in high amounts. It also increases the water or wastewater treatment cost, reduction in fish resources and degradation in aquatic environmental ecology (Bilotta & Brazier, 2008). For a drinking water, 500 mg/l is the allowable limit for dissolved solids (Association et al., 2012). The total solids present in water is the total sum of suspended and dissolved solids present in the water. To determine the total solids, present in water, evaporation of the sample is carried out and the residue left in the vessel is dried in an oven under defined temperature (Association et al., 2012). The obtained residue is the total solids present in the sample expressed as mg/l. Similarly, to obtain total suspended solids, a known volume of sample is filtered first for the suspended residue then kept in an oven to dry under the defined temperature (Association et al., 2012). This gives total suspended solid whereas, the dissolved solids are obtained by evaporating the filtered sample. The volatile suspended solids are mostly organics which may affect oxygen resources of the water bodies but these total organics are not the direct measure (Muttamara, 1996).

4.2.6. Nitrate (NO_3):

Like chloride, ions of hydrogen, sulfur, heavy metals and compounds yielding alkalinity, nitrogen and phosphorous are also a common inorganic constituent of wastewater (Muttamara, 1996). The four major forms of nitrogen, ammonia nitrogen (NH_3-N), organically bonded nitrogen, nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N) can be found in wastewater (Sun et al., 2016). The main source of these nutrients is human activities (Korostynska et al., 2012). The nitrification can cause oxidation of NH_3-N and form nitrite and nitrate (Sun et al., 2016). This process is affected by wastewater temperature, amount of dissolved oxygen and microorganisms present in wastewater (Sun et al., 2016).

The trace concentration of these inorganic compounds has growth-limiting or eutrophic characteristics in the receiving waters (Muttamara, 1996). Korostynska et al. (2012) mentioned that the quantity of nitrates is increasing in the water bodies and groundwater due to leaching from agricultural fields as there is an increase in the use of nitrate fertilizer. Therefore, environmental pollutions are growing fatal especially, for the aquatic life and ecosystem which creates a necessity for detection and quantification of these pollutants.

In order to determine Nitrate from the water or wastewater through the Colorimetric method used in this study, Hydrazine Sulphate, an alkaline solution is used to reduce nitrate into nitrite with a copper catalyst (SYSTEA, 12/03/2009). Then, under an acidic condition, a soluble dye is produced with sulfanilamide which is measured by colorimeter.

4.2.7. Ammonium (NH_4):

The human and animal wastes, agricultural wastes and industrial effluents are the sources of ammonium in wastewater and when these effluents are disposed of in the environment, it creates an enormous negative effect on the environment. Initially through eutrophication and since ammonium freely dissolves in the water it badly affects the aquatic life (Carrera et al., 2004). Ammonium (NH_4) is produced when the water reacts with the ammonia.

The determination of ammonia in the sample can be done with automated, colorimetric test using Phenate as conducted in this study. Principally, when ammonia-containing aqueous solution reacts with hypochlorite gives monochloramine which further reacts with phenol when sufficient hypochlorite is present (SYSTEA, 27/01/2009). Then indophenol blue is formed from the reaction of phenol and monochloramine as shown in Figure 4, in an amount proportional to the ammonia concentration(SYSTEA, 27/01/2009). The absorbance is measured at 660 nm.

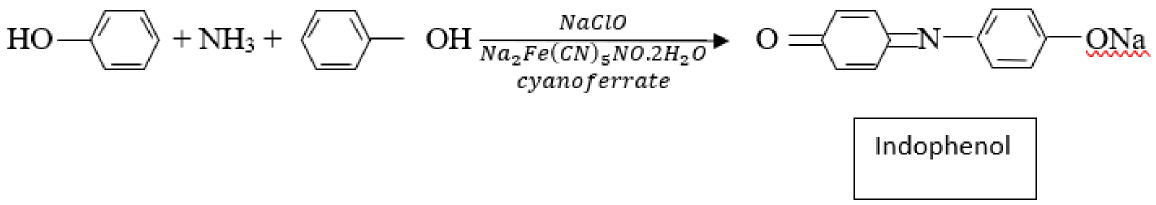

Figure 4 Chemical reaction for the formation of Indophenol (SYSTEA, 27/01/2009).

4.2.8. Phosphorus:

The main sources of phosphorus in wastewater are from agricultural fertilizer and domestic detergents (Korostynska et al., 2012) but in case of Norway, dishwashing and laundry detergents contain very low phosphorus due to the environmental limits. Among various forms of phosphates that can exist in wastewater, orthophosphates, condensed phosphates (pyro-, meta-, and poly-) and organic phosphorus are generally three classes of phosphorus (Korostynska et al., 2012). The orthophosphate (PO_4) is approximately 50 to 70 % of the phosphate that is present in wastewater which may be in the forms of Dihydrogen phosphate ($H_2PO_4^-$), Phosphoric acid (H_3PO_4), Hydrogenphosphate($HPO4^{2-}$) and Phosphate ion (PO_4^{3-}) (Al-Dasoqi et al., 2011). All of these phosphorous as a whole is termed as Total phosphorous expressed in mg/l of Tot-PP and PO_4-P. Orthophosphate can be detected by automated colorimetric method using ascorbic acid (SYSTEA, 01/03/2009). The sulfuric acid, ammonium molybdate and antimony potassium tartrate when mixed with the orthophosphate containing aqueous sample forms a complex. This complex gives blue heteropoly acid (molybdenum blue) after being reduced by ascorbic acid. The obtained blue complex absorbance (660 nm or 880nm) is proportional to the concentration of orthophosphate.

4.2.9. COD:

The organic strength of domestic and industrial waste are now-a-days widely measured in terms of Chemical Oxygen Demand (COD) over Biological Oxygen Demand (BOD) because of the ability of strong oxidizing agents to oxidize most of the organic compounds under acidic conditions. The COD test also have very short procedure duration, approximately 2 hours instead of 5 days for BOD_5 (Bourgeois et al., 2001). Moreover, COD measurements are not affected by presences of toxic substances in the water. It is measured in mg/l.

The principle behind the COD measurement by using Hach Lange instrument and chemical vials involves oxidizing the principal oxidizable substances (basically, organic matters) with sulfuric acid and potassium dichromate solution with a catalyst silver sulfate (LANGE). The presence of chloride is marked by mercury sulfate. Then, the former green coloration (Cr^{3+}) is evaluated.

4.3. Statistical method

In order to study all the potential pollution loads in the incoming sewer water, different related parameters like physical, biological and chemical characteristics of the water should be taken into the account. In general practice as the global parameters pH, TSS, conductivity, turbidity, nitrate (NO_3), ammonium (NH_4), orthophosphates (O-P), total phosphates (T-P) and COD are examined in wastewater. However, this creates a large dataset to analyze. Fortunately, many useful statistical tools are developed for extract and structured information example Multivariate statistics (MVS) (Rosén & Lennox, 2001).

Principal Component Analysis (PCA) is a widely used multivariate statistical approach for exploration of data and monitoring method which displays correlation among the several variables (wastewater sample constituents in our case). Thus, only useful and structured set of variables can be processed further (Olsen et al., 2012). PCA analysis depends upon many factors such as considered parameters, field and laboratory measurements and the process of the variables, quality of the data, data treatment before PCA analysis and PCA result interpretation (Olsen et al., 2012). The overall information carried by the original data are explained in certain amount in each principal component. Highest information is carried in first principal component (PC-1) and further in decreasing order, PC-2, PC-3 so on (*Unscrambler® X*). The use of conventional PCA for wastewater treatment monitoring have some limitations such as stationary data assumption and one time-scale event data analysis in PCA which in both the cases are not valid in the actual wastewater treatment process. Though these limitations can be overcome by using Adaptive PCA which uses exponential memory function for continuous updating of PCA model and by using time decomposition methodology using wavelets respectively (Rosén & Lennox, 2001).

5. Methodology

All the samples collection, storage and analysis procedure were consistently performed in the same manner for the accuracy of the work. As far as possible, the experiments, instruments and analysis were carefully done to avoid various possible errors such as instrumental and human error but as we all know there is always an uncertainty of the tests.

5.1. Uncertainty of the measurements

There is always an error in all the measurements even when done with all possible care which can be within the permissible limits or beyond. The error can be of the same magnitude called as a systematic error or of varying magnitude called as a random error which can be positive or negative (Association et al., 2012). These errors in measurements cause deviation of the results making the data less reliable. Therefore, for the validation of the data, analysts should check precision and biasness (systematic error) of the method (Association et al., 2012). If random errors are low, then precision will be high which means repeated measurements have less discrepancy and accuracy of the method indicates how close is the measurements towards the true value. When both the random and systematic errors are low the measurements are reasonably accurate.

An equational representation of the measurement M (Association et al., 2012):

M = T+E   where, T is unknown true value

E is measurement error / unknown deviation of the measurement M

The state of knowledge regarding this uncertainty deviation is called measurement uncertainty 'U'.

Thus, to reduce this unavoidable uncertainty of the method some measures were adopted such as calibration of the instruments with standards before starting the laboratory analysis of the samples and afterward randomly whenever felt necessary. For example, calibrating pH meter, rechecking the measured volume with different measuring instruments, operating the colorimetric test (Systea Easychem plus) with standards and discarding expired reagents, cross-checking weighed amount of chemicals, proper cleaning of the flasks etc.

5.2. Samples collection and storage

Figure 5 ISCO 3700 portable auto sampler at the sampling point, Våkas.

The total 9 days sewer samples were collected from the upstream sewer inlet at Vakås, Asker from autosampler (3700 Portable Samplers) as shown in Figure 5. The sampling period was from January to April, with at least 2 days samples from each month. The autosampler have 24 sample containers each of 500 ml volume. These flasks are made up of polyethylene with polyethylene foam lined caps. This autosampler enables a user to collect both sequential and composite samples at desired uniformed or nonuniformed time interval. All the samples were collected sequentially at time interval of 1 hour between each consecutive sample for this study. A total of 24 samples over a period of 24-hours were collected with approximate volume of 450ml in each of the samples containers. Sampling days were selected in such a way that it could represent hourly, daily, weekly and seasonal variation of the incoming sewer flow. All the samples were collected under pumped flow with the speed of pump approximately 250 RPM to generate sufficient velocity for true representative sample collection. The accuracy of the 3700 Portable Samplers for programmed volume is within 10 % and repeatable volume within ± 10ml. The operational temperature ranges from 0℃ to 50℃ and for storage is -20℃ to 60℃. After each sampling, the portable sample containers holder was properly washed 2-3 times with tap water so as to avoid any possible contamination for the next day sampling process. This was a simple, easy and multiprogrammable flexible auto sampling tool used throughout the analysis process.

Sampling date and Type of samples:

Table 4 Samples descriptions

Sample no:	Sample series Id	Sampling Date	Type
1	S1	17-18 January	DWF, Weekday
2	S2	24-25 January	WWF, Weekday
3	S3	3-4 February	DWF, Weekend(WE)
4	S4	8-9 February	DWF, Weekday
5	S5	10-11 February	DWF, Weekend(WE)
6	S6	21-22 March	DWF, Weekday
7	S7	30-31 March	WWF, Weekend(WE)
8	S8	5-6 April	WWF, Weekday
9	S9	14-15 April	WWF, Weekday

The first sample (24 hours) was taken in January 2018 on two different weekdays 'S1' and 'S2' respectively. In February one weekday and two weekends as 'S4', 'S3WE' and 'S5WE' respectively. Similarly, in March and April one weekday and one weekend samples from each month was collected as 'S6', 'S7WE', 'S8' and 'S9WE' respectively. Even though the 7th sample 'S7' was a weekday but considered as weekend due to the Easter holidays. Thus, from same sampling point total 9 days samples were collected each having 24hour sample series so in total 216 sewage samples was analyzed in the University's laboratory. The descriptions of the samples are given in Table 4. During the transport of the samples from site to the laboratory no preservatives were used. In the laboratory, pH, Conductivity, Turbidity, Colorimetric test for NO_3, NH_4, O-P and T-P, TSS and COD tests were performed to study the composition and quality of the incoming wastewater. Colorimetric test for NO_3 and NH_4 was done within the 24 hours after the completion of the sampling process through 3700 Portable Samplers. For NO_3, NH_4 and O-P test, filtered sewer samples were used. However, COD and T-P tests were done with unfiltered sewer samples. For storing the samples for COD analysis, they were kept in deep-freezer at frozen state in a labeled samples bottles. The O-P and T-P colorimetric test was conducted within 3 days till then the samples were stored in cold room at temperature less than 4℃ for maximum. No chemical preservatives were used for the preservation of the samples. The guidelines from *Standard methods for the examination of water and wastewater*, Association et al. (2012) were followed for the sample collection and storage (Table 5).

Sample collection and storage Guidelines:

Table 5 Guidelines for sampling and storage(Association et al., 2012)

Determinant	Container	Minimum Sample size (ml)	Sample Type	Preservations	Maximum Storage Recommended
pH	P,G	50	gs	Analyze immediately	0.25h
Solids	P,G	200	gs, cs	Cool, ≤6°C	7days
Turbidity	P,G,FP	100	gs, cs	Analyze same day,store in dark up to 24hour,Cool,≤6°C	24h
Ammonia	P,G,FP	500	gs, cs	Analyze as soon as possible or add H2SO4 to pH < 2, Cool, ≤6°C	7d
Nitrate	P,G,FP	100	gs, cs	Analyze as soon as possible, Cool, ≤6°C	48h
Phosphate	G(A)	100	gs	For dissolved phosphate filter immediately, Cool, ≤6°C	48h
Total Phosphorus	P,G,FP	100	gs, cs	Add H2SO4 to pH < 2, Cool, ≤6°C	28d
COD	P,G,FP	100	gs, cs	Analyze as soon as possible or add H2SO4 to pH < 2, Cool, ≤6°C	7d

P = plastic (polyethylene or equivalent), G = glass, G(A) = rinsed with 1+ 1HNO_3, FP = fluoropolymer (polytetrafluoroethylene or other fluoropolymer).
gs = grab sample, cs = composite sample
d = days and h = hour

5.3. Data collection

5.3.1. Regnbyge.no

The sensor's data of pH, Conductivity, turbidity set at Våkas and flow measurement data such as velocity and discharge of the incoming wastewater was collected online from Regnbyge.no. The sensor's data for pH, conductivity and turbidity are online so data can be obtained continuously from the website, but the flow parameters measurement are offline, so the readings are manually updated in the system. The data can be obtained for every minute, hour or on daily basis from the website. The wastewater quality measuring sensors such as pH, Conductivity and Turbidity installed at the location 'Asker vannkvalitet' which is the sampling point of all 9 days sample series (24hour samples) and the flow measuring station at location point 'Sid 2535' shown in Figure 6.

Figure 6 Wastewater flow and quality measuring stations, Våkas (*Regnbyge.no*).

5.3.2. Temperature and Precipitation

The atmospheric temperature and precipitation data of the sampling days was obtained from the online website www.yr.no. The temperature data (in ℃) and rainfall data (in mm) are collected from the measuring station, Asker (Sem) observation station (19710), situated in Asker municipality, 163 m.a.s.l. (near to the Sem gjestegård Figure 7). The rain gauge stations near the catchment are Semgjestegård, Mellom- Nes Skole and Asker brannstasjon, marked by red circle in Figure 7.

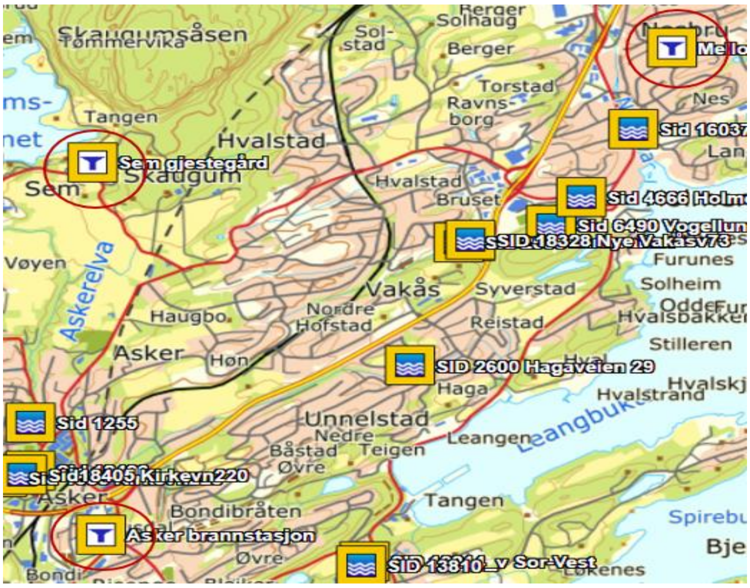

Figure 7 Rain gauge stations near the sampling location, Våkas (*Regnbyge.no*) .

5.4. Samples Analysis

After bringing the portable autosampler in the lab, 50 ml volume of each sample were filtered except for 1st and 2nd day sample which was taken only 30 ml for filtration and kept in the bottles with labels indicating sample numbers, date and ‘F’ for filtered samples. Then the remaining volume of unfiltered samples was kept in separate bottles with sample number, date and ‘UF’ unfiltered labels on each. The labeling was done by the permanent markers on the HDPE (High-density Polyethylene) bottles used for sample storing. Whenever needed to reuse the sample bottles they were cleaning with tap water for several times then dried and relabeling was done but new filtered samples were always stored in the new bottles. All the details were properly noted down in the lab notebook for an account of detail information of task carried out on that specific day. Throughout the lab analysis of sewage quality, lab-safety procedures were followed such as using lab-aprons, gloves, goggles with side covers, reagents preparation especially for the toxic chemical was done inside the fume hood, only clean and washed apparatus were used for the experiment and chemical wastes were disposed of properly.

When the samples were brought to the lab, firstly pH and conductivity were measured then filtration was carried out. The filtered and unfiltered samples were then kept in different sample bottles with separate labels. Then colorimetric test and turbidity tests were done simultaneously performed.

The selected global parameters for sample analysis measured in the laboratory:

Figure 8 pH and Conductivity measurement of the samples in Laboratory.

5.4.1. pH:

To determine acidity or basicity of the incoming sewer, pH was measured. The device pH3110 was used for the pH measurement as shown in Figure 8. The readings were noted after dipping the pH device in the samples until it stabilized. Before the use, pH device was calibrated by using pH buffer solution 7 or 10. But stabilizing of the values was time consuming.

5.4.2. Conductivity:

To determine the conductivity of the samples, conductivity device 'Cond3210' (Figure 8) was used. The slender tube of the device was dipped directly in each of the sample collection containers of the autosampler. The approximate volume of the sample during the measurement of the conductivity was 400ml and device. The accuracy of the device is ±1 digit. The measurement was comparatively quick than pH measurement since it stabilized within a minute. The unit of the measured values was in µS/cm.

5.4.3. Turbidity:

To determine the clarity of the sample, turbidity tests was carried out in a Nephelometric Turbiditymeter as shown in Figure 9. The device was turned on at least 20 minutes before use. The samples were filled inside the special glass tube of the device directly from the sample containers of the autosampler after shaking it well. Then after a minute, the reading was noted down. The same procedure was followed for all the samples. The unit of the measurement was NTU/ FTU with an accuracy of ± 2% reading plus 0.01 NTU/FNU from 0 to 1000.

Figure 9 Nephelometric Turbiditymeter.

5.4.4. Filtration:

Filtration of the samples were done with 50 ml volume except for first 2 days samples which were taken 30 ml volume. The accuracy of the measurements for small units are comparatively less so the filter volume of the samples was increased. Glass fiber filter paper of pore size 1.2µm, 47mm diameter was used. The dry weight of the container with the filter paper was weighted and noted as dry weight in grams then after the filtration of all the samples, filter paper with residue was kept inside the oven at 105°C temperatures for two hours. Then obtained filtered sample was used for colorimetric test of NO_3, NH_4, and O-P. The filter paper with residue shown in Figure 10 obtained after 2 hours in the oven was measured again as wet weight (gram) to calculate the TSS.

5.4.5. Total suspended solids:

The total suspended solids present in the samples was measured from the filtration process as mentioned above by using the following formula:

TSS = [Wet Weight(g) – Dry Weight(g)] / Volume of sample filtered (l)

Figure 10 Filter residue of the 24hour samples after 2 hours of oven dry.

5.4.6. Colorimetric tests from Systea:

A device working on the principal of Beer- Lambert's law (the medium absorbs the light transmitted to it on the equal proportion to its concentration), which measures the transmittance and absorbance of light when it passes through a liquid sample is called colorimeter (Arnold, 5/16/2015). The color is developed in a solution by introducing a specific reagent capable of forming color which can later be measured either as in intensity of color or concentration (Arnold, 5/16/2015).

For the determination of pollutants present in samples such as NO_3, NH_4, O-P and T-P, the colorimetric test was performed using Systea Easychem plus shown in Figure 11. Firstly, the standards and reagents were prepared as a working solution by following the systea manual and filled it in the different reagent containers. The working solution preparation table given in appendix, Table 12.Then, the calibration was done for each test by diluting the standard into different known concentrations and analyzing them to obtain the optical density (O.D.) of each diluted standard. Then the obtained O.D. for each known concentration was manually feed to obtain the calibration curve. Once the calibration is done, samples can be kept in the cuvettes for analysis with the first cuvette with blank (Deionized water) then from interpolation or extrapolation, the concentration of the pollutants can be known. The results are displayed in the connected computer screen in unit mg/l.

Figure 11 Colorimetric test by Systea EasyChem Plus.

Systea Easychem Plus is a discrete analyzer that contains 60 sample trays including blank, controls and calibrations cups, cooled 18 reagents tray and auto dilution option. The accuracy of the dosing syringe for samples and reagents is ± 0.5% (5 to 1000 microliters). The process is temperature controlled, extended UV emission with a halogen lamp and wavelength with automated zero setting. The accuracy is ± 1% from 0 to 2.5 O.D. and noise less than ± 2m absorption at 340 nm 2.5 O.D.(S.p.A, 2015).

i. Nitrate(NO_3):

For the determination of NO_3 filtered samples were analyzed within 24 hours of sample collection. Three working solutions R1, R2 and R3 prepared by using Cupric Sulphate, Sodium Hydroxide and Hydrazine Sulphate, Sulfanilamide, Concentrated Hydrochloric acid and N-1-Naphthylethylenediamine Dihydrochloride.

ii. Ammonium (NH_4):

The determination of NH_4 was done by using chemical compounds such as Phenol, Sodium Hydroxide, Disodium EDTA, Sodium Nitroferricyanide and Sodium Hypochlorite. Three working solutions R1, R2 and R3 were prepared from these chemicals.

iii. Orthophosphate (PO_4):

The two working solutions were prepared R1 and R2 for measuring orthophosphate present in the sewer samples using the colorimetric method. The chemical compounds such as Sodium molybdate, Potassium antimony (III) oxide tartrate trihydrate and acids like Ascorbic and Sulphuric were used.

iv. Total phosphate:

Total phosphorus was determined by using the same calibration as orthophosphate but before, digestion of the mixture solution containing 2.5 ml of sample, 100 µm sulfuric acid and 3 ml of potassium peroxodisulphate was carried out inside the thermostat at 120℃ for 45 minutes.

5.4.7. COD

Figure 12 Hach Lange COD measuring instrument.

Figure 13 Kit LCK 514 and LCK 314 for COD measurement.

The Chemical Oxygen Demand (COD) of the samples were measured by using LCK514 and LCK 314 Hach Lange chemical vials Figure 13 at the expected range of 100-2000 mg/l O_2 and 15-150 mg/L O_2 of COD respectively. To carry out this test, unfiltered samples were used. Firstly, the chemical vials were shaken to bring all the sediments present in the vials into suspension then 2ml of the unfiltered samples were mixed in each of it using pipette. The mixing was done inside the fume hood because of the toxic chemicals present in the vials.

Afterwards, the vials were kept in the Hach Lang (LT200) thermostat for the digestion. The COD program was set, 148℃ temperature for 120 minutes to digest the samples. 30 sample vials can be kept in the thermostat at the same time. Then, after 2 hours, samples were taken out from thermostat and kept for cooling (lower than body temperature). Finally, the readings were measured by inserting sample vials in the COD measurement instrument DR3900, 605nm wavelength. The unit of measurement was mg/l. The LCK514 COD vials contains 90 % Sulfuric acid, mercury sulphate and potassium dichromate (LANGE), a corrosive, harmful and toxic chemical so they were handled with more care and attention. Similar toxic effect of the LCK 314 COD vial due to it's constituent. Therefore, for the proper disposal after the test it was sent to the authorized body responsible for the disposal.

<u>The parameters measured from the sensors in the WWTP, Asker</u>

- pH:

The PHEH (pH, Redox and Temperature) sensor is used for the pH measurement. It does not require recalibration due to stored calibration in it. The range for pH is 0 to 14 units, Redox is from -1000 to +1000 mV and Temperature from -10℃ to +50℃. But for instance, only pH is measured with an accuracy of ± 0.1pH. This device is based on combined electrode Ag/AgCl and gelled electrolyte (KCL) (Aqualabo, April 2011). The figure of sensor shown in Figure 14.

Figure 14 pH sensor (PHEH) installed at Våkas (Aqualabo, April 2011).

- Conductivity:

The Digital Sensor C4E Figure 15 was used to measure the conductivity of the samples. It consists of 2 graphic and 2 platinum electrodes which measure conductivity from the range 0 to 200 mS/cm. It has a wide range of applicability, from drinking water to Urban wastewater treatment, industrial effluent treatment, sea water and Surface water monitoring. Like pH sensor, this also does not need to be recalibrated due to calibration data and history data storage. Accuracy ±1 % of full range. (AQUALABO, September 2013)

Figure 15 Conductivity Sensor (Digital Sensor C4E) (AQUALABO, September 2013).

- Turbidity:

The RANGE DIGISENS Nephelometric turbidity sensor was used to measure turbidity from 0 to 4000 NTU Figure 16. It is an infrared optical sensor with optical fiber. It is suitable for use in Urban wastewater treatment inlet/outlet controls, industrial effluent treatment, drinking water, sanitation network etc. Based on diffusion IR at 90^{o} nephelometry/ 850 nm and can be calibrated with a standard solution fromazine. The accuracy of the device <5% of the reading. (Aqualabo, August 2014)

Figure 16 Nephelometric Turbidity Sensor at Våkas (Aqualabo, August 2014).

5.5. Statistical Data Analysis

After 4months of laboratory analysis of all 9 days wastewater samples, the obtained data were analyzed by using statistical software 'Unscrambler X' whereas some of the graphical comparisons of the samples and variables were also done by using 'Microsoft Excel'. Sometimes results from the colorimetric test with Systea Easychem plus was not consistent. For example, showing a high concentration of nutrients (NO_3 and NH_4) for deionized water (blank) and even for the standard solutions, displayed a different range of concentrations for the same sample during the repetition of the test. These technical difficulties were assumed to be related with reagents preparation or sometimes with the calibration of the test. As a remedy, the test was repeated with re-prepared reagents and standards. When needed the new calibration curve was also made with freshly prepared standards. However, some of the test results were still way too high as such, result of NH_4 test for sample 'S5' (40-71 mg/l). Later found to be due to the defect in the light sensor of the instrument so new light sensor was installed but this took few days so NH_4 test for S5 could not be repeated. Therefore, PCA model was run firstly with all the data including S5 sample series with very high range NH_4 concentration and afterwards without the high range NH_4 concentration data. Also, the very low negative values from the colorimetric test were made zero '0' during statistical analysis. The analyzed data set can be seen in the Table 13 (appendix). The principal component analysis (PCA) was done to explore the data and find a useful correlation between the variables.

6. Results and Discussion

According to the information provided by the Asker municipality contact, Kristin Jenssen Sola, the sewer system of the catchment area (Våkas, Asker) is a separate sewer system. Basically, separate sewer system conveys domestic and industrial sanitary sewage as a DWF and the storm water as a WWF separately in different sewer networks. DWF mainly depends upon water supply rate, population and their economic status, type of the area, climatic condition and groundwater infiltration in the pipelines mostly when sewer networks (pipelines) are laid below the groundwater table. In case of combined sewer system, DWF is sewage flow during dry seasons with no rainfall and WWF during the rainfall season. Therefore, to study the behavior of the sewage in terms of sewage flow rate and pollution load during dry and wet season, among 9 days of autosampling at upstream sewer line in Våkas, Asker municipality, the samples were divided into DWF and WWF. For the study purpose, an account of increased sewage flow rate as a discharge(m^3/s) of the incoming wastewater was considered for the classification of the samples as WWF. While, the remaining day's samples with low discharges as DWF samples. Therefore, sample series S2, S7, S8 and S9 sample were considered as WWF and remaining sample series S1, S3, S4, S5 and S6 were considered as DWF samples. The sewage flow rates of all the WWF samples are greater than 0.020 m^3/s. All the statistical analysis is done under this assumption.

As, Norway is a cold country with the cold polar zone of the Artic on the northern part and the temperate climatic zone in the southern part (Eglitis), snowfall and low atmospheric temperature is more common than warm days. December to February is the peak winter season followed by spring season from March to May. Therefore, sample series S1 to S5 are winter samples during the snow fall and snow covers. Whereas, samples series S6 to S9 are spring season samples with warmer atmospheric temperature. Therefore, more volume of snow melt runoff contributing to higher sewage discharge was observed in later sample series S7 to S9 additionally, the rain event during S8 sampling day also contributed to the higher sewage flow. The WWF samples therefore comprises discharge mainly from snow melt rather rainfall runoff and DWF samples comprises few low intensity rainfall runoffs. This is often the case in cold climate countries where the combined effect of rain and snow melt causes a hinder in analyzing the effect of individual events (either storm runoff or snowmelt runoff) in the pollution load of wastewater. The area with cold climate causing frequent snowfall and snowmelt remarkably affects the characteristics of the wastewater (Wang et al., 2017). The dilution so caused greatly reduce the possibility of comparing the wastewater influent during warm season and cold season (Wang et al., 2017). The storm runoff carries significant amount of pollutants since precipitation washes different objects present in the surroundings such as buildings, vehicles, streets, landfills, agricultural fields, roofs and so on whereas, snowmelt carries comparatively lower amounts of pollutants (Bennett et al., 1981). While studying about the effect of urban runoff on streams through separate storm sewer, Bennett et al. (1981) found that the concentration of suspended solids and COD in case of snow precipitation loading was about one-half of the concentrations present in stormwater. Meanwhile, the concentrations of nutrients (nitrogen, nitrate and total phosphorus) being one-fourth or less in snowfall than in rain. However, Orhon et al. (1997) illustrated from this study that characteristics or quality of the generated wastewater are highly site-specific so differ from location to location.

The graphical representation of the relation between precipitation and sewage flow rate is illustrated in Figure 17 and that between the atmospheric temperature and sewage flow rate in Figure 18. From Figure 18 we can see that, with the increase in atmospheric temperature sewage flow does not increase instantaneously but only after certain hours of high temperature. Since, the accumulated snow must be sufficiently heated up for melting. The Figure 17 and Figure 18 indicate how the sewage flow rate changes with the change in the environmental conditions such as rainfall and atmospheric temperature causing snowmelt. However, the separate sewer system carries storm water separately, so the effect of rainfall and snowmelt should not be high in the sanitary sewer flow lines. The observed flow rates of the sanitary sewage samples did however show a significant linear relation with rainfall and snowmelt events. This can indicate that there is significant infiltration in the sewer pipelines. It could be of interest to predict infiltration in the sewer pipelines which is causing the separate system to appear like a combined sewer system, in regard to response to rainfall and snowmelt events. This gives an opportunity to study the contribution of rainfall and snowmelt on sewage flow rate and pollution loads.

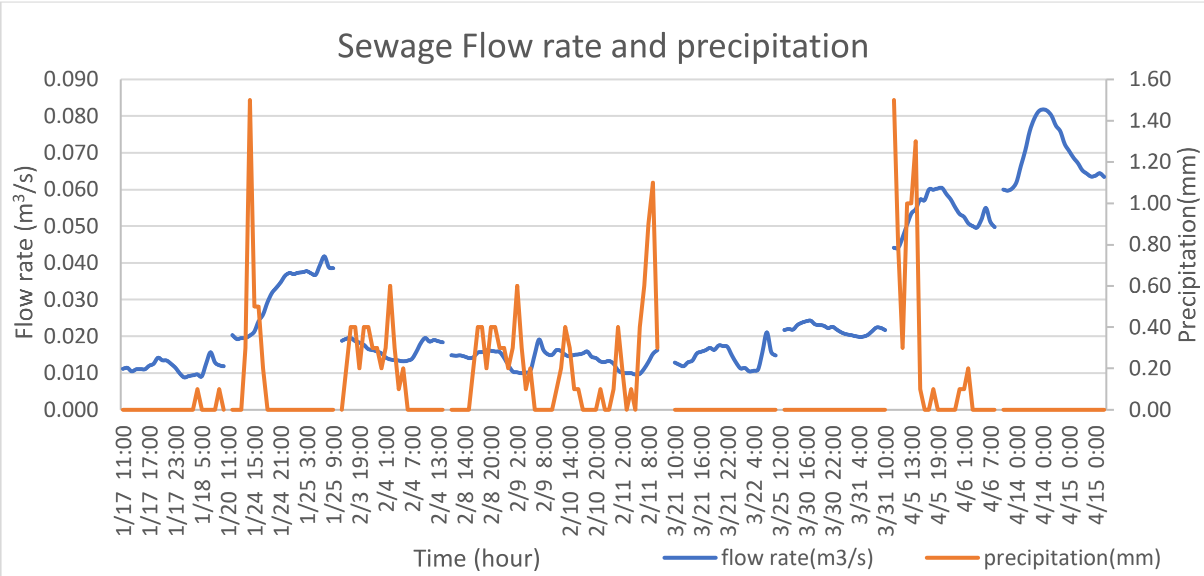

Figure 17 Hourly variation in samples' Sewage Flow rate (m^3/s) and Precipitation(mm).

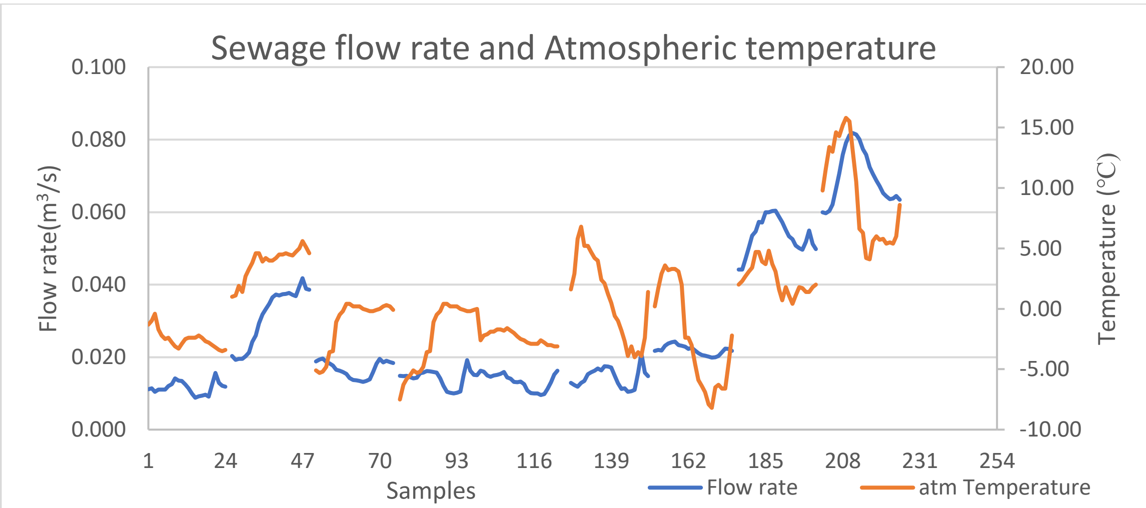

Figure 18 Graphical representation of Sewage flow rate (m^3/s) and atmospheric Temperature (℃).

The relationship between the precipitation on each sampling day and sewage flow rate of the wastewater indicates the time lag between precipitation in millimeters and volumetric flow in cubic meters per second (m^3/s) of wastewater as observed from the Figure 17. After each contributing precipitation, the increase in sewage flow volume was observed either delayed or on the next sampling event. This is because of time of concentration 'Tc', the time required for the flow of wastewater from the farthest point of the catchment area 'A' to the design point 'P' as shown in Figure 19. Time of concentration includes time of travel and time of entry.

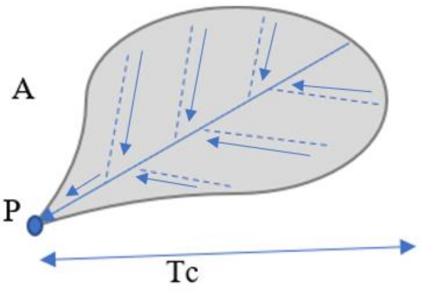

Figure 19 Flow of wastewater in the Catchment.

As sample collections was not done with a high enough temporal resolution the actual effect or variation due to time lag between precipitation or snowmelt in sewage flow rate cannot be studied well. Though, the general concept of time lag can be acquired. Furthermore, we can observe that the longer the gap is between the sampling events, the more deviated the relation is between precipitation and temperature with sewage flow rate.

6.1. Variation in Sewage Flow:

The sanitary sewage flow rate of any particular area is directly related to the rate of water supply in the locality, the population size, living style, type of area (such as residential, commercial, hotels, industries and hospitals) and infiltration from the groundwater and surface runoffs. The relation between water demand and sewage flow rate on an hourly basis is illustrated in Figure 20. Sewage flow vary hour to hour, day to day, weather to weather and season to season. Basically, the household activities of the people are more usually during peak hours at morning when everyone is getting ready for the day (bathing, cooking, toilet flushes and washing), festivals, weekends, holidays, get-together and so on. This increases the water consumption, so more wastewater is produced. Numerically, Water consumption is a function of design population and average per capita rate of water supply (usually expressed as liters per capita per day) (Von Sperling, 2007). In general practice, the average daily wastewater discharges was estimated as 60-90% of per capita water consumption (Butler et al., 1995). The population in the catchment area is about 1900 and if we suppose the average water supply rate as 190 lpcd then taking 70% of 3,61,000 l/day (190 × 1900) the amount of wastewater produced will be 2,52,700 l/day ($0.003 m^3/s$).

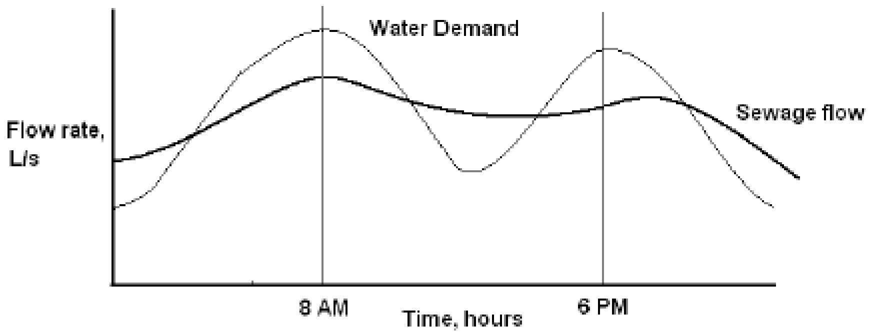

Figure 20 Hourly variation in Water demand and Sewage flow rate (Kharagpur).

With the aim of observing the hourly variation in the sewage flow rate of the considered catchment area, two graphs are presented. One with the average values of the sewage flow rate in hourly basis calculated from all 216 samples and another with only 'S6' sample series (24hours) collected on 21 to 22nd March 2018. The reason behind selecting S6 sample series was to observe hourly variation of the sewage flow rate when the effect of rainfall and snowmelt is possibly minimum. Thus, the undisturbed variation of the sanitary dry weather flow can be studied. However, the clear indication of the infiltration in the sanitary sewer pipelines has already been noticed (Figure 17). Therefore, the completely undisturbed variation of the sewage flow rate from the environmental exposures (runoff from precipitation and snowmelt) is difficult to express.

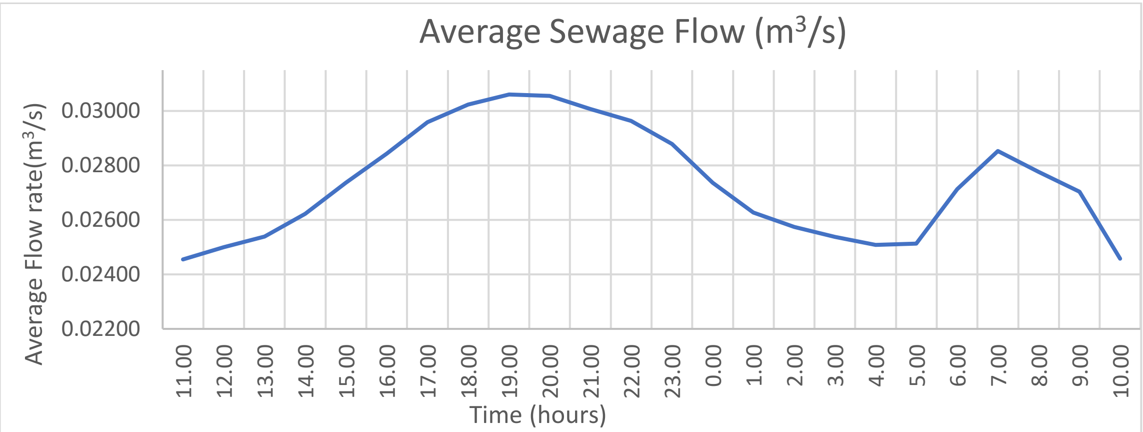

Figure 21 Hourly variation of Average Sewage flow rate of all the samples.

Figure 21 illustrates the average sewage flow rate from 9 days sample series (S1 to S9) at each hour of the day. In general, the sewage flow rate is a function of water consumption by the residents of the catchment therefore, the highest peak in the sewage flow is expected at morning. In contrast, it was observed that from 5am in the morning, the average sewage flow rate increased and hit the second highest peak of the entire day at around 7 am. Then gradually decreases till 11am from which average sewage flow again slowly elevated till the highest point at around 7pm in the evening. The lowest values of average sewage flow rate were observed during the night time from midnight till 4 am at early morning. Therefore, the average sewage flow rate seems to be increased dominantly at evening (1 to 7pm) probably at the time of lunch and dinner or maybe some cleanings or laundry and secondly at the morning (5-9am) when people are getting ready for their work or school. Whereas, when the sewage flow rate for S6 sample series was plotted against time in hours, the expected pattern was obtained. The highest sewage flow rate was during the peak hours in the morning around 5 to 7 am, shown in Figure 22. However, this may not indicate the true timing of the maximum and minimum sewage flow rate due to travel time and sewer network size (Butler et al., 1995), but the variation pattern will be relatively same. The shift in the actual variation of sewage flow rate for the given time will be high if the distance between the origin of sewage flow and the sampling point or flow measuring station is greater. The reason behind the contradictory pattern of the average sewage flow rate in Figure 21 should be the infiltration in the pipelines which increases during rainfall and snowmelt events. In case of the S6 sample series the interference from rain and snowmelt is comparatively less since precipitation on the sampling day was null and average atmospheric temperature was zero '0'. Thus, sewage flow rate variation should be mainly from the variation in sanitary sewage flow. Meanwhile, when the sewage flow rate of S8 sample series was plotted with the precipitation data of that day, the highest sewage flow rate was not during the peak hours but at rainfall period and snowmelt period, illustrated in Figure 23.

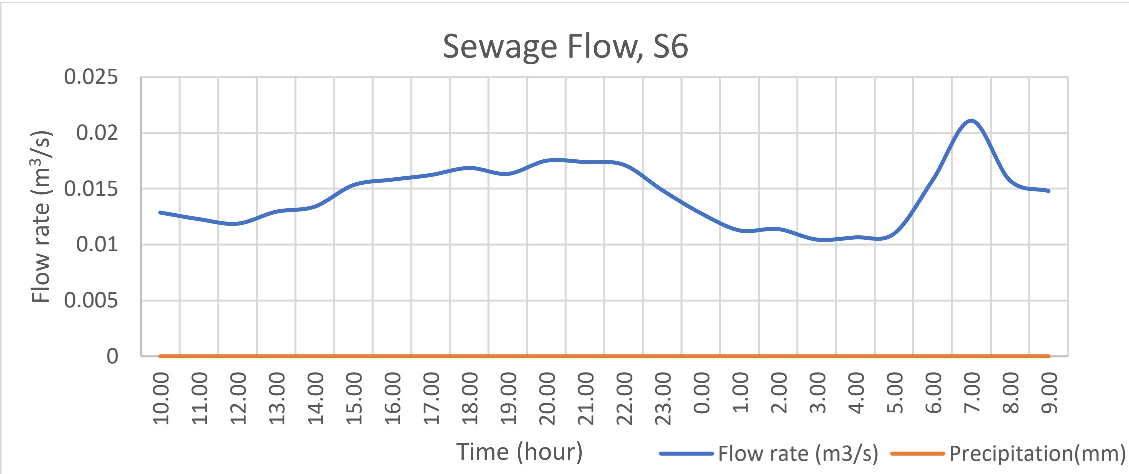

Figure 22 Hourly variation of the sewage flow rate of S6 sample series.

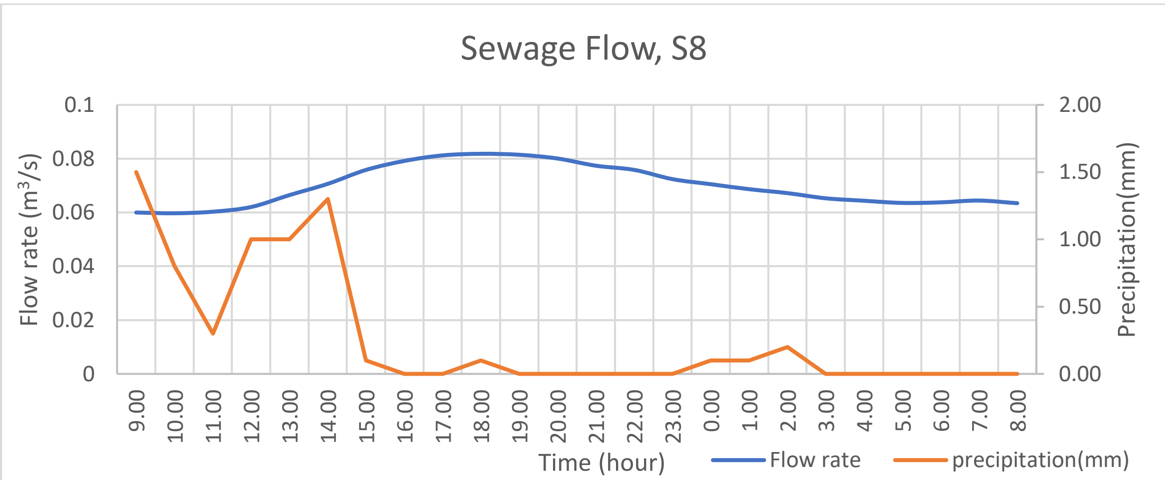

Figure 23 Hourly variation of the sewage flow rate of S8 sample series.

6.2. Descriptive Analysis of the parameters and variation in the pollutant loads

The descriptive analysis of all the 9 days samples taken from the period of January to April, was performed in statistical tool 'Unscrambler X' to see the maximum, minimum, average and standard deviation of each considered variables, given in Table 6 along with DWF and WWF samples separate descriptive analysis given in Table 6. From these values, the variation of pollutant loads in the incoming wastewater under different circumstances can be known furthermore, the reasons behind those variation can also be interpreted.

Table 6 Descriptive Analysis of the parameters for all the samples.

Variables	Maximum	Minimum	Mean	Standard Deviation
Atm Temp°C	15.800	-8.200	0.638	4.589
Precipitation (mm)	1.500	0.000	0.110	0.249
pH lab	8.800	6.260	7.521	0.534
Conductivity lab (µS/cm)	729.000	385.000	496.588	65.600
Turbidity lab(NTU)	236.000	1.610	38.830	37.577
TSS(mg/l)	526.000	-33.333	89.544	79.313
NH_4(mg/l)	35.286	0.149	8.399	7.112
NO_3(mg/l)	3.302	0.000	1.275	1.030
COD(mg/l)	979.000	9.220	165.340	150.072
Ortho-P (mg/l)	6.874	-0.089	1.126	1.069
Total-P(mg/l)	12.208	-0.015	2.020	1.882
pH sensor	8.220	6.823	7.648	0.275
Conductivity sensor (µS/cm)	532.798	280.904	430.443	58.418
Turbidity sensor(FNU)	6904.964	29.778	831.646	1171.202
Flow (m/s)	2.646	1.135	1.698	0.451
Sewage flow rate (m^3/s)	0.082	0.009	0.027	0.020

Table 7 Descriptive Analysis of the parameters for the DWF and WWF samples.

Variable	DWF				WWF			
	Maximum	Minimum	Mean	Standard Deviation	Maximum	Minimum	Mean	Standard Deviation
Atm Temp°C	6.800	-7.500	-1.485	2.540	15.800	-8.200	3.293	5.173
Precipitation (mm)	1.100	0.000	0.118	0.196	1.500	0.000	0.099	0.302
pH lab	8.800	6.260	7.638	0.524	8.100	6.380	7.376	0.512
Conductivity lab (µS/cm)	729.000	397.000	525.750	60.776	652.000	385.000	460.135	51.917
Turbidity lab (NTU)	236.000	2.780	51.541	41.563	192.000	1.610	22.941	23.928
TSS(mg/l)	526.000	3.300	121.890	84.227	200.000	-33.333	49.111	48.749
NH_4(mg/l)	35.286	0.149	12.876	7.176	14.446	0.388	3.922	3.112
NO_3(mg/l)	3.302	0.000	1.685	0.972	2.294	0.000	0.762	0.859
COD (mg/l)	979.000	23.500	228.113	167.990	320.000	9.220	86.874	66.491
Ortho-P (mg/l)	6.874	0.269	1.666	1.125	1.784	-0.089	0.452	0.415
Total-P(mg/l)	12.208	-0.015	2.995	1.953	3.045	0.020	0.802	0.733
pH sensor	8.220	7.292	7.704	0.225	7.942	6.823	7.578	0.315
Conductivity sensor (µS/cm)	532.798	357.068	460.346	33.809	470.179	280.904	392.671	61.145

Turbidity sensor(FNU)	6904.964	29.778	1145.328	1429.028	3620.347	120.683	435.415	503.308
Sewage flow rate (m^3/s)	0.021	0.009	0.014	0.003	0.082	0.019	0.044	0.020

6.2.1. Sewage Flow rate (m^3/s):

The average sewage flow rate of incoming wastewater for the considered 4 months (January to April) was observed to be 0.027 ± 0.020 m^3/s. The maximum sewage discharge of 0.082 m^3/s was found in sample 'S8' collected in the month of April. This is due to the infiltration in the sanitary sewer pipelines from the runoff during the rainfall events in the sampling days and snowmelts due to high atmospheric temperature of 19℃. The minimum discharge of 0.009 m^3/s observed in samples series S1 and S5 collected in the winter seasons January and February with no snowmelt volume in the sewer pipelines. The average atmospheric temperature on samples series S1 and S5 sampling day was -2.45℃.

In case of DWF samples series S1, S3, S4, S5 and S6 (total 120 samples) average sewage flow rate was 0.014 ± 0.003 m^3/s and minimum to maximum range of 0.009 to 0.021 m^3/s. The average flow of wastewater seems to be increased significantly in the WWF samples by 214% more than average DWF samples which indicates high infiltration in the sewer networks. The small stream near the sampling station shown in Figure 6, may also have contributed along with the infiltration from surface runoffs including rainwater and snowmelt. The increase in average atmospheric temperature from -2.45℃ during DWF sampling to +3.29℃ during WWF samples sampling contributing more snowmelt runoff and also, due to the precipitations during WWF S2 and S8 sampling days causes significant increase in the sewage flow rate during WWF. S1 weekday sample has the lowest discharge. The general trend of slightly increased discharge in weekend samples than in weekday samples was observed in this study. This may be due to the more household and entertainment activities of the people in weekends than in weekdays such as cleaning, laundry, gardening, get-togethers and many other reasons. The hourly variation in the sewage flow as discharge (m^3/s) of all samples is illustrated in Figure 24 where, S3WE, S5WE, S7WE and S9WE are the weekend samples and remaining sample series are weekday samples. The first four samples with higher sewage flow rate are the WWF samples.

It is necessary to estimate the incoming sewage flow accurately in order to make an economical and efficient hydraulic design of the sewer networks. The quantity of sewage discharge governs the idea for the diameters of the pipelines and the capacity of the treatment plant. Moreover, correct estimation of water consumption and sewage flow rate of the catchment can help to predict approximate quantity of the infiltrated wastewater from the pipelines to the surrounding and vice versa. This gives an opportunity to have control over the potential groundwater contamination risk and environmental regulations. The infiltration rate in the sewer networks depends upon the permeability of the ground soil which is a difficult parameter to estimate (Kharagpur). Metcalf and Eddy (1991) suggested the range of 0.01 to 1.0 m^3/day/mm (pipe diameter)/ km length for the infiltration amount. The study conducted in the United Kingdom (UK) have found the infiltration range of 15 to 50 % of average dry weather flows and 10 to 20 % of total wet weather flows (Ellis, 2001). These literature values give an indication of high infiltration of groundwater in the sewer system of the study area but for better understanding and more findings, a more detailed study is needed. But, in general infiltration can be estimated volumetrically by deducting the normal water consumption from sewage flow rate at the outlet of the catchment (Ellis, 2001). The rough estimation of the average amount of wastewater produced from the catchment was found to be 0.003m^3/s and the average sewage flow rate of the samples was 0.027 ± 0.020 m^3/s so on average 24 liters of additional volume of wastewater is infiltrated in the sewer line in every second.

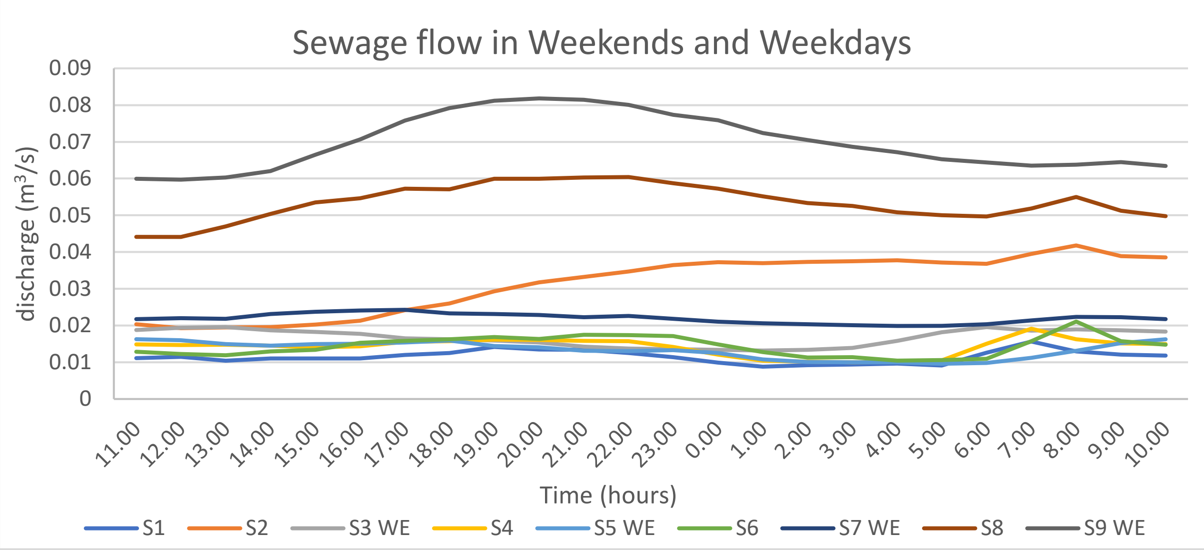

Figure 24 Hourly variation of the Sewage flow for each sample.

6.2.2. Various parameters:

i. pH:

The pH sensor along with conductivity and turbidity sensors are installed in Våkas, Asker which gives continuous pH, conductivity and turbidity reading of the incoming wastewater. The pH of the samples was also measured manually in the laboratory by using electrode pHmeter ‘pH 3110’. For all 216 samples, the mean pH measured in laboratory (pH lab) was found 7.52 ± 0.534 whereas, average value obtained from the pH sensor (PHEH) was 7.64 ± 0.275. The pH lab showed a variation in pH value of 6.26 to 8.8 whereas, pH sensor showed a variation of 6.82 to 8.22 in pH values. In case of DWF samples, the average pH lab was observed 7.638 ± 0.524 with range of 6.26 to 8.8 and average pH sensor was observed 7.704 ± 0.225 within the range of 7.292 to 8.22. On the other hand, average pH lab and pH sensor was obtained 7.376 ± 0.512 and 7.578 ± 0.315 respectively with the range of 6.380 to 8.1 and 6.823 to 7.942 respectively for the WWF samples. The lowest pH values were observed in S2 sample series collected in the month of January whereas, the highest pH values in S6 sample series from March. The hourly variation in pH lab and pH sensor indicates mostly the similar pattern except for sample series S6 and S7 as illustrated in Figure 25. This may be due to the error in manual pH reading from the pHmeter or maybe the instrumental error. The pH sensor and pH lab of same samples are measured in different environment, pH sensor as located in the site can provide the actual exposed environment, but the pH lab cannot. For example, temperature difference in sample at site and laboratory. Therefore, the installation of pH sensor in the wastewater treatment plant at various steps from inlet to the outlet of the treatment plant process will help for better process control, water quality check and environmental sustainability.

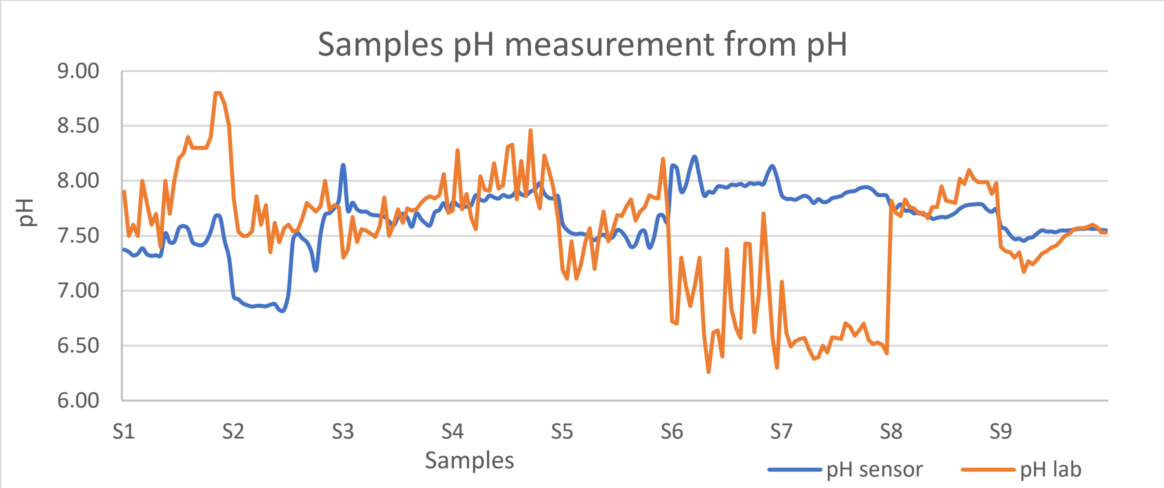

Figure 25 Samples pH measured from pH 3110 (pH lab) and at site from sensor (pH sensor).

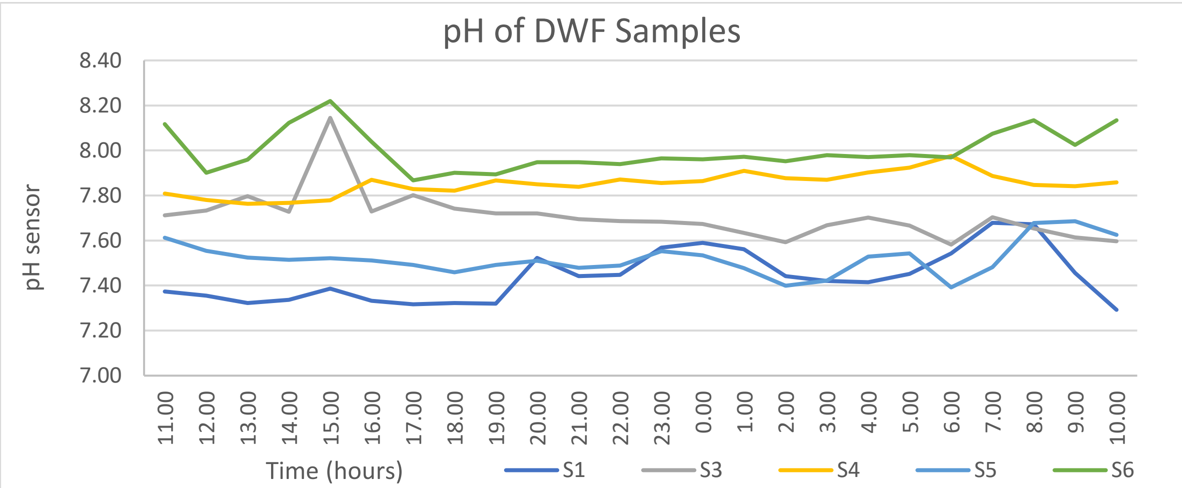

Figure 26 Hourly variation in pH(sensor) of DWF samples.

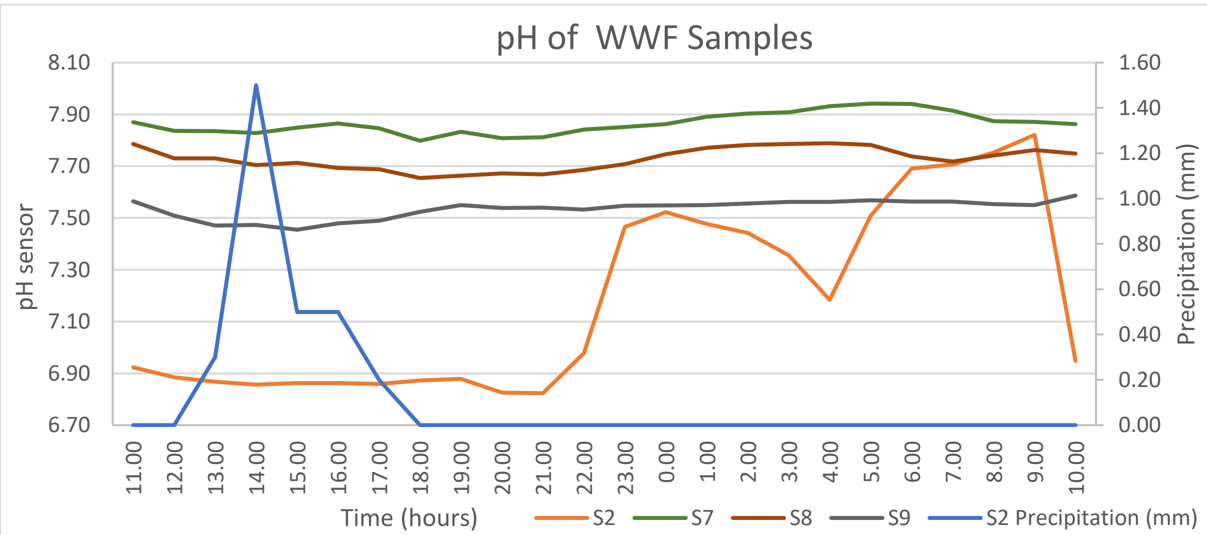

Figure 27 pH (sensor) of WWF samples and Precipitation(mm) on the S2 sampling day.

While observing pH of the samples for an entire day on the hourly basis, pH seems to be varying throughout. The average pH of DWF samples' hourly variation indicates the two peaks in pH one at early morning (6 to 8 am) and another at afternoon (2-3pm) shown in Figure 26. However, this trend seems to be suppressed in WWF samples as indicated in Figure 27. Meanwhile, WWF samples seem to exhibit some similar trends of variation among them except S2 sample series with lowest pH values throughout in comparison to other samples as shown in Figure 27. The increase in pH during peak hours is due to more domestic water consumption for example, toilet flushing. This activity contributes to a higher concentration of organic matter, nitrogen (mostly as urea) and phosphorus in urine and fecal matters. As a result urea converts into ammonium which releases bicarbonate ions and hydroxyl during hydrolysis which then contributes in increasing the pH of the sewage (Sharma et al., 2013). The reaction involved for the formation of 2 mole of ammonium, 1 mole of OH^- and 1 mole of HCO_3^- from every mole of urea is shown below (Sharma et al., 2013):

$$(NH_2)_2CO + H_2O \longrightarrow 2NH_3 + CO2$$

$$2NH_3 + 2H_20 \longleftrightarrow 2NH_4^+ + 2OH^-$$

$$CO_2 + H_20 \longleftrightarrow HCO_3 + H$$

$$H + OH^- \longleftrightarrow H_2O$$

According to Sharma et al. (2013), the significant variation in sewage pH is due to the dynamic composition of wastewater and the in-sewer processes. Another, significant relation was observed in between pH of the sample especially DWF samples and concentration of Orthophosphate (mg/l) present in the samples as represented in Figure 28. The increase in phosphate should decrease the pH as phosphate is a weak acid but instead the similar variation pattern was mostly exhibited, this may be the effect of buffer capacity of the sewage (Sharma et al., 2013).

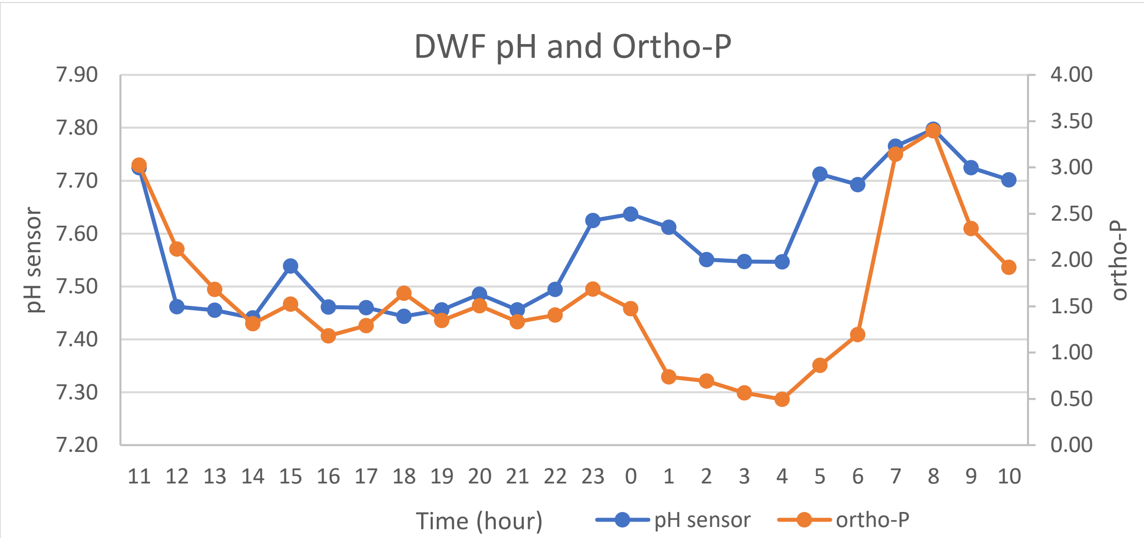

Figure 28 Average pH of DWF samples and average Concentration of O-P (mg/L).

ii. Conductivity:

The average conductivity for all the samples measured in laboratory (conductivity lab) was found 496.588 ± 65.600 µS/cm within the range of 385 to 729 µS/cm and the average conductivity from the sensor (conductivity sensor) was found 430.443 ± 58.418 µS/cm within the range of 280.904 to 532.798 µS/cm. There is a very similar pattern for the hourly variation of the conductivity measured in laboratory by conductivity device 'Cond3210' and sensor 'Digital Sensor C4E'as shown in Figure 29. In this graph, a break in conductivity sensor line can be observed in sample series S7 which is due to the missing value at time 21:00 in the Regnbyge.no similar is the case with turbidity reading. The average conductivity of the DWF samples are higher than the average conductivity of the WWF samples but the hourly variation pattern for an entire day are same in both cases as shown in Figure 43 Therefore, conductivity is higher in the morning at around 6 to 8 am and least after midnight till early morning. The graphical representation of the average conductivity of all the samples at each hour of the day is shown in Figure 30.

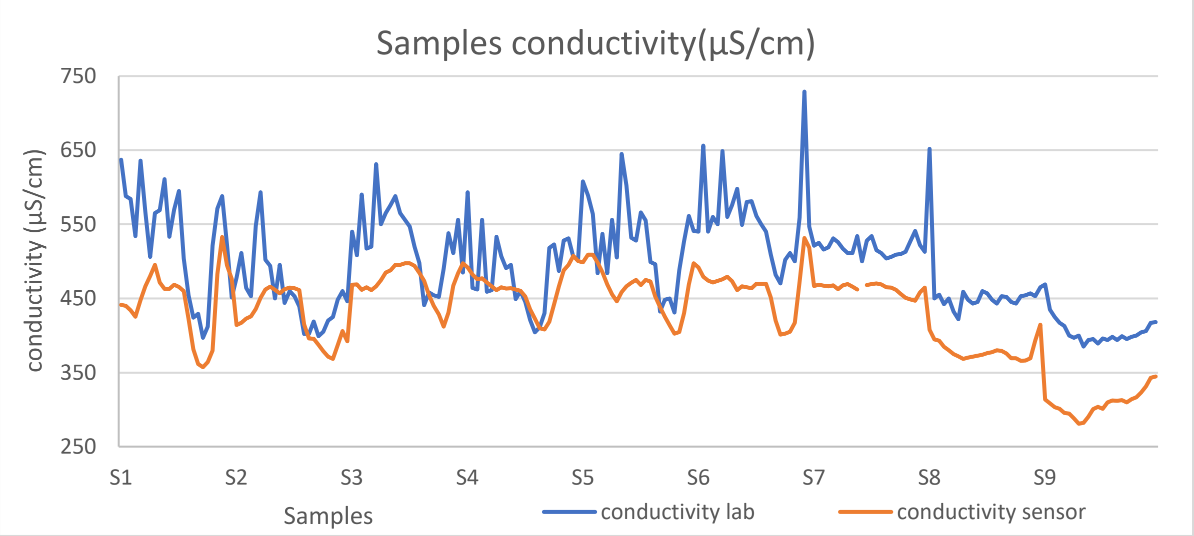

Figure 29 Samples conductivity (µS/cm) measured from Cond3210 (conductivity lab) and Digital Sensor C4E (conductivity sensor).

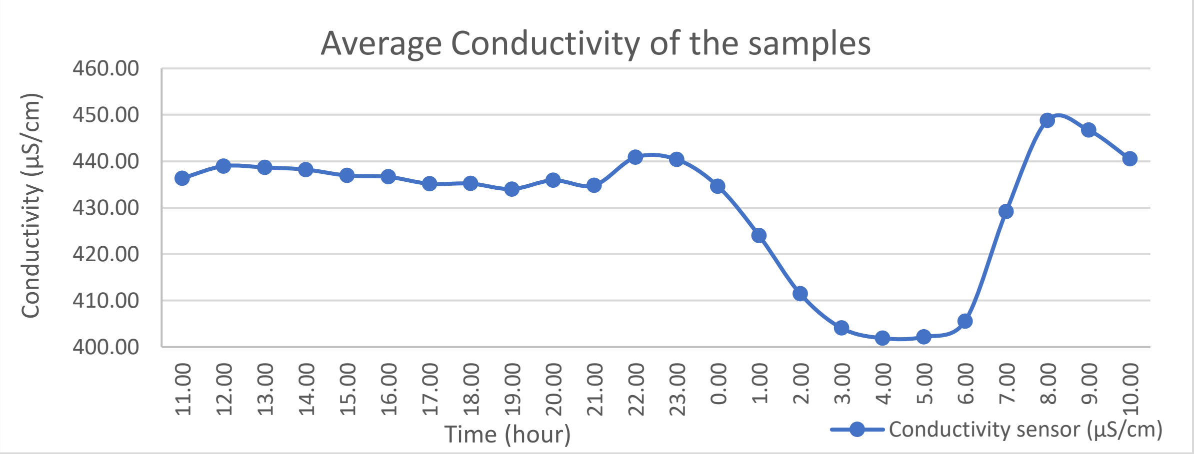

Figure 30 Hourly variation of average conductivity (µS/cm) of the samples taken from conductivity sensor.

iii. Turbidity:

The average turbidity of the samples measured in the laboratory (Turbidity lab) was found 38.830 ± 37.577 NTU within the wide range of 1.610 to 236 NTU whereas, average turbidity of the samples measured from turbidity sensor (Turbidity sensor) is 831.646 ± 1171.202 FNU within the range of 29.778 to 6904.964 FNU. Therefore, a huge difference between the Turbidity lab and sensor readings is seen in S3 sample series as shown in Figure 31. This is due to the higher readings of the turbidity values form the turbidity sensor as a result of sensor clogging with wastes. Afterwards the sensor was cleaned, and the workability was improved but again the fluctuation between the instruments reappeared. Therefore, regular maintenance and proper data observation should be done to improve the efficiency of the instrument. The average DWF samples Turbidity lab readings are higher than that of WWF samples as shown in Figure 44. Figure 32 represents hourly variation of average turbidity readings of the samples from Turbidity lab.

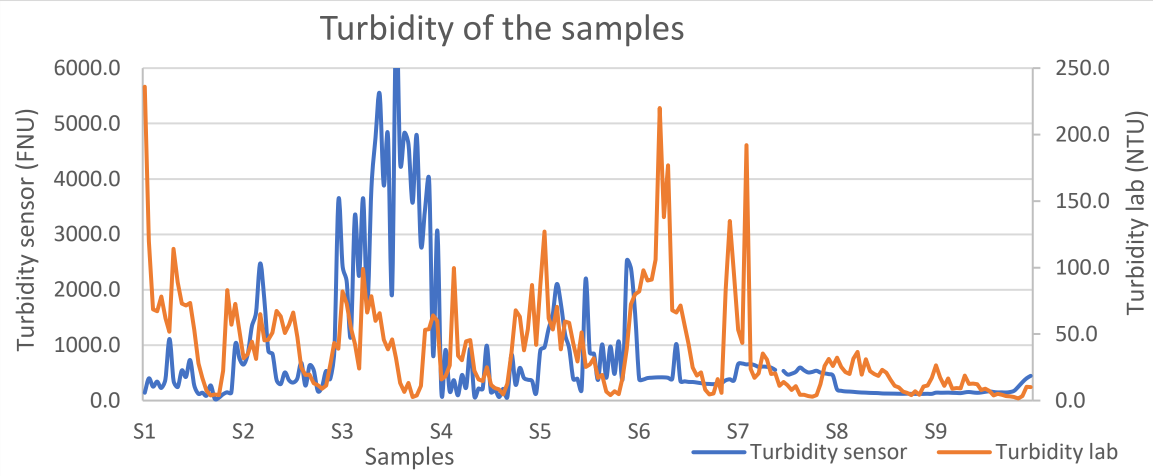

Figure 31 Samples Turbidity measurement from Nephelometric turbidity meter (Turbidity lab) and turbidity sensor (Turbidity sensor)

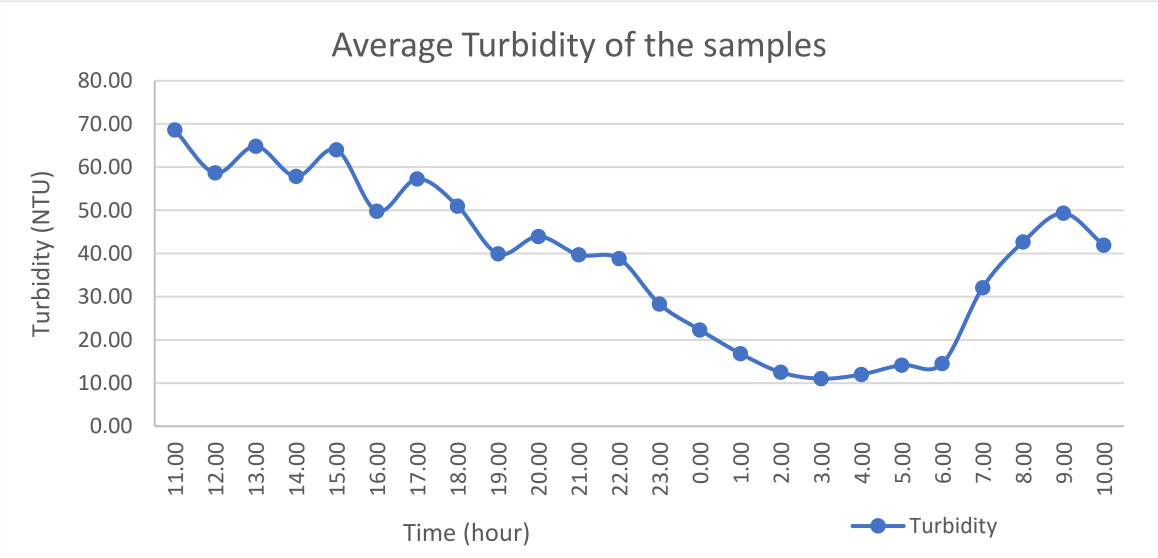

Figure 32 Hourly variation of average turbidity measured in lab.

Average concentration of pollutants (mg/l) in DWF and WWF

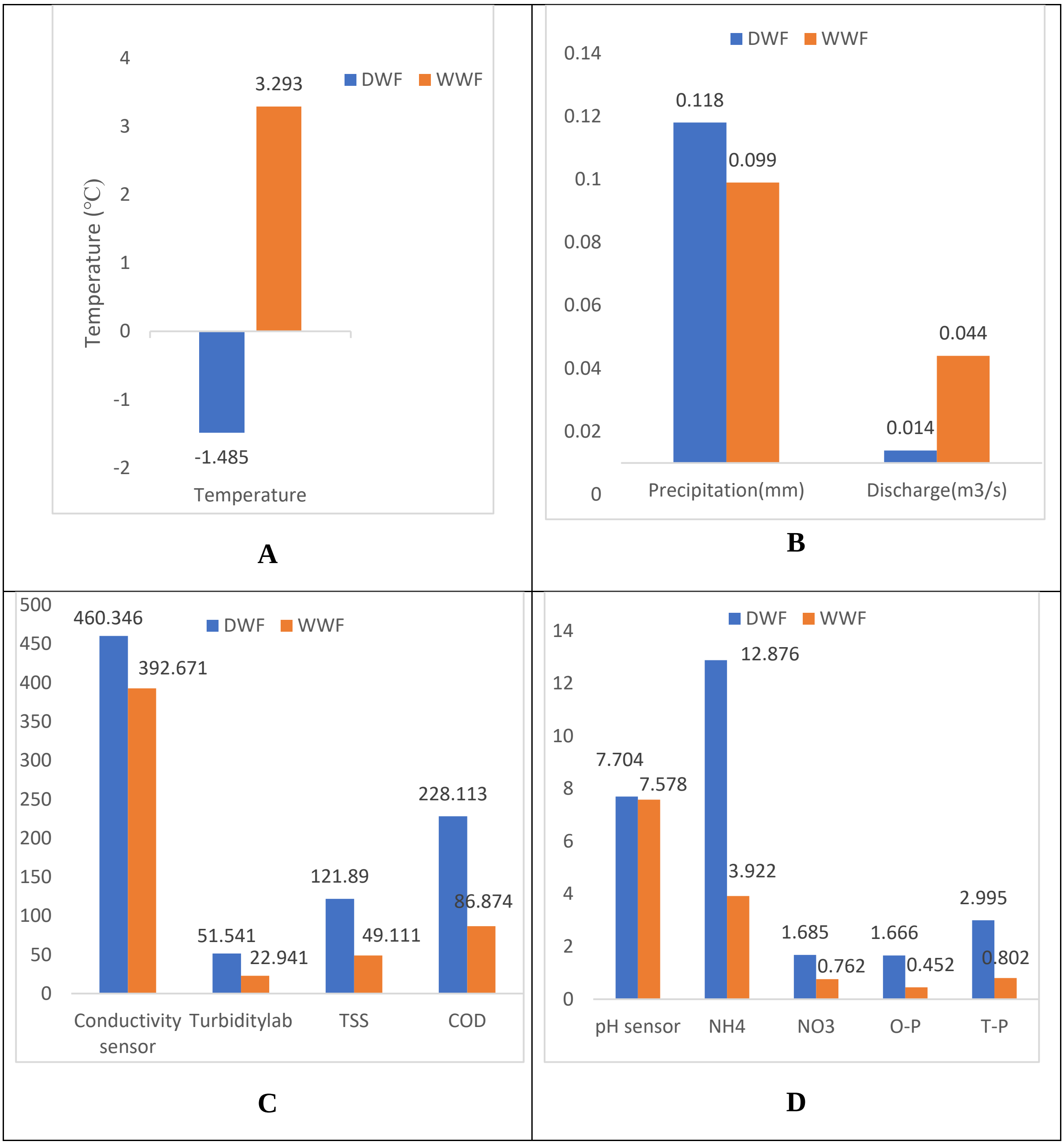

Figure 33 Average concentrations of the parameters during DWF and WWF represented by blue and orange bar respectively. In graph 'A' atmospheric temperature is given in °C, 'B' precipitation(mm) represents the amount of rainfall during the sampling days and sewage flow rate as discharge(m^3/s) during DWF and WWF, 'C' shows reading of conductivity sensor in µS/cm, Turbidity lab (NTU), TSS in mg/l and COD in mg/l and in graph 'D', average concentration of nutrients in mg/l and pH sensor average reading for DWF and WWF.

From this study, we found that the actual concentration of all the pollutants drastically reduced during the WWF in comparison to DWF as illustrated in Table 7 and Figure 33. In Figure 33 the average values of the considered parameters during DWF and WWF are displayed and the precipitation(mm) represents the rainfall event only during the sampling days. The average concentration of TSS was found to be 89.544 ± 79.313 mg/l. The maximum concentration was observed 526 mg/l during S1 sample series and minimum concentration was found -33.33 mg/l during S2 sample series. Negative values of TSS were observed when the weight of the container with the residue was lower than the weight of the container without the residue. This seems little impractical, but this may be caused due to the volatilization of the substances present in the container from before during oven drying process or due to the error in weight measurements in scale. To avoid this measurement error, higher amounts of volume during the filtration was taken. The negative values also indicate lower or even negligible TSS, so they can be assumed zero ‘0’. S1 is a dry weather sample as less sewage flow rate and no rainfall event in the sampling day but in contrast S2 is a wet weather sample with high sewage flow rate and rainfall event occurred during sampling. The lowest TSS (mg/l) amount in sample series S2 may be due to the dilution from the infiltrated water in the actual concentration of TSS produced in sanitary sewage whereas sample series S1 with no rainfall or snowmelt dilution might be representing the actual concentration of TSS produced in the catchment. Likewise, with the increment of 214% in average sewage flow rate in WWF samples in comparison to DWF samples, the average concentration of NH_4 reduced by 69.54%, NO_3 by 0.923%, COD by 141.239%, O-P by 72.87% and T-P by 73.22%. When wastewater discharges increases, certain concentrations of contaminants (e.g. COD) can be diluted also in the water-rich areas where there is infiltration of surface water and groundwater at wastewater discharge and collection systems (Sun et al., 2016). The average concentration of these pollutants in overall samples were found to be 8.399 ± 7.112 mg/l for NH_4, 1.275 ± 1.030 mg/l for NO_3, 165.340 ± 150.072mg/l for COD, 1.126 ± 1.069 mg/l for O-P and 2.02 ± 1.882 mg/l for T-P. The larger values of the standard deviation are due to the large range of values. The average concentrations of all the measured pollutants except for NO_3, are lower than the concentrations given in Table 3 representing pollutant concentrations of domestic wastewater. The lower concentration of the samples is due to the dilution and higher concentration of nitrate may be from the agriculture and forest runoffs containing nitrate-based fertilizer.

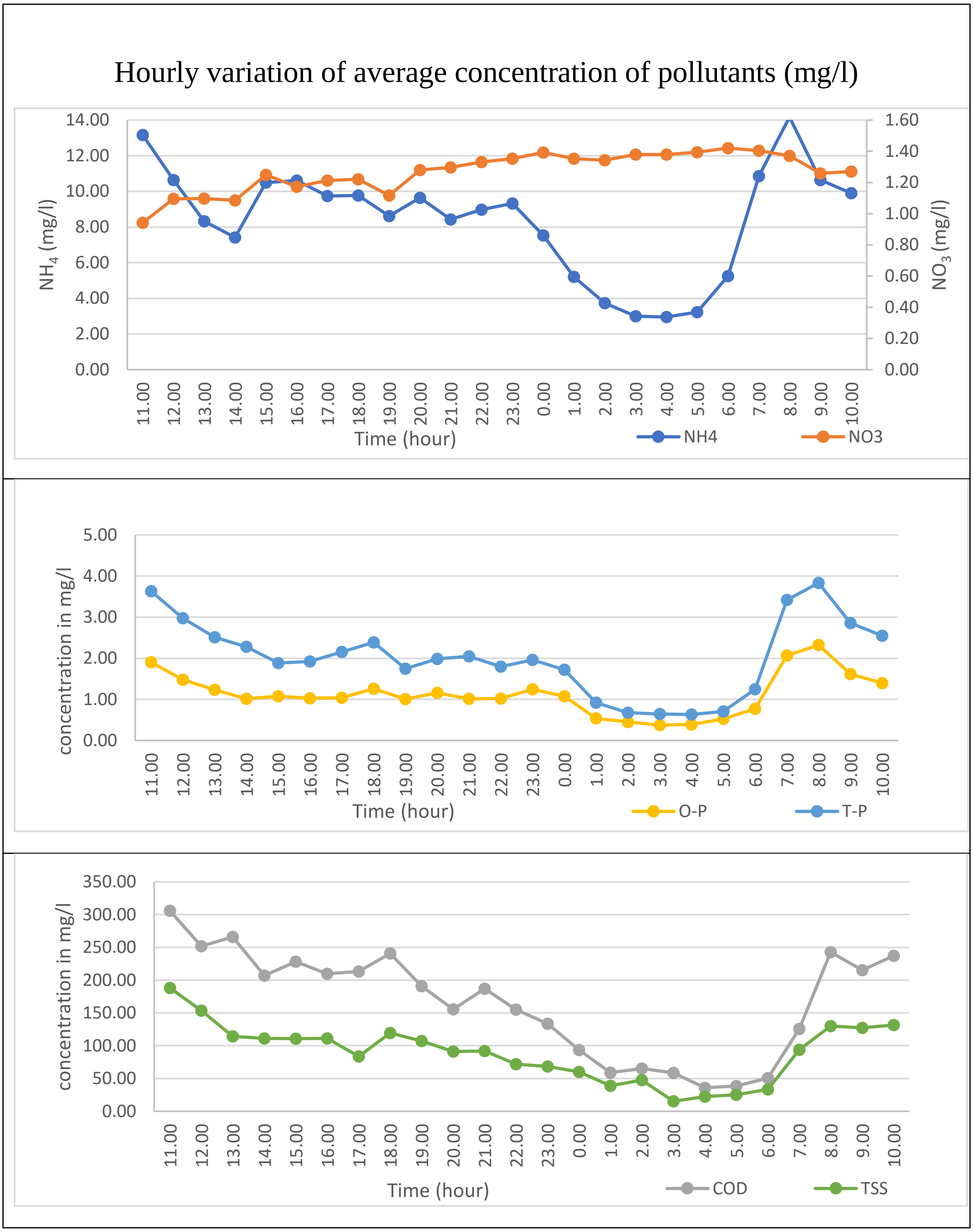

Figure 34 Hourly variation of the pollutants average concentration in mg/l.

Figure 34 exhibits the hourly variation of the average concentration of pollutant for all the samples, during the entire day. The similar hourly variation pattern was obtained for the DWF samples whereas, slightly varied pattern was observed in case of WWF samples. The graphs are presented in the Appendix. All the pollutant concentrations seem to be high during the peak hour at morning approximately from 6 to 10 am and then gradually lowers with minimum concentration after midnight. As sanitary wastewater is a primary source of influent into sewer networks, the information about the various household appliances contributing wastewater can be very helpful to know the quantity and quality of the generated wastewater (Butler et al., 1995). Almeida et al. (1999) found in their study that among 6 considered household appliances (Bath, Water closet, Wash basin, Shower, Kitchen sink and wash machine) the highest quantity of wastewater comes from the water closet (flush toilet) along with the highest pollutant load for total COD, ammonia (NH_3-N), PO_4-P and TSS. Kitchen sinks were found to be the main source of nitrate along with the second highest source of total COD, TSS and PO_4-P. These pollutant concentrations will likely be higher at the source than at the inflow of the WWTP due to the in-sewer processes that happens during conveyance of the wastewater (Almeida et al., 1999). But it is worth noting that these characteristics depends upon the individual household activities and habits which varies geographically and in time (Almeida et al., 1999).

6.3. Variables Correlation

Table 8 Cross correlation between the parameters.

Variables	Atm Temp°C	Precipitation	pH sensor	conductivity sensor	Turbidity lab	TSS	NH_4	NO_3	COD	O-P	TP	discharge(m^3/s)
Atm Temp°C	1.000	-0.069	-0.229	-0.658	-0.079	-0.213	-0.362	0.173	-0.266	-0.272	-0.275	**0.736**
Precipitation (mm)	-0.069	1.000	-0.078	0.060	0.010	0.004	-0.020	0.096	-0.029	-0.012	-0.001	-0.057
pH sensor	-0.229	-0.078	1.000	0.187	0.038	-0.063	0.021	0.387	-0.014	-0.007	0.049	-0.134
Cond sensor	-0.658	0.060	0.187	1.000	0.507	0.528	0.595	-0.055	0.501	0.478	0.526	**-0.834**
Turbidity lab (NTU)	-0.079	0.010	0.038	0.507	1.000	**0.707**	0.572	0.027	0.675	0.616	0.649	-0.366
TSS (mg/l)	-0.213	0.004	-0.063	0.528	**0.707**	1.000	**0.723**	-0.063	**0.784**	**0.763**	**0.815**	-0.434
NH_4 (mg/l)	-0.362	-0.020	0.021	0.595	0.572	**0.723**	1.000	-0.026	0.678	**0.841**	**0.815**	-0.587
NO_3 (mg/l)	0.173	0.096	0.387	-0.055	0.027	-0.063	-0.026	1.000	-0.010	0.063	0.095	-0.006
COD (mg/l)	-0.266	-0.029	-0.014	0.501	0.675	**0.784**	0.678	-0.010	1.000	**0.703**	**0.740**	-0.431
O-P (mg/l)	-0.272	-0.012	-0.007	0.478	0.616	**0.763**	**0.841**	0.063	**0.703**	1.000	**0.933**	-0.469
TP (mg/l)	-0.275	-0.001	0.049	0.526	0.649	**0.815**	**0.815**	0.095	**0.740**	**0.933**	1.000	-0.478
discharge(m^3/s)	**0.736**	-0.057	-0.134	**-0.834**	-0.366	-0.434	-0.587	-0.006	-0.431	-0.469	-0.478	1.000

The cross correlation between the observed variables were performed in the statistical tool Unscrambler X and are presented in Table 8. All the correlation coefficients greater than 0.70 are boldfaced as an indication of significant correlation between the variables. The sewage flow rate (m^3/s) has positive correlation coefficient of 0.736 with atmospheric temperature (℃). The increase in atmospheric temperature affects flow rate that is why sewage flow for later samples (S7 onwards) was observed higher. The infiltration of snow melt runoff as an effect of higher atmospheric temperature is the reason for higher sewage flow. In the case of precipitation (mm), pH and NO_3 no significant correlation can be seen. This could indicate that it isn't possible to get a good quality regression model for these parameters. The conductivity (µS/cm) of the samples illustrates significant negative correlation coefficient of -0.834 with sewage flow (m^3/s). The correlation coefficients of the turbidity (NTU) within the parameters are comparatively higher. This indicates that it is a significant parameter for assessing most of the wastewater parameter such as TSS, COD, O-P, T-P and conductivity. Turbidity greatly depends upon TSS present in the sample. The correlation coefficient of turbidity with TSS is 0.707 and above 0.60 with COD, O-P and T-P. Similarly, TSS is also a significant parameter for the study about wastewater quality. It has a notable correlation above 0.70 with NH_4, COD, O-P and T-P. It also seems to be correlated with conductivity with correlation coefficient of 0.528. Therefore, the parameters conductivity, mainly TSS and Turbidity are correlated with the NH_4, O-P and T-P content in wastewater as there exists strong correlation between them. Their proper assessment can provide reliable and useful information about the presences of the pollutants. Hence, the obtained information about the pollutants present in the domestic wastewater such as ammonia, nitrogen and phosphorus in terms of their concentration and variation can be very beneficial for the proper choice of the treatment process and cost efficiency (Schwinn & Dickson Jr, 1972). After several study of raw domestic wastewaters, Schwinn and Dickson Jr (1972) proposed the independency in the concentrations of ammonia, total nitrogen and phosphorus with respect to the BOD, Suspended solids and flow. Similar outcome was encountered in this study for NO_3 but not in case of NH_4 and phosphorus as they illustrated a strong correlation with TSS. This may be due the high infiltration of the ground water in the sewer system which have greatly altered the inherent composition of the sanitary wastewater.

6.4. Statistical Analysis in Unscrambler X

The Principal component analysis of the influent wastewater quantity and quality with all the 216 samples were performed. The category sets of DWF and WWF samples, Weekend and Weekday samples and day and night samples were made to see if there exist any significant trend among the variables within the category. All the PCA models was verified by cross validation method and Non-linear Iterative Partial Least Squares (NIPALS) algorithm. NIPALS was selected due to need of handling the missing values in the datasets. Here the missing values are for S7 sample series at 21:00 pm for pH, conductivity and turbidity reading from the sensors which were missing from the Regnbyge.no website. This may be due to the power failure or server down in the online system or telecommunication error.

When PCA model was run with all considered variables including very high range NH_4 concentration of S5 sample series, the PC-1 (first principal component) represented total variance of the data by 35.8% calibrated and 31.61% for validated. All four principal components explained 66.39% of total variance for calibration while, validation was explained by 52.25%. Then PCA model was again run but this time without the high range concentration of NH_3 as there was a high probability of creating noise in the model by this data. As expected, the PCA model functionality was improved. PC-1 explained 37.97% of total variance of data (calibrated) for which validation was explained by 33.84% of total variance. All four principal components (PC-1 to PC-4) explained 68.53% of total variance for calibration and 55.79% for validation as shown in Figure 35 . Among all categorical sets, the samples grouping was distinct for DWF and WWF samples as shown in Figure 36.

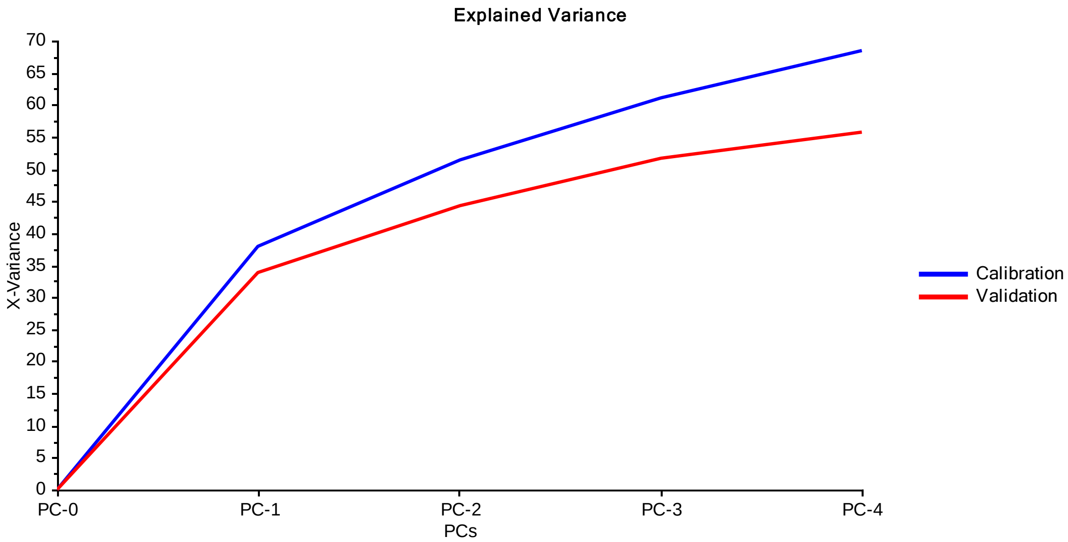

Figure 35 The cumulative explained variance of all the principal components with calibration and validation represented by blue line and red line respectively. The calibration is the fitted line of PCA model result and validation line represents the results of cross validation.

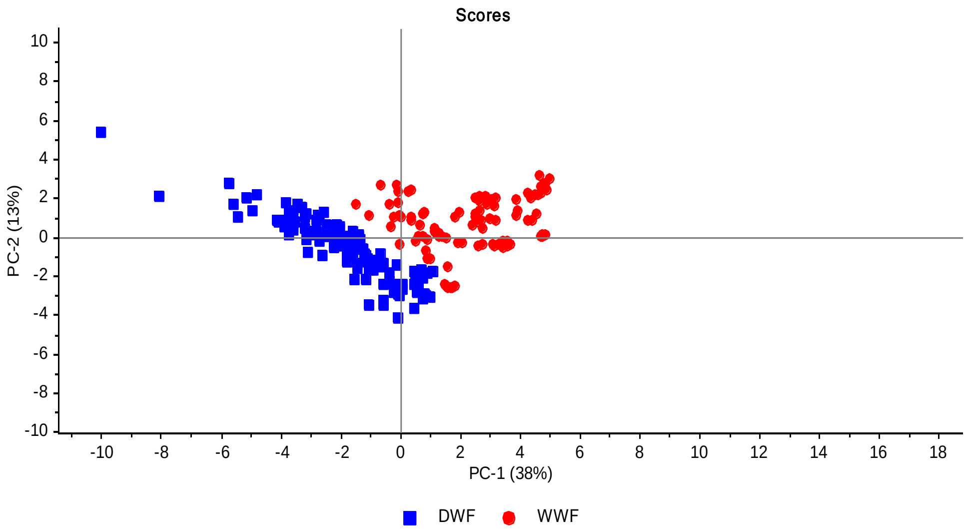

Figure 36 Scores plot of the PCA model with sample grouping as DWF represented by blue boxes and WWF by red dots on the plane of PC-1 and PC-2.

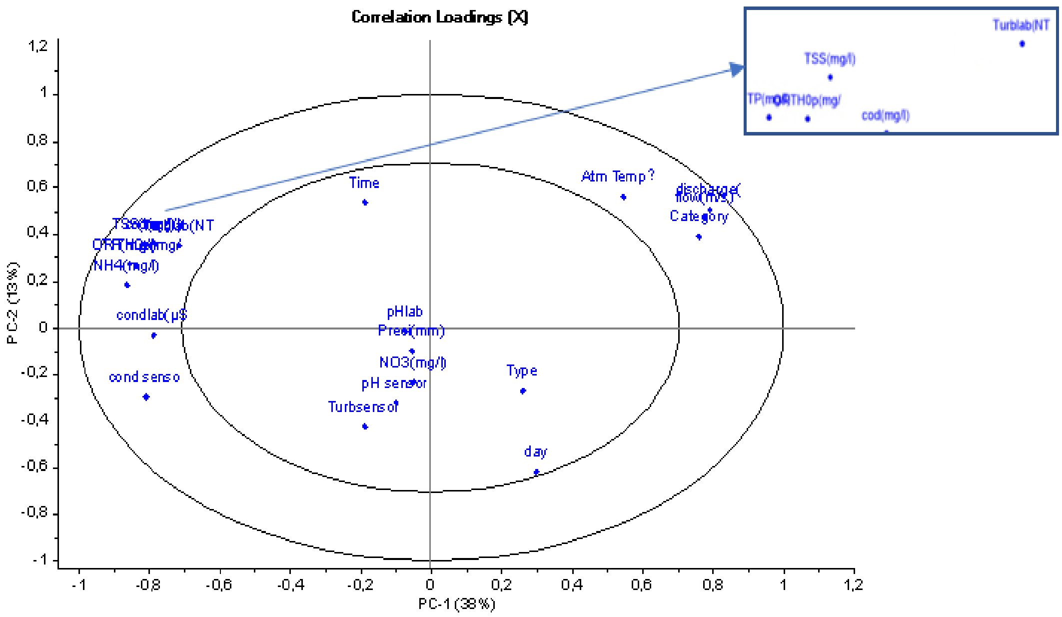

Figure 37 Correlation loading plot on the plane of PC-1 and PC-2 for all the variables.

Figure 37 illustrates the correlation loadings between the variables which appear to be split into three groups. The first group with higher PC-1 loading included atmospheric temperature (Atm Temp°C), sewage flow rate and flow velocity as ‘discharge(m^3/s)’, ‘flow(m/s)’ and category (non-numeric variable). The second group has positive PC-2 loading and higher negative loading on PC-1. This group includes Turbidity from lab measurement (TurblabNTU), COD (mg/l), TSS (mg/l), orthophosphate (ORTHOp(mg/l)), total phosphorus (TP(mg/l)), ammonium (NH4(mg/l)), conductivity lab as ‘condlab(µS/cm)’ and conductivity sensor as ‘cond sensor’ respectively. The third group includes time, pH lab (pHlab)and pH sensor, nitrate (NO3mg/l), precipitation (Preci(mm)), turbidity sensor (Turbsensor) and categorical variable type and day. The variable groups in the outer ellipse represents 100% explained variance whereas, the inner ellipse indicates 50% of explained variance (*Unscrambler® X*). The first and the second group variables are negatively correlated to each other in PC-1. The third group is within the inner ellipse and contains less than 50% of the explained variance with PC-1 and PC-2. These variables can contribute to noise in the PCA and was therefore removed during the second analysis. The categorical variables and ‘condlab(µS/cm)’ were also removed as conductivity can be represented by variable ‘cond sensor’. The second group variables are not significantly explained by PC-1 alone, but in combination with PC-2 it is above 50%.

<u>PCA with highly correlated variables:</u>

The variables within the inner ellipse of the correlation loadings plot which represents less than 50 % of explained variance were removed in the second PCA model. The visual outcomes of the model are exhibited in Figure 38 and Figure 39.

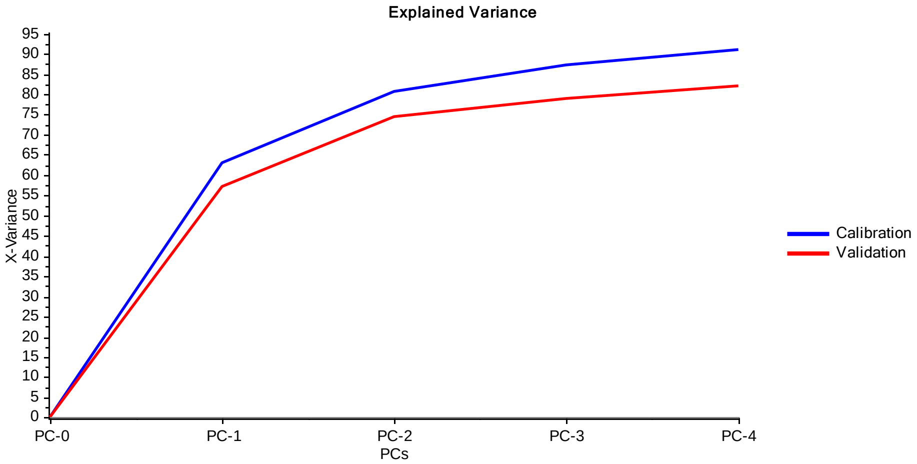

Figure 38 The cumulative explained variance for second PCA model of all the principal components with calibration (blue) and validation (red).

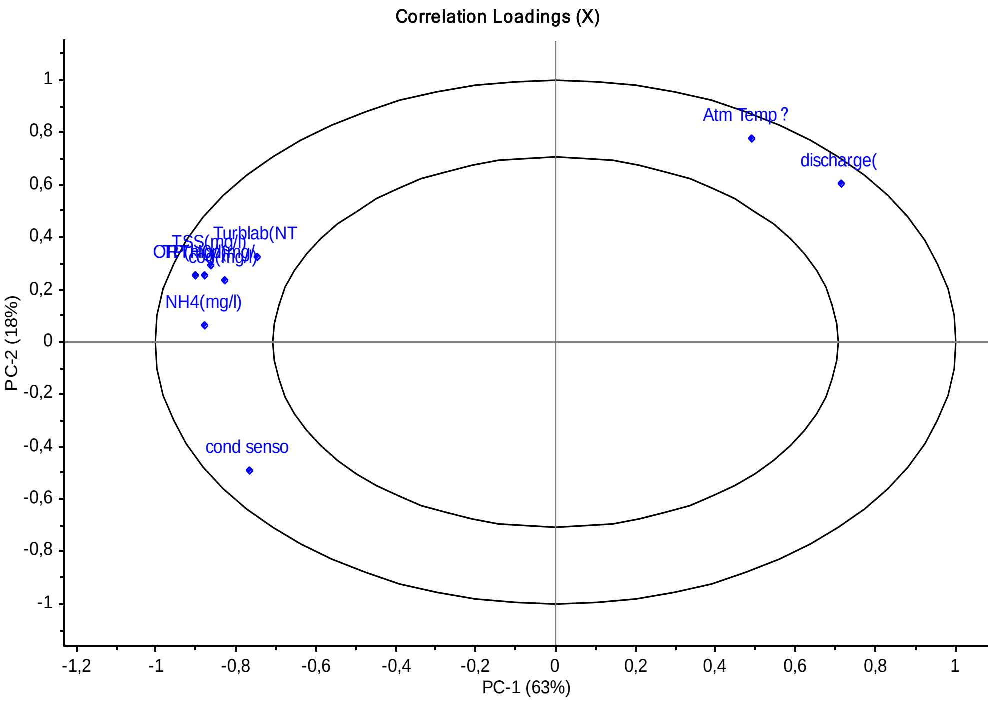

Figure 39 Correlation Loading plot of the variables on the plane PC-1 and PC-2, second PCA model.

In this model, PC-1 is explained by 63.11 % of total variance of data (calibrated) for which validation was explained by 57.21 % of total variance. All four principal components (PC-1, PC-2, PC-3 and PC-4) explained 91.1% of total variance in calibration and 81.91 % for validation as shown in Figure 38. The correlation loading plot is illustrated in Figure 39. The correlation between the first and second group variables are same as observed in previous model. Only the total percentage of the explained variance for calibration and validation are increased. The numerical values of all the variable loadings can be seen from Table 9.

Table 9 Correlation coefficient between principal components and original variables.

Variables	PC-1	PC-2
Atm Temp°C	0.492	**0.776**
Turblab(NTU)	**-0.747**	0.323
TSS(mg/l)	**-0.862**	0.291
NH_4(mg/l)	**-0.877**	0.064
cod(mg/l)	**-0.829**	0.237
ORTH0p(mg/l)	**-0.876**	0.251
TP(mg/l)	**-0.899**	0.252
cond sensor	**-0.767**	-0.492
discharge(m^3/s)	**0.716**	0.606

PCA model with interaction terms:

From the interactions and squares, the combinations of the variables can be obtained. This helps to detect the presence of any nonlinearities between the variables within a data set. Meanwhile, interactions and square terms can also add noninformative variables which increase the noise in the model (*Unscrambler® X*).

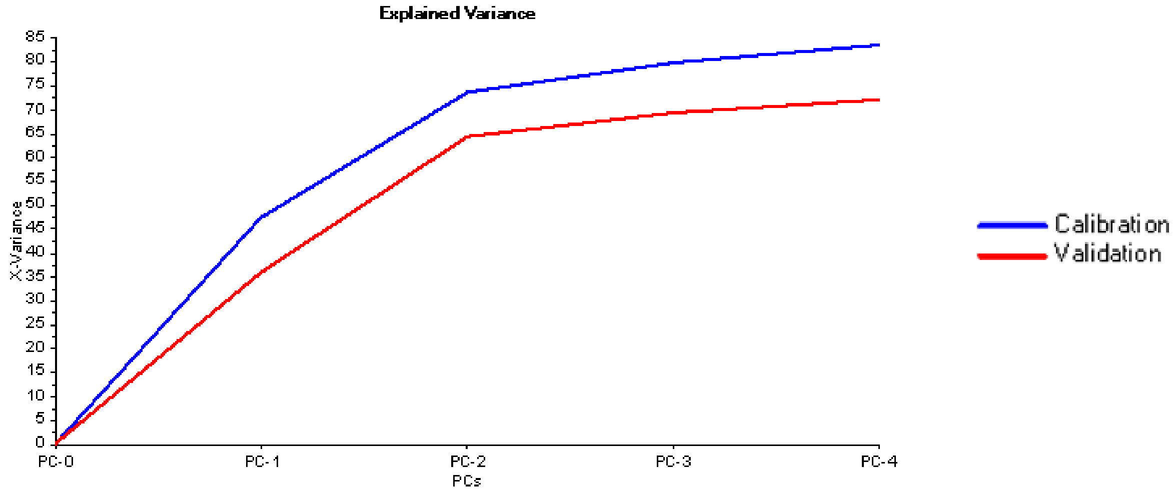

Figure 40 Cumulative explained variance of the principal components with the interaction terms in PCA model. Blue line for calibration of the PCA model and validation represented by red lines.

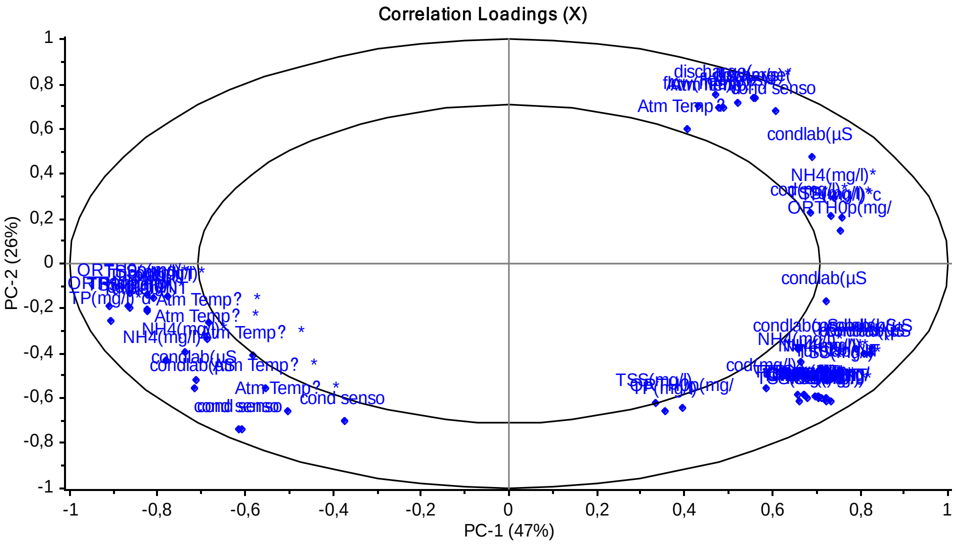

Figure 41 Correlation loadings plot of the PCA model with variables interaction terms.

The presence of interaction terms in the model reduced the PC-1 explained percentage to 47.2% and 31.51% of total variance of data for calibration and validation respectively. All four principal components (PC-1 to PC-4) indicated 84.8% of total variance in calibration and 71.2% for validation as shown in Figure 40. Meanwhile, the correlation loading plot illustrated in Figure 41 indicates the new correlation between the variables along with the interaction terms. The three main variable clusters are formed in three quadrants two on higher PC-1 plane and one variable cluster on the negative PC-1 and PC-2 plane. The two variables cluster on higher PC-1 are highly correlated to each other whereas, the one on the opposite quadrant are inversely correlated to each other. Table 10 illustrates the correlation coefficient for each variable with principal components and the most significant correlation are bold faced.

Table 10 Correlation coefficients of principal components and original variables with interaction terms.

Variables	PC-1	PC-2
Atm Temp°C	0.233	0.689
TSS(mg/l)	0.493	-0.491
ORTH0p(mg/l)	0.569	-0.479
TP(mg/l)	0.532	-0.502
cond sensor	-0.173	**-0.752**
discharge(m3/s)	0.247	**0.820**
Atm Temp°C*TSS(mg/l)	-0.536	-0.476
Atm Temp°C*NH_4(mg/l)	-0.488	-0.601
Atm Temp°C*ORTH0p(mg/l)	-0.627	-0.482
Atm Temp°C*TP(mg/l)	-0.610	-0.554
Atm Temp°C*cond sensor	-0.333	**-0.769**
Atm Temp°C*discharge(m3/s)	0.301	**0.789**
Turblab(NTU)*TSS(mg/l)	**0.812**	-0.432
Turblab(NTU)*NH_4(mg/l)	**0.835**	-0.284
Turblab(NTU)*cod(mg/l)	**0.782**	-0.424
Turblab(NTU)*ORTH0p(mg/l)	**0.853**	-0.416
Turblab(NTU)*TP(mg/l)	**0.840**	-0.416
Turblab(NTU)*discharge(m3/s)	**-0.715**	-0.387
TSS(mg/l)*NH_4(mg/l)	**0.855**	-0.276

TSS(mg/l)*cod(mg/l)	**0.801**	-0.421
TSS(mg/l)*ORTH0p(mg/l)	**0.872**	-0.416
TSS(mg/l)*TP(mg/l)	**0.864**	-0.423
TSS(mg/l)*cond sensor	0.652	0.437
TSS(mg/l)*discharge(m3/s)	**-0.768**	-0.399
NH_4(mg/l)*cod(mg/l)	**0.808**	-0.261
NH_4(mg/l)*ORTH0p(mg/l)	**0.759**	-0.221
NH_4(mg/l)*TP(mg/l)	**0.814**	-0.242
NH_4(mg/l)*cond sensor	0.639	0.519
NH_4(mg/l)*discharge(m3/s)	-0.626	-0.621
cod(mg/l)*ORTH0p(mg/l)	**0.834**	-0.411
cod(mg/l)*TP(mg/l)	**0.826**	-0.414
cod(mg/l)*cond sensor	0.600	0.438
cod(mg/l)*discharge(m3/s)	**-0.725**	-0.392
ORTH0p(mg/l)*TP(mg/l)	**0.848**	-0.391
ORTH0p(mg/l)*cond sensor	0.697	0.395
ORTH0p(mg/l)*discharge(m3/s)	**-0.822**	-0.410
TP(mg/l)*cond sensor	0.690	0.453
TP(mg/l)*discharge(m3/s)	**-0.807**	-0.472
cond sensor*discharge(m3/s)	-0.394	**-0.852**
TSS(mg/l)**2	**0.803**	-0.444
cod(mg/l)**2	**0.718**	-0.405
ORTH0p(mg/l)**2	**0.847**	-0.386
TP(mg/l)**2	**0.817**	-0.391
cond sensor**2	0.419	**0.818**
discharge(m3/s)**2	0.345	**0.834**

Therefore, from the PCA we can conclude that there is a high correlation between atmospheric temperature and the sewage influent discharge. The infiltration in the sewer line seems to be increased during higher atmospheric temperature probably from the snowmelt runoff. The conductivity of the wastewater has high negative correlation with sewage influent discharge. This result may be site specific, as higher degree of urbanization usually means more ionic pollutants in the runoff.

The stronger correlation between NH_4 with orthophosphate and total phosphorus observed may be due the presence of ammonium phosphate (Deffontis et al., 2013). This substance used as a fertilizer or present in the outfall from industries. Therefore, the presence of phosphate ion raises the correlation between the orthophosphate and total phosphorus with conductivity. Also, the presence of ionic colloidal phase may have caused the correlation between conductivity and turbidity (Deffontis et al., 2013). The COD concentration is related to organic matter from the point source, sanitary sewage. Therefore, it has negative correlation with sewage discharge due to dilution from the infiltrated water. Basically, all the pollutant concentrations have a negative correlation with the sewage discharge which is a result of dilution of the sanitary sewage with the infiltration. Thus, PCA aided to find the interesting correlations and hidden structures between the variables. Therefore, an important wastewater parameter which can be used to estimate the pollutant concentrations of the catchment was identified. The important wastewater parameters specific to the study area, was found to be conductivity, turbidity, TSS and sewage flow rate. Also, the observed interrelated behavior of the pollutants (NH_4, COD, O-P, T-P and TSS) can be of great interest. Hence, from further statistical analysis the estimation of time consuming and costly pollutant variables such as COD, T-P can be done by using simple, quick and cost-effective wastewater parameters such as sewage flow, turbidity, conductivity.

6.5. Quantification of pollutant loads

After the sewage sample analysis of 9 days sample series (24hour samples) in laboratory, the obtained concentration of all the measured pollutants (TSS, NH_4, NO_3, COD, O-P and T-P) in milligram per liter of sample (mg/l) was entered in MS-Excel along with the sewage flow (m^3/s) data for each hour of the sampling days taken from Regnbyge.no. The rate of sewage flow given in cubic meter per second was converted into liters per hour as the concentrations of the pollutants was in milligram per liter. Therefore, for all 9 days samples series (S1 to S9), the concentrations of pollutant in milligram per hour (mg/hr) was obtained for which each pollutants concentration (mg/l) was multiplied by the sewage flow rate of that hour (l/hr). Finally, after adding all the hourly flow of pollutants (mg/hr), the total concentration of each pollutants in that sampling day was calculated as kilogram per day (kg/day) which is listed in Table 11. The calculated average DWF and WWF pollutant loads (kg/day) are also illustrated in bar graphs for the easy comparison of their variation Figure 42. The excel data sheet and calculations are available in Table 14 (appendix).

Table 11 Pollutants quantification (kg/day) for each sampling events.

Sample series	Sampling Month	Sewage Discharge (L/day)	TSS (kg/day)	NH_4 (kg/day)	NO_3 (kg/day)	COD (kg/day)	O-P (kg/day)	T-P (kg/day)
S1	January	996181.2	176.0751	18.7446	0.1183	310.6704	2.5217	4.0634
S2	January	2718424.8	213.8546	16.8757	0.8940	367.7616	2.4244	4.2876
S3	February	1439938.8	143.1414	12.5816	3.0135	189.9017	1.1437	3.0439
S4	February	1225573.2	137.6679	15.8693	2.4453	319.5447	2.0945	4.6078
S5	February	1149969.6	124.6081	0.0000	1.5532	241.6754	1.9521	2.8307
S6	March	1244005.2	176.7037	16.2106	3.4158	344.1785	2.4558	4.1668
S7	March	1896606	99.5309	9.0822	0.0332	184.7859	0.5210	1.0417
S8	April	4622641.2	159.1925	12.6895	2.8092	286.8651	1.4148	3.0616
S9	April	6031666.8	144.4133	8.3823	12.7658	276.1336	1.7093	2.0370
Total load		21325006.800	1375.188	110.436	27.048	2521.517	16.237	29.140
Total DWF load		6055668.000	758.196	63.406	10.546	1405.971	10.168	18.713
Total WWF load		15269338.800	616.991	47.030	16.502	1115.546	6.070	10.428
Total Weekends pollutants load		10518181.200	511.694	30.046	17.366	892.497	5.326	8.953
Total Weekdays pollutants load		10806825.600	863.494	80.390	9.683	1629.020	10.911	20.187
Average DWF pollutants load		1211133.600	151.639	15.851	2.109	281.194	2.034	3.743
Average WWF pollutants load		3817334.700	154.248	11.757	4.126	278.887	1.517	2.607
Average Weekend pollutants load		2629545.300	127.923	7.512	4.341	223.124	1.332	2.238
Average Weekday pollutants load		2161365.120	172.699	16.078	1.937	325.804	2.182	4.037

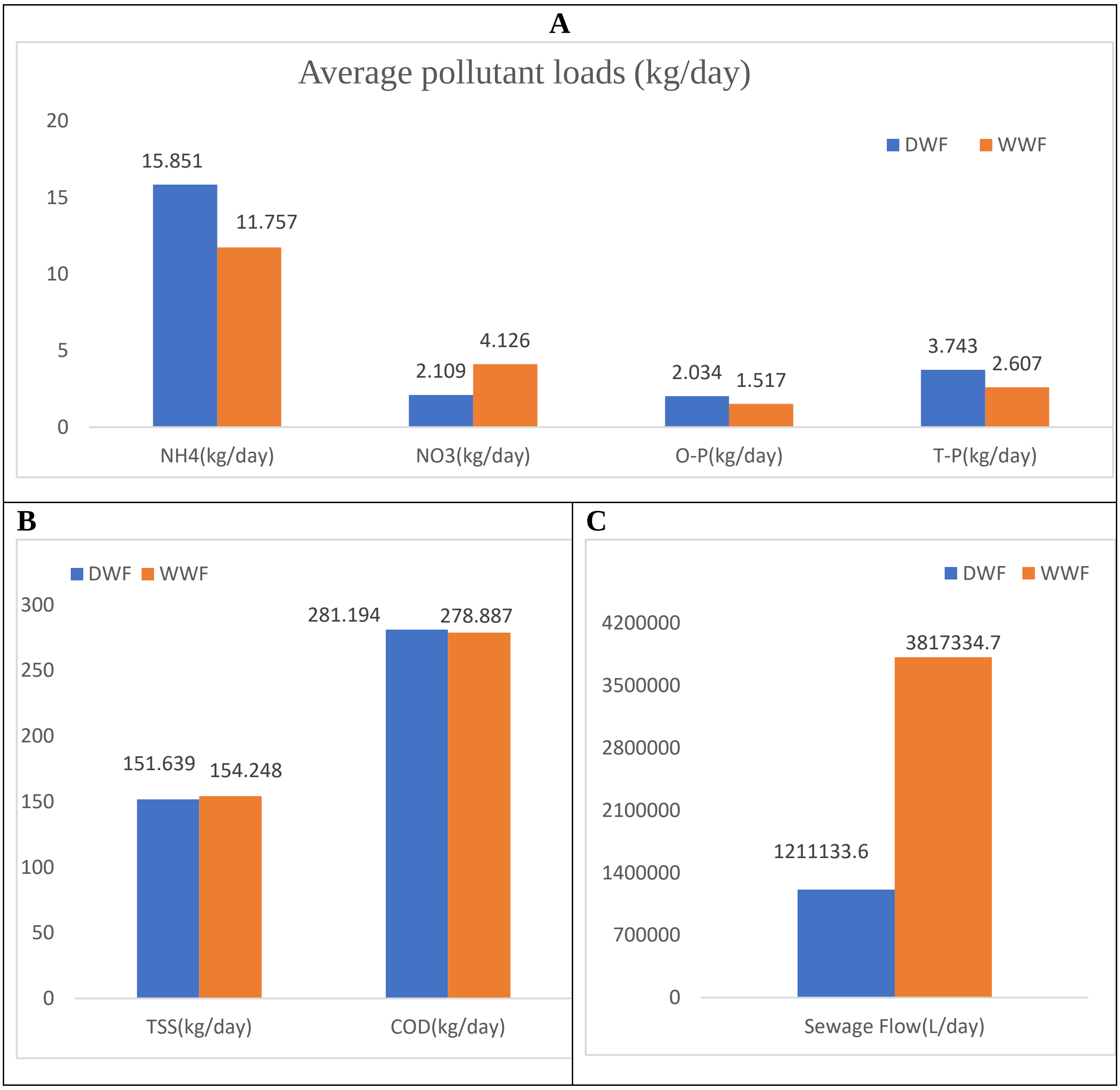

Figure 42 Average pollutant loads (kg/day) during DWF and WWF. The graph 'A' indicates the average pollutants load for NH_4, NO_3, O-P and T-P in kg/day. Graph 'B' indicates average pollutant load (kg/day) for TSS and COD and in graph 'C' sewage flow in l/day for the DWF and WWF are given. Blue bar indicates DWF and orange bar are for WWF samples.

The Figure 42 illustrates the average load of pollutants (kg/day) in DWF and WWF samples. Except nitrate all other pollutants load (kg/day) for DWF is slightly higher than WWF. This may be due to the leaching of nitrate-based fertilizer from the agriculture fields located at the catchment (Figure 2) and from nitrogen saturated forest soil. The leaching of nitrate from nitrogen saturated forest soil are higher in case of spruce trees (Borken & Matzner, 2004) which is a common type of forest tree in Norway (Dalen, 2013). In graph 'B', TSS and COD pollutants load (kg/day) is presented and both pollutants load for DWF are slightly greater than WWF. From graph 'C' the significant difference in incoming sewage flow during DWF and WWF can be observed. Despite of separate sewer system network in the catchment, the effect of rainwater and snow melt has been significantly affecting the sewer system due to infiltration.

6. Conclusion

The study carried on the wastewater quantity and quality of the separate sanitary sewage for the catchment at Våkas, Asker indicated that the characteristics of the influent wastewater varies temporally and are highly influence by the environmental exposures of the catchment. The high degree of infiltration of the groundwater possibly from nearby water stream, surface runoffs from rainfall and snowmelt into the sewer network was observed. This has raised dependency of the influent wastewater characteristics to the environmental exposures. Such as physical properties, land use, geographical and climatic condition. The average WWF discharge (m^3/s) increased approximately three times the average DWF discharge. The average pollutant concentration during WWF reduced notably than in DWF due to the dilution effect from the rainwater and snowmelt. The sewer overflow possibilities during wet weathers and high environmental contamination risks can be predicted due to the leaky sewer network system. Therefore, the urgent need of proper maintenance of the sewer network system can be concluded. The parameters conductivity, turbidity, NH_4, flow (m^3/s) are highly correlated. These can be used as predictor for slower and more costly pollutant loads (example COD, T-P) in the wastewater can be made possible from multivariate statistical analysis. This can save the energy and resources up to the great extent. Additionally, new innovative ideas for the virtual sensor development can be obtained from further multivariate statistical analysis.

7. References

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8. Appendix

Table 12 Chemical Reagents for colorimetric tests (SYSTEA, 12/03/2009).

Nitrate (NO_3) Test with working solution R1, R2 and R3		
R1: Cupric sulfate stock 0.05% - 5 ml and diluted till 100 ml (Cupric sulfate – 0.05 g to 100 ml DI water)	R2: Sodium hydroxide NaOH 0.4N stock – 80 ml Hydrazine sulfate – 20 ml (sodium hydroxide – 8 g to 500 ml DI water, Hydrazine Sulfate – 0.6 g to 100 ml DI water)	R3: Sulfanilamide – 1 g Hydrochloric acid conc. – 5 ml N-1-naphthylethylenediamine dihydrochloride – 0.1 g And diluted the mixture to 100 ml by DI water
Stability: 1 month	Stability: 2 days	Stability: 4 weeks
Ammonia (NH_3) Test with working solution R1, R2		
R1: Stock A Phenol - 6 ml Stock B EDTA - 6 ml Stock C Nitroferricyanide – 8 ml (stock A: Phenol (88%) C6H5OH - 8.3g and Sodium hydroxide - 3.207 g diluted to 100 ml DI water, Stock B: Disodium EDTA – 5 g diluted to 100 ml DI water, Stock C: Sodium Nitroferricyanide – 0.05 g diluted to 100 ml)	R2: Sodium hypochlorite 14 % - 17.9 ml Diluted to 100 ml DI water	
Stability: 3 days	Stability: 2 days	
Orthophosphate Test with R1, R2		
R1: Molybdate Stock - 15 mL (sodium molybdate – 2.22 g diluted to 100 ml DI water) Sulfuric Acid (5N) Stock - 50 mL (Sulphuric acid conc. - 14 ml diluted to 100 ml DI water) Antimony Stock - 5 mL (Potassium antimony(III) oxide tartratetrihydrate - 0.3 g	R2: Ascorbic Acid - 1.810 g Diluted to 100 ml DI water	
stable	stable	

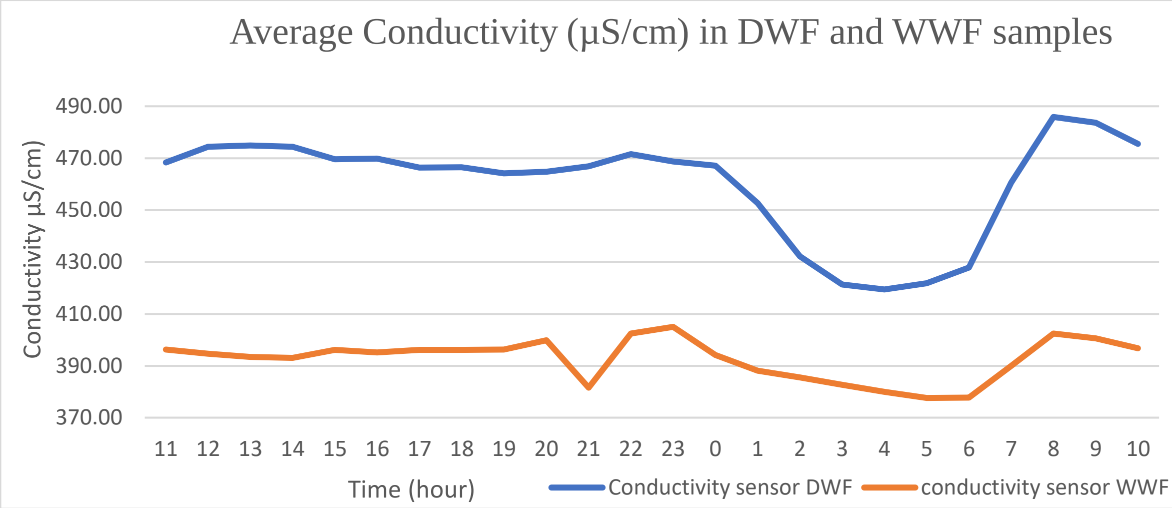

Figure 43 Hourly variation in average conductivity of the DWF and WWF samples.

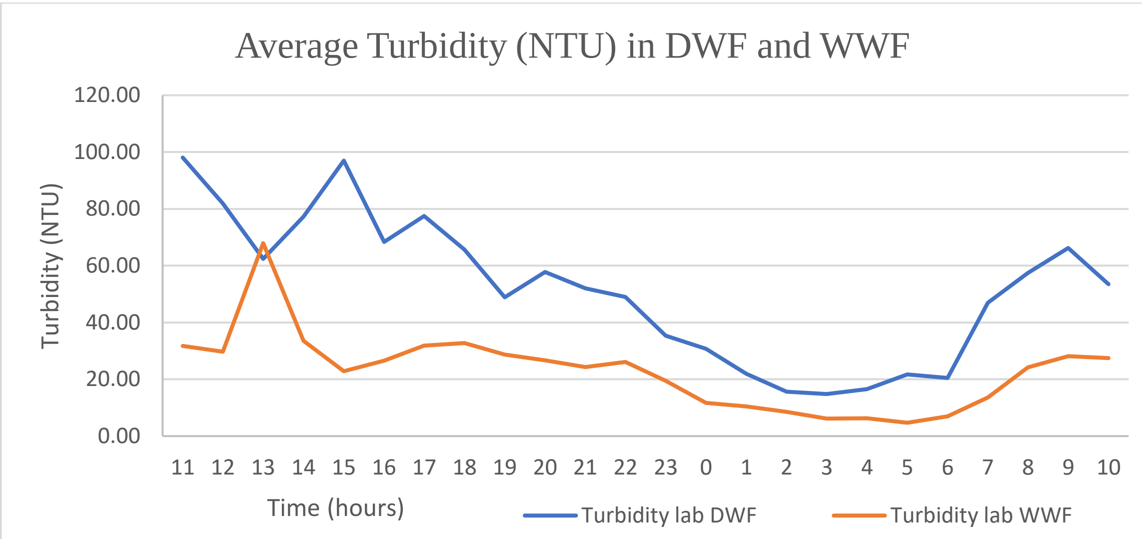

Figure 44 Hourly variation in average turbidity of the DWF and WWF samples.

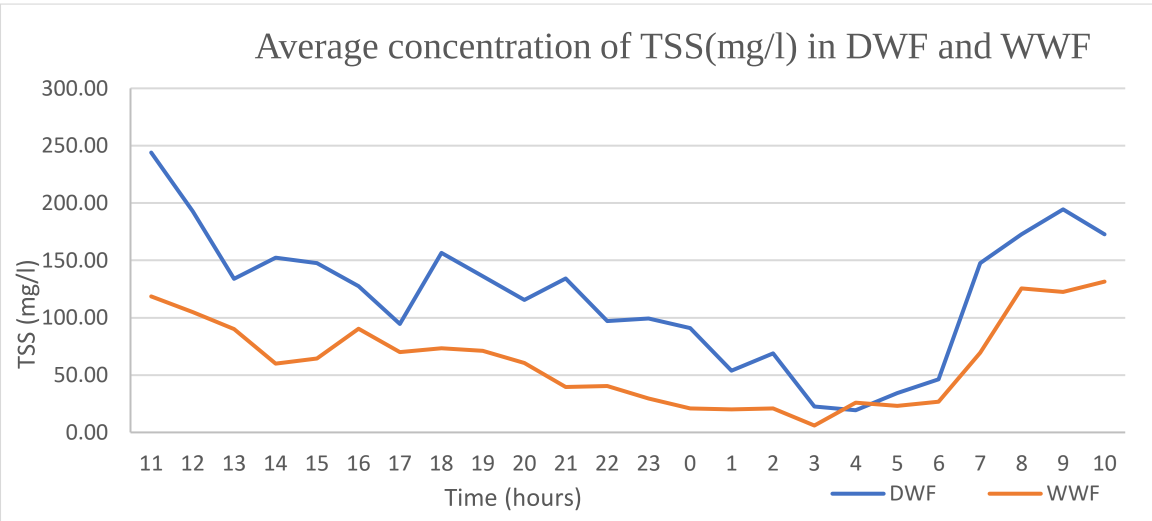

Figure 45 Hourly variation of average concentration of TSS (mg/l) in DWF and WWF samples.

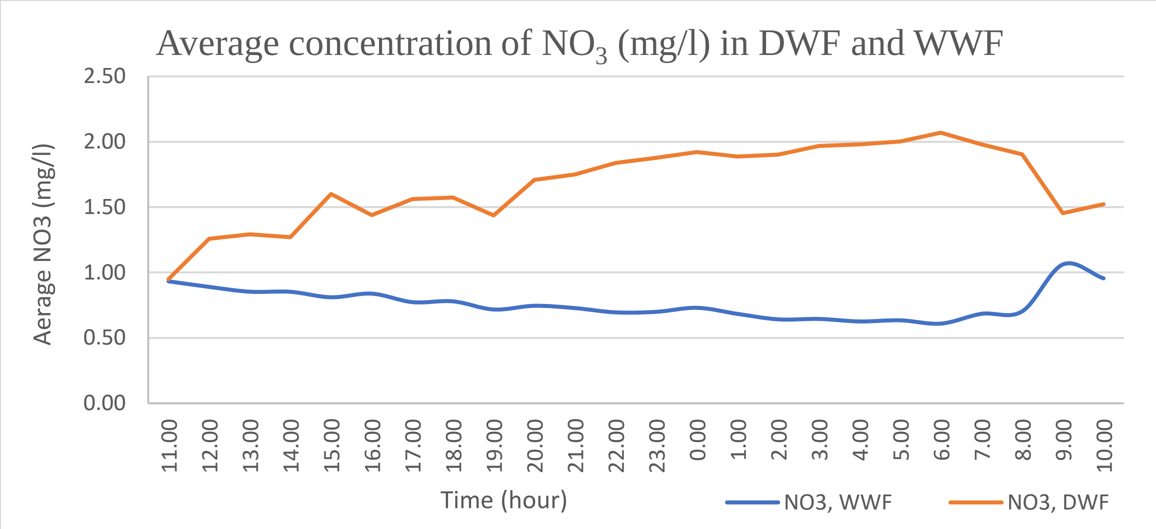

Figure 46 Hourly variation in average concentration of NO_3 (mg/l) in DWF and WWF samples.

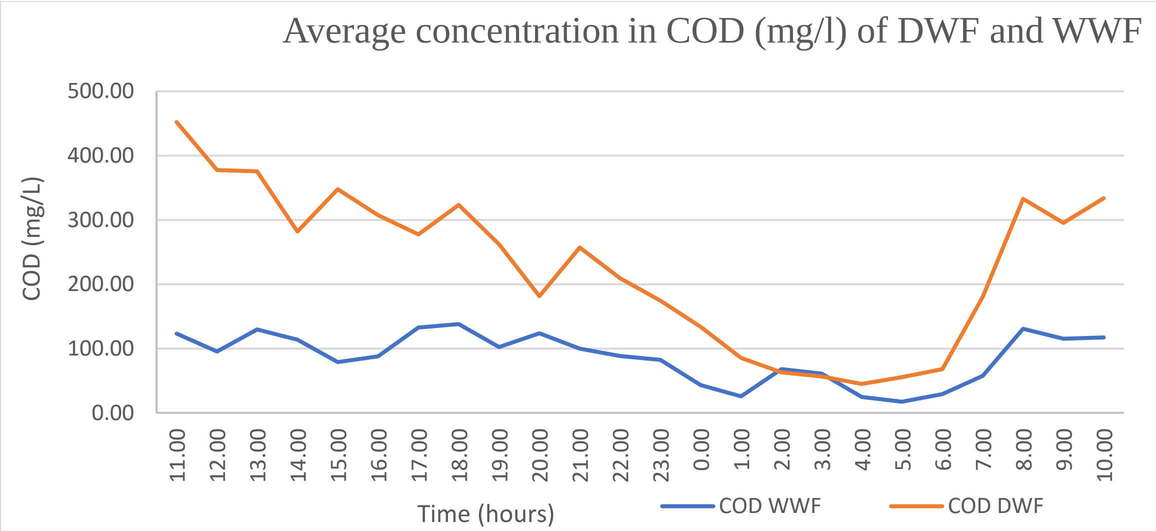

Figure 47 Hourly variation in average concentration of COD (mg/l) in DWF and WWF samples.

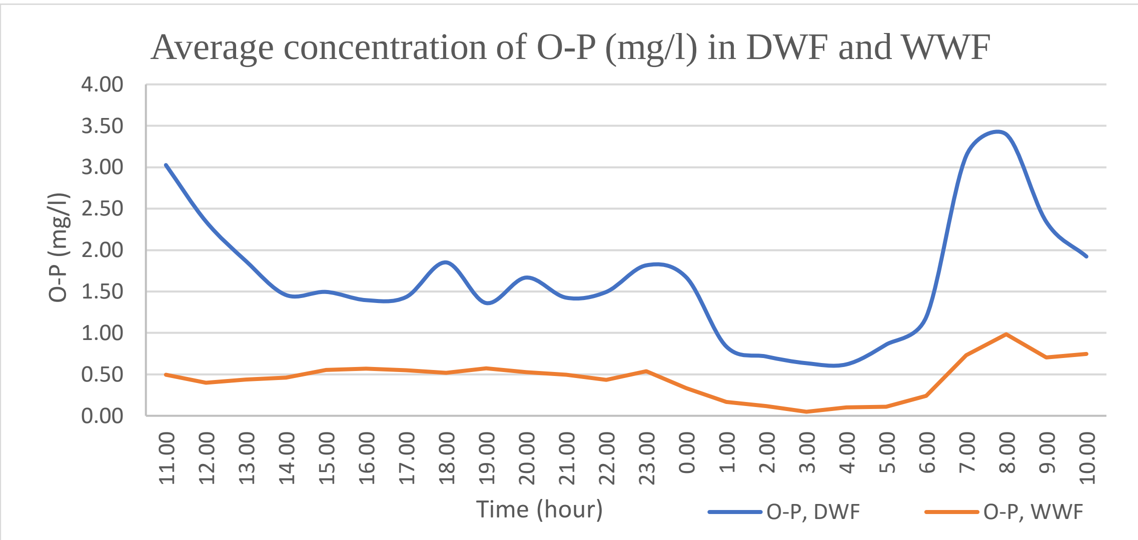

Figure 48 Hourly variation in average concentration of O-P (mg/l) in DWF and WWF samples.

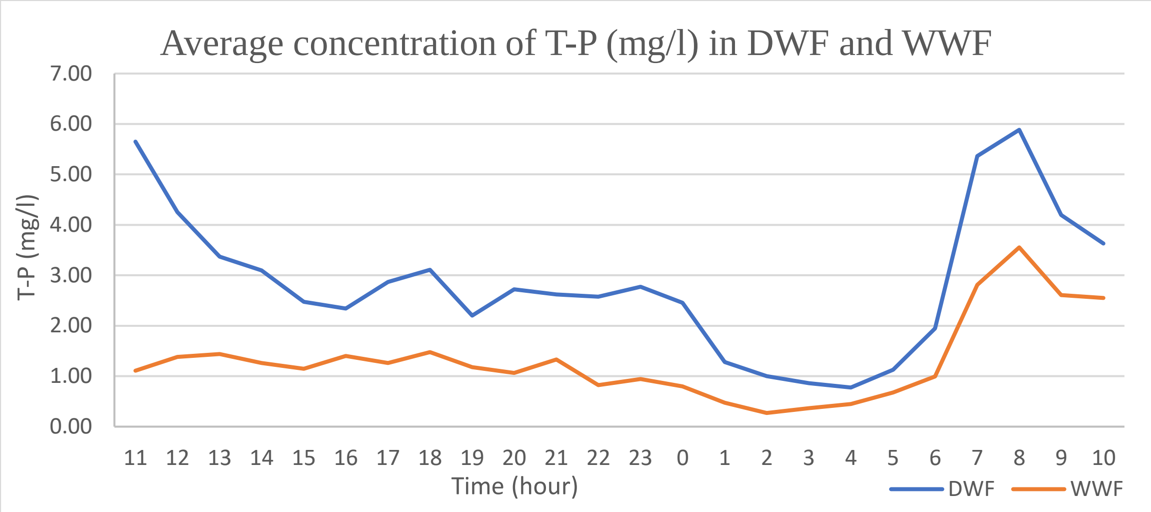

Figure 49 Hourly variation in average concentration of T-P (mg/l) in DWF and WWF samples.

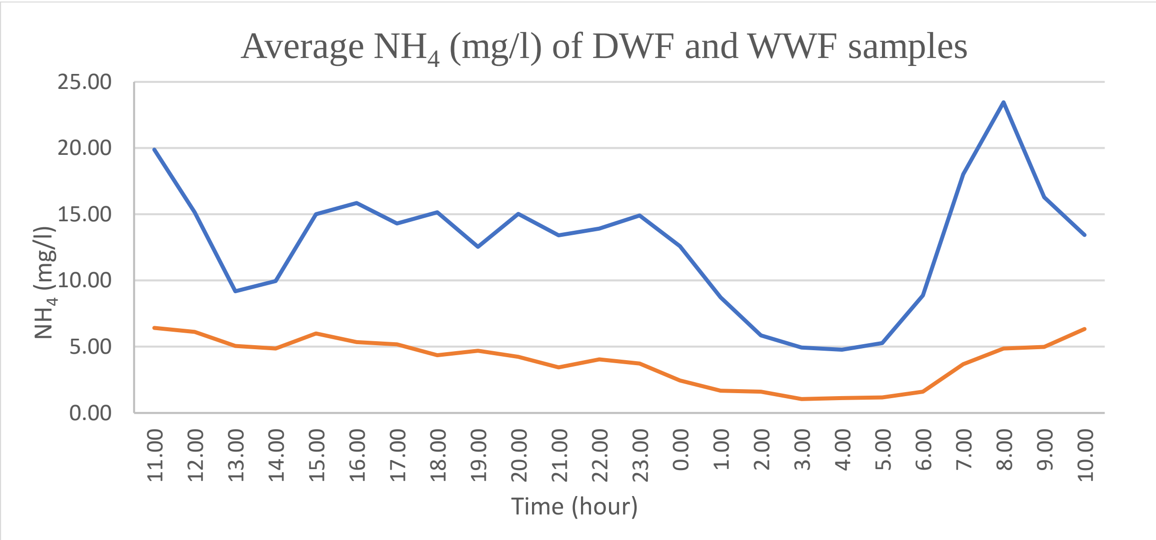

Figure 50 Hourly variation in average concentration of NH_4 (mg/l) in DWF (blue lines) and WWF (orange line) samples.

Table 13 Excel Data sheet of the Samples and variables used in PCA.

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S1	DWF	weekday	11.00	-1.30	0.00	day	7.90	637.00	236.00	526.00	22.23	0.01	979.00	6.87	12.21	7.37	441.11	141.94	1.281	0.011
S1	DWF	weekday	12.00	-1.00	0.00	day	7.50	588.00	120.00	316.00	21.16	0.00	548.00	4.30	7.12	7.35	439.83	401.40	1.311	0.011
S1	DWF	weekday	13.00	-0.40	0.00	day	7.60	584.00	68.60	154.00	1.32	0.24	413.00	2.72	4.18	7.32	434.00	252.00	1.236	0.010
S1	DWF	weekday	14.00	-1.70	0.00	day	7.50	534.00	67.20	240.00	1.85	0.01	394.00	2.09	4.05	7.34	425.51	342.33	1.278	0.011
S1	DWF	weekday	15.00	-2.20	0.00	day	8.00	636.00	78.30	270.00	27.60	0.08	470.00	3.27	5.20	7.39	447.56	227.72	1.283	0.011
S1	DWF	weekday	16.00	-2.50	0.00	day	7.79	567.00	61.90	164.00	19.79	0.07	408.00	1.70	3.12	7.33	466.23	379.99	1.277	0.011
S1	DWF	weekday	17.00	-2.40	0.00	day	7.60	506.00	51.80	158.00	16.06	0.12	262.00	1.62	3.29	7.32	480.30	1111.55	1.339	0.012
S1	DWF	weekday	18.00	-2.80	0.00	day	7.70	565.00	114.00	260.00	17.59	0.13	535.00	3.11	4.55	7.32	495.32	353.04	1.362	0.013
S1	DWF	weekday	19.00	-3.10	0.00	day	7.40	569.00	89.00	228.00	14.00	0.01	529.00	1.15	3.54	7.32	471.56	244.53	1.427	0.014
S1	DWF	weekday	20.00	-3.30	0.00	day	8.00	611.00	73.00	152.00	22.91	0.06	313.00	2.47	3.73	7.52	462.63	545.12	1.397	0.013
S1	DWF	weekday	21.00	-2.90	0.00	day	7.70	533.00	71.50	152.00	17.13	0.08	320.00	1.68	3.02	7.44	462.71	428.35	1.397	0.013
S1	DWF	weekday	22.00	-2.50	0.00	day	8.00	570.00	73.50	142.00	23.74	0.13	346.00	2.35	3.67	7.45	468.26	731.81	1.370	0.012
S1	DWF	weekday	23.00	-2.40	0.00	night	8.20	595.00	52.90	126.00	24.88	0.13	235.00	2.53	3.56	7.57	465.62	277.69	1.318	0.011
S1	DWF	weekday	0.00	-2.40	0.00	night	8.25	504.00	28.00	90.00	19.03	0.15	138.00	1.76	2.35	7.59	460.03	123.58	1.220	0.010
S1	DWF	weekday	1.00	-2.40	0.00	night	8.40	454.00	17.20	82.00	14.84	0.18	90.70	0.97	1.50	7.56	422.07	141.18	1.135	0.009
S1	DWF	weekday	2.00	-2.20	0.00	night	8.30	424.00	7.60	58.00	12.39	0.12	67.70	0.81	0.98	7.44	381.18	88.83	1.194	0.009
S1	DWF	weekday	3.00	-2.40	0.00	night	8.30	429.00	4.00	30.00	10.17	0.18	31.30	0.70	0.84	7.42	361.53	273.92	1.264	0.009
S1	DWF	weekday	4.00	-2.70	0.10	night	8.30	397.00	4.57	52.00	9.40	0.06	53.40	0.40	0.68	7.41	357.07	29.78	1.280	0.010
S1	DWF	weekday	5.00	-2.80	0.00	night	8.30	412.00	4.20	42.00	10.48	0.15	51.30	1.01	0.94	7.45	363.83	53.51	1.194	0.009
S1	DWF	weekday	6.00	-3.00	0.00	day	8.40	521.00	22.30	88.00	20.25	0.24	106.00	2.07	3.24	7.54	379.58	114.42	1.353	0.013
S1	DWF	weekday	7.00	-3.20	0.00	day	8.80	571.00	83.00	290.00	30.32	0.25	141.00	5.25	8.31	7.68	482.72	150.47	1.461	0.016
S1	DWF	weekday	8.00	-3.40	0.00	day	8.80	588.00	57.00	168.00	35.29	0.17	327.00	4.77	6.07	7.67	532.80	144.80	1.379	0.013
S1	DWF	weekday	9.00	-3.50	0.10	day	8.70	523.00	72.70	164.00	26.09	0.15	209.00	3.18	4.85	7.46	494.92	1023.02	1.346	0.012
S1	DWF	weekday	10.00	-3.40	0.00	day	8.50	451.00	52.30	134.00	18.04	0.13	299.00	1.57	2.57	7.29	476.34	754.44	1.341	0.012
S2	WWF	weekday	11.00	1.10	0.00	day	7.54	511.00	34.90	116.67	9.64	0.09	126.00	1.10	1.75	6.92	417.02	846.11	1.376	0.019
S2	WWF	weekday	12.00	1.90	0.00	day	7.50	464.00	44.30	66.67	6.60	0.09	184.00	0.95	1.71	6.89	422.61	1343.03	1.391	0.020
S2	WWF	weekday	13.00	1.40	0.30	day	7.50	453.00	31.40	66.67	8.31	0.18	180.00	0.95	1.66	6.87	425.83	1590.44	1.391	0.020

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S2	WWF	weekday	14.00	2.70	1.50	day	7.54	548.00	65.00	166.67	10.16	0.13	234.00	1.05	2.09	6.86	435.68	2473.55	1.438	0.020
S2	WWF	weekday	15.00	3.30	0.50	day	7.86	593.00	45.20	200.00	14.45	0.16	171.00	1.78	2.68	6.86	450.82	1835.25	1.482	0.021
S2	WWF	weekday	16.00	3.80	0.50	day	7.60	502.00	45.70	140.00	10.87	0.23	155.00	1.32	2.05	6.86	461.95	894.98	1.559	0.024
S2	WWF	weekday	17.00	4.60	0.20	day	7.78	494.00	51.10	66.67	9.71	0.18	200.00	1.19	2.07	6.86	465.95	844.24	1.531	0.026
S2	WWF	weekday	18.00	4.60	0.00	day	7.35	450.00	67.40	66.67	7.39	0.14	320.00	1.24	2.65	6.87	461.46	368.74	1.576	0.029
S2	WWF	weekday	19.00	3.90	0.00	day	7.62	495.00	63.40	166.67	10.26	0.21	231.00	1.51	3.04	6.88	456.93	297.53	1.647	0.032
S2	WWF	weekday	20.00	4.20	0.00	day	7.44	444.00	50.90	166.67	6.63	0.24	188.00	0.98	1.92	6.83	462.43	507.83	1.666	0.033
S2	WWF	weekday	21.00	4.00	0.00	day	7.57	460.00	57.00	166.67	8.03	0.24	223.00	1.26	2.40	6.82	464.65	368.24	1.689	0.035
S2	WWF	weekday	22.00	4.00	0.00	day	7.60	453.00	66.10	100.00	6.87	0.29	193.00	0.93	2.15	6.98	463.59	325.58	1.738	0.036
S2	WWF	weekday	23.00	4.20	0.00	night	7.54	439.00	47.60	133.33	6.28	0.32	176.00	1.00	1.65	7.47	461.25	394.94	1.749	0.037
S2	WWF	weekday	0.00	4.50	0.00	night	7.55	402.00	25.00	133.33	3.67	0.41	73.80	0.43	0.91	7.52	414.82	682.00	1.734	0.037
S2	WWF	weekday	1.00	4.50	0.00	night	7.66	402.00	19.20	66.67	2.53	0.41	27.10	0.30	0.42	7.48	396.03	270.29	1.756	0.037
S2	WWF	weekday	2.00	4.60	0.00	night	7.80	419.00	19.60	33.33	3.79	0.44	60.70	0.39	0.49	7.44	395.54	634.46	1.761	0.037
S2	WWF	weekday	3.00	4.50	0.00	night	7.76	399.00	13.10	0.00	1.96	0.42	33.00	0.23	0.28	7.36	387.49	548.29	1.783	0.038
S2	WWF	weekday	4.00	4.40	0.00	night	7.72	405.00	11.50	-33.33	1.77	0.42	30.90	0.18	0.25	7.18	378.58	171.03	1.775	0.037
S2	WWF	weekday	5.00	4.70	0.00	night	7.77	420.00	8.94	0.00	2.43	0.46	29.00	0.31	0.31	7.51	371.40	244.12	1.765	0.037
S2	WWF	weekday	6.00	5.00	0.00	day	8.00	425.00	11.40	0.00	2.92	0.47	44.10	0.37	0.51	7.69	368.49	533.61	1.804	0.039
S2	WWF	weekday	7.00	5.60	0.00	day	7.74	448.00	27.30	0.00	6.44	0.47	98.00	1.22	1.85	7.71	386.98	391.78	1.844	0.042
S2	WWF	weekday	8.00	5.10	0.00	day	7.78	460.00	43.40	66.67	6.60	0.47	177.00	1.61	2.49	7.75	405.73	897.28	1.819	0.039
S2	WWF	weekday	9.00	4.60	0.00	day	7.76	446.00	39.10	66.67	4.92	0.52	163.00	0.94	2.08	7.82	391.87	3620.35	1.833	0.039
S2	WWF	weekday	10.00	1.00	0.00	day	7.83	478.00	31.90	100.00	11.07	0.22	125.00	1.43	2.68	6.95	414.18	651.36	1.427	0.020
S3	DWF	weekend	11.00	0.20	0.00	day	7.84	538.00	53.30	124.00	11.85	2.14	130.00	1.43	4.15	7.71	431.12	3438.56	1.501	0.019
S3	DWF	weekend	12.00	0.30	0.00	day	7.87	511.00	53.70	208.00	11.45	1.99	233.00	1.46	4.38	7.73	467.03	3977.91	1.505	0.019
S3	DWF	weekend	13.00	0.20	0.00	day	8.06	556.00	64.00	196.00	9.08	1.76	280.00	1.11	3.45	7.80	484.17	805.00	1.507	0.019
S3	DWF	weekend	14.00	-0.10	0.00	day	7.71	485.00	60.00	92.00	9.18	1.94	198.00	0.96	2.31	7.73	497.46	3067.49	1.530	0.018
S3	DWF	weekend	15.00	-5.10	0.00	day	7.30	540.00	82.20	62.00	8.69	1.94	92.80	0.46	1.40	8.14	468.29	2430.82	1.529	0.019
S3	DWF	weekend	16.00	-5.30	0.20	day	7.37	508.00	72.90	40.00	8.76	2.14	58.20	0.50	1.22	7.73	468.71	2149.35	1.518	0.019
S3	DWF	weekend	17.00	-5.20	0.40	day	7.67	590.00	55.00	42.00	9.55	1.94	98.10	0.70	1.90	7.80	461.75	1158.83	1.518	0.020

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S3	DWF	weekend	18.00	-4.80	0.40	day	7.45	517.00	42.30	92.00	11.95	1.96	204.00	0.86	2.33	7.74	464.95	3344.88	1.492	0.019
S3	DWF	weekend	19.00	-3.60	0.20	day	7.56	520.00	24.10	66.00	8.66	1.99	137.00	0.52	1.30	7.72	461.23	2250.50	1.477	0.018
S3	DWF	weekend	20.00	-3.50	0.40	day	7.55	631.00	98.90	76.00	9.01	2.08	116.00	0.53	1.49	7.72	466.11	3649.24	1.483	0.018
S3	DWF	weekend	21.00	-1.10	0.40	day	7.52	550.00	66.20	152.00	11.88	1.87	180.00	0.98	2.71	7.69	474.62	1711.34	1.460	0.017
S3	DWF	weekend	22.00	-0.50	0.30	day	7.49	565.00	78.40	114.00	10.59	2.04	163.00	0.71	1.87	7.69	484.80	3828.18	1.451	0.016
S3	DWF	weekend	23.00	-0.20	0.30	night	7.59	576.00	60.00	80.00	9.57	2.06	118.00	0.58	1.56	7.68	488.02	4745.95	1.461	0.016
S3	DWF	weekend	0.00	0.40	0.20	night	7.85	588.00	65.80	62.00	9.56	2.21	81.00	0.82	1.71	7.67	495.26	5535.46	1.451	0.015
S3	DWF	weekend	1.00	0.40	0.30	night	7.50	565.00	45.70	80.00	6.99	2.36	82.90	0.50	1.19	7.63	495.08	3887.42	1.432	0.014
S3	DWF	weekend	2.00	0.20	0.60	night	7.60	556.00	38.50	96.00	6.57	2.20	68.00	0.48	1.13	7.59	497.46	4796.00	1.431	0.014
S3	DWF	weekend	3.00	0.20	0.30	night	7.74	547.00	45.90	46.00	4.21	2.36	63.50	0.44	0.70	7.67	497.46	1925.04	1.418	0.014
S3	DWF	weekend	4.00	0.20	0.10	night	7.62	520.00	32.10	58.00	3.26	2.50	71.20	0.33	0.59	7.70	493.73	6904.96	1.407	0.013
S3	DWF	weekend	5.00	0.00	0.20	night	7.75	498.00	13.30	60.00	2.50	2.49	30.90	0.27	0.45	7.67	484.53	4276.76	1.400	0.013
S3	DWF	weekend	6.00	-0.10	0.00	day	7.73	441.00	6.50	54.00	2.75	2.47	25.00	0.33	0.51	7.58	473.73	4831.41	1.405	0.013
S3	DWF	weekend	7.00	-0.20	0.00	day	7.74	458.00	13.20	70.00	6.01	2.40	55.80	0.64	1.25	7.70	454.85	4624.47	1.447	0.014
S3	DWF	weekend	8.00	-0.20	0.00	day	7.80	454.00	2.78	124.00	10.33	2.20	99.50	1.38	4.65	7.65	440.08	3570.26	1.477	0.016
S3	DWF	weekend	9.00	-0.10	0.00	day	7.84	452.00	4.00	188.00	10.49	1.68	223.00	1.47	3.59	7.61	428.44	4788.17	1.498	0.018
S3	DWF	weekend	10.00	0.00	0.00	day	7.86	490.00	11.10	144.00	9.89	2.10	208.00	0.96	2.71	7.60	411.79	2805.52	1.518	0.020
S4	DWF	weekday	11.00	-7.50	0.00	day	7.73	593.00	16.00	276.70	13.51	0.95	418.00	1.14	2.52	7.81	491.79	135.29	1.395	0.015
S4	DWF	weekday	12.00	-6.30	0.00	day	8.28	464.00	18.30	136.70	12.19	1.26	436.00	1.28	2.81	7.78	482.25	915.91	1.388	0.015
S4	DWF	weekday	13.00	-5.80	0.00	day	7.74	462.00	26.40	100.00	17.28	1.65	622.00	1.74	3.82	7.76	475.60	168.83	1.391	0.015
S4	DWF	weekday	14.00	-5.50	0.00	day	7.88	556.00	99.70	120.00	14.12	1.67	283.00	1.70	3.73	7.77	476.89	368.24	1.379	0.014
S4	DWF	weekday	15.00	-5.10	0.00	day	7.66	459.00	33.70	40.00	13.53	2.15	683.00	1.03	2.27	7.78	471.29	96.10	1.368	0.014
S4	DWF	weekday	16.00	-5.30	0.20	day	7.56	461.00	30.40	200.00	19.68	1.45	213.00	1.75	3.85	7.87	466.21	463.01	1.377	0.014
S4	DWF	weekday	17.00	-5.20	0.40	day	8.04	533.00	44.50	70.00	15.04	1.90	530.00	1.57	3.46	7.83	461.01	236.52	1.413	0.016
S4	DWF	weekday	18.00	-4.80	0.40	day	7.92	507.00	45.40	186.70	15.35	1.60	302.00	1.84	4.04	7.82	464.84	938.93	1.427	0.016
S4	DWF	weekday	19.00	-3.60	0.20	day	7.91	491.00	22.40	130.00	15.03	1.72	258.00	1.43	3.15	7.87	463.15	72.31	1.435	0.016
S4	DWF	weekday	20.00	-3.50	0.40	day	8.16	495.00	15.80	126.70	15.41	1.93	159.00	1.94	4.26	7.85	463.79	218.82	1.427	0.016
S4	DWF	weekday	21.00	-1.10	0.40	day	7.93	449.00	14.70	90.00	12.43	2.10	273.00	1.47	3.23	7.84	462.01	212.85	1.415	0.016

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S4	DWF	weekday	22.00	-0.50	0.30	day	7.96	460.00	25.10	80.00	12.07	2.10	124.00	1.69	3.71	7.87	460.15	992.18	1.405	0.016
S4	DWF	weekday	23.00	-0.20	0.30	night	8.31	445.00	11.90	93.30	14.35	2.21	142.00	1.89	4.15	7.85	452.51	153.89	1.356	0.014
S4	DWF	weekday	0.00	0.40	0.20	night	8.33	421.00	9.40	60.00	12.66	2.33	184.00	2.10	4.63	7.86	435.31	195.38	1.269	0.012
S4	DWF	weekday	1.00	0.40	0.30	night	7.83	404.00	8.40	20.00	8.23	2.42	101.00	0.86	1.89	7.91	422.57	64.08	1.187	0.010
S4	DWF	weekday	2.00	0.20	0.60	night	8.18	411.00	4.50	113.30	3.91	2.30	94.70	0.38	0.83	7.88	409.88	211.88	1.171	0.010
S4	DWF	weekday	3.00	0.20	0.30	night	7.86	430.00	12.80	16.70	5.22	2.41	95.50	0.88	1.94	7.87	408.20	65.82	1.162	0.010
S4	DWF	weekday	4.00	0.20	0.10	night	8.46	518.00	36.40	16.70	4.97	2.33	44.20	0.74	1.62	7.90	418.32	836.86	1.170	0.010
S4	DWF	weekday	5.00	0.00	0.20	night	7.91	523.00	68.00	20.00	5.30	2.37	53.00	0.78	1.71	7.92	442.26	284.47	1.189	0.011
S4	DWF	weekday	6.00	-0.10	0.00	day	7.75	487.00	63.00	46.70	7.73	2.47	33.50	1.74	3.82	7.98	466.43	589.20	1.383	0.015
S4	DWF	weekday	7.00	-0.20	0.00	day	8.23	528.00	37.80	130.00	15.79	2.39	104.00	4.30	9.46	7.89	487.85	411.39	1.538	0.019
S4	DWF	weekday	8.00	-0.20	0.00	day	8.10	531.00	53.60	163.30	15.88	2.23	189.00	2.72	5.98	7.85	495.02	375.89	1.444	0.016
S4	DWF	weekday	9.00	-0.10	0.00	day	7.94	506.00	87.00	180.00	16.16	2.27	322.00	2.03	4.47	7.84	507.26	352.05	1.393	0.015
S4	DWF	weekday	10.00	0.00	0.00	day	7.66	504.00	42.00	140.00	12.07	2.22	367.00	1.74	3.82	7.86	500.48	136.82	1.383	0.015
S5	DWF	weekend	11.00	-2.60	0.10	day	7.19	608.00	87.00	176.70		0.63	397.00	2.21	4.33	7.61	498.56	908.30	1.410	0.016
S5	DWF	weekend	12.00	-2.20	0.20	day	7.11	589.00	127.00	236.70		0.33	255.00	2.61	5.26	7.55	508.87	960.99	1.406	0.016
S5	DWF	weekend	13.00	-2.10	0.40	day	7.45	564.00	62.00	153.30		0.70	236.00	1.89	3.77	7.52	509.21	1293.63	1.371	0.015
S5	DWF	weekend	14.00	-1.90	0.30	day	7.11	484.00	53.40	143.30		0.67	202.00	0.77	3.31	7.52	498.05	1552.94	1.363	0.015
S5	DWF	weekend	15.00	-1.90	0.10	day	7.23	537.00	70.60	166.70		0.60	111.00	1.07	0.84	7.52	485.25	2102.74	1.371	0.015
S5	DWF	weekend	16.00	-1.70	0.10	day	7.44	484.00	38.60	93.30		1.00	466.00	0.63	1.47	7.51	468.86	1737.45	1.382	0.015
S5	DWF	weekend	17.00	-1.70	0.00	day	7.57	556.00	59.40	136.70		1.15	184.00	1.37	3.61	7.49	455.69	1196.25	1.383	0.015
S5	DWF	weekend	18.00	-1.80	0.00	day	7.20	505.00	58.50	176.70		0.88	270.00	1.16	1.98	7.46	446.04	937.97	1.403	0.016
S5	DWF	weekend	19.00	-1.60	0.00	day	7.49	645.00	42.80	90.00		1.03	107.00	2.11	-0.02	7.49	458.55	387.05	1.351	0.014
S5	DWF	weekend	20.00	-1.80	0.00	day	7.72	602.00	29.50	56.70		1.33	116.00	1.63	2.20	7.51	466.20	393.96	1.353	0.014
S5	DWF	weekend	21.00	-2.00	0.10	day	7.45	532.00	51.40	110.00		1.57	269.00	1.27	1.74	7.48	471.06	192.43	1.324	0.013
S5	DWF	weekend	22.00	-2.30	0.00	day	7.55	528.00	25.20	50.00		1.73	193.00	1.35	1.48	7.49	474.84	2197.62	1.317	0.013
S5	DWF	weekend	23.00	-2.50	0.00	night	7.69	566.00	27.30	63.30		1.88	222.00	2.44	2.94	7.55	467.88	865.49	1.327	0.013
S5	DWF	weekend	0.00	-2.60	0.10	night	7.68	555.00	31.80	110.00		2.09	159.00	2.27	2.69	7.53	474.99	846.31	1.289	0.013
S5	DWF	weekend	1.00	-2.80	0.40	night	7.77	499.00	17.00	20.00		1.76	65.20	1.07	1.40	7.48	472.65	372.85	1.200	0.011

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S5	DWF	weekend	2.00	-2.90	0.20	night	7.83	496.00	19.40	43.30		1.96	35.00	1.41	1.60	7.40	452.46	1014.87	1.167	0.010
S5	DWF	weekend	3.00	-2.90	0.00	night	7.64	432.00	6.70	20.00		2.08	68.50	0.58	0.54	7.42	438.08	411.27	1.157	0.010
S5	DWF	weekend	4.00	-2.90	0.10	night	7.72	448.00	4.17	3.30		2.14	27.30	0.83	0.74	7.53	425.34	975.73	1.146	0.010
S5	DWF	weekend	5.00	-2.60	0.00	night	7.76	450.00	7.06	10.00		2.13	32.00	0.75	0.77	7.54	413.71	481.08	1.139	0.010
S5	DWF	weekend	6.00	-2.80	0.40	day	7.87	431.00	4.86	3.30		2.09	91.00	0.44	0.41	7.39	402.33	1070.35	1.151	0.010
S5	DWF	weekend	7.00	-3.00	0.60	day	7.85	488.00	17.40	46.70		1.99	187.00	2.03	2.42	7.48	404.62	409.97	1.223	0.011
S5	DWF	weekend	8.00	-3.00	0.90	day	7.84	527.00	38.70	100.00		2.05	447.00	2.73	3.41	7.68	430.14	2521.83	1.319	0.013
S5	DWF	weekend	9.00	-3.10	1.10	day	8.20	561.00	72.50	170.00		1.73	238.00	2.79	3.71	7.69	468.75	2382.72	1.387	0.015
S5	DWF	weekend	10.00	-3.10	0.30	day	7.74	541.00	80.00	180.00		1.52	331.00	3.67	4.72	7.62	497.16	1571.57	1.423	0.016
S6	DWF	weekday	11.00	2.90	0.00	day	6.70	656.00	98.00	192.00	32.01	1.03	336.00	3.48	5.06	8.12	479.38	381.10	1.363	0.012
S6	DWF	weekday	12.00	5.80	0.00	day	7.30	540.00	90.30	296.00	15.78	2.71	414.00	2.09	4.14	7.90	473.98	406.67	1.357	0.012
S6	DWF	weekday	13.00	6.80	0.00	day	7.05	560.00	90.90	214.00	18.80	2.10	326.00	1.87	3.95	7.96	471.36	412.77	1.394	0.013
S6	DWF	weekday	14.00	5.20	0.00	day	6.86	550.00	106.00	156.00	14.68	2.06	333.00	1.77	3.56	8.12	473.79	417.90	1.412	0.013
S6	DWF	weekday	15.00	5.20	0.00	day	7.06	649.00	220.00	136.00	10.17	3.23	381.00	1.65	3.35	8.22	475.67	419.93	1.515	0.015
S6	DWF	weekday	16.00	4.70	0.00	day	7.30	560.00	138.00	264.00	15.15	2.54	390.00	2.40	4.13	8.04	479.08	418.94	1.536	0.016
S6	DWF	weekday	17.00	4.20	0.00	day	6.60	576.00	177.00	150.00	16.59	2.70	314.00	1.90	3.06	7.87	473.19	412.20	1.550	0.016
S6	DWF	weekday	18.00	4.00	0.00	day	6.26	598.00	67.90	158.00	15.78	3.30	305.00	2.29	3.76	7.90	461.26	391.68	1.584	0.017
S6	DWF	weekday	19.00	2.40	0.00	day	6.62	549.00	66.20	124.00	12.45	2.43	279.00	1.59	3.49	7.89	466.45	1021.52	1.558	0.016
S6	DWF	weekday	20.00	2.10	0.00	day	6.64	580.00	71.40	114.00	12.85	3.14	202.00	1.78	2.83	7.95	465.20	352.14	1.612	0.017
S6	DWF	weekday	21.00	1.20	0.00	day	6.40	581.00	56.40	94.00	12.23	3.14	244.00	1.73	3.44	7.95	463.72	348.23	1.607	0.017
S6	DWF	weekday	22.00	0.50	0.00	day	7.38	561.00	42.60	68.00	9.27	3.20	219.00	1.38	2.07	7.94	469.78	336.47	1.597	0.017
S6	DWF	weekday	23.00	-0.60	0.00	night	6.83	550.00	24.80	62.00	10.86	3.11	155.00	1.65	2.07	7.97	469.62	335.64	1.490	0.015
S6	DWF	weekday	0.00	-1.00	0.00	night	6.66	540.00	18.90	50.00	9.16	2.83	107.00	1.42	1.74	7.96	469.68	325.54	1.398	0.013
S6	DWF	weekday	1.00	-1.80	0.00	night	6.57	509.00	21.30	42.00	4.85	2.72	87.60	0.79	1.19	7.97	451.25	314.37	1.326	0.011
S6	DWF	weekday	2.00	-2.70	0.00	night	7.43	482.00	8.11	28.00	0.58	2.93	50.30	0.50	0.54	7.95	420.04	303.38	1.329	0.011
S6	DWF	weekday	3.00	-3.90	0.00	night	7.43	470.00	4.68	14.00	0.15	2.81	23.50	0.58	0.60	7.98	401.00	300.43	1.284	0.010
S6	DWF	weekday	4.00	-3.10	0.00	night	6.62	502.00	5.40	10.00	1.48	2.88	28.60	0.80	0.93	7.97	402.59	296.59	1.299	0.011
S6	DWF	weekday	5.00	-4.00	0.00	night	6.97	511.00	16.10	40.00	2.81	2.88	111.00	1.50	1.77	7.98	404.89	305.14	1.306	0.011

Sample ID	Category	Type	Time	Atm Temp℃	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S6	DWF	weekday	6.00	-3.60	0.00	day	7.70	500.00	5.89	40.00	4.79	3.08	83.30	1.40	1.77	7.97	417.14	317.42	1.528	0.016
S6	DWF	weekday	7.00	-3.90	0.00	day	7.15	559.00	83.20	202.00	20.01	2.88	413.00	3.50	5.38	8.07	472.93	366.70	1.752	0.021
S6	DWF	weekday	8.00	-2.40	0.00	day	6.57	729.00	135.00	308.00	32.35	2.88	600.00	5.38	9.31	8.13	531.38	384.39	1.534	0.016
S6	DWF	weekday	9.00	1.40	0.00	day	6.30	547.00	94.90	270.00	12.37	2.90	485.00	2.23	4.36	8.02	518.71	365.67	1.481	0.015
S6	DWF	weekday	10.00	1.60	0.00	day	6.72	540.00	82.00	266.00	13.76	1.64	463.00	1.67	4.35	8.13	491.82	383.51	1.391	0.013
S7	WWF	weekend	11.00	0.20	0.00	day	7.08	521.00	53.30	200.00	9.13	0.05	220.00	0.34	1.81	7.87	466.91	657.97	1.787	0.022
S7	WWF	weekend	12.00	1.70	0.00	day	6.62	525.00	43.40	60.00	12.84	0.02	82.70	0.29	0.69	7.84	468.29	668.53	1.788	0.022
S7	WWF	weekend	13.00	2.90	0.00	day	6.49	516.00	192.00	60.00	5.33	0.03	193.00	0.22	0.79	7.84	467.11	653.09	1.779	0.022
S7	WWF	weekend	14.00	3.60	0.00	day	6.54	519.00	23.80	20.00	4.40	0.00	124.00	0.24	0.58	7.83	466.34	659.51	1.823	0.023
S7	WWF	weekend	15.00	3.20	0.00	day	6.56	531.00	17.20	60.00	6.14	0.00	51.10	0.21	0.48	7.85	467.51	639.60	1.845	0.024
S7	WWF	weekend	16.00	3.30	0.00	day	6.57	526.00	20.50	0.00	4.93	0.00	60.30	0.26	0.52	7.86	462.53	607.47	1.854	0.024
S7	WWF	weekend	17.00	3.30	0.00	day	6.47	517.00	35.30	20.00	6.16	0.03	88.60	0.25	0.40	7.85	467.57	614.15	1.859	0.024
S7	WWF	weekend	18.00	3.10	0.00	day	6.38	511.00	30.90	40.00	6.16	0.02	86.80	0.37	0.70	7.80	469.50	608.84	1.829	0.023
S7	WWF	weekend	19.00	2.00	0.00	day	6.40	511.00	20.00	100.00	4.45	0.01	63.60	0.20	0.34	7.83	465.70	595.34	1.824	0.023
S7	WWF	weekend	20.00	-2.40	0.00	day	6.50	534.00	20.40	60.00	5.60	0.00	154.00	0.38	0.46	7.81	462.10	553.16	1.810	0.023
S7	WWF	weekend	21.00	-2.40	0.00	day	6.44	500.00	11.10	0.00	1.99	0.00	44.40	0.14	0.31				1.797	0.022
S7	WWF	weekend	22.00	-3.00	0.00	day	6.58	528.00	13.90	60.00	5.86	0.00	81.00	0.27	0.45	7.84	467.95	536.00	1.809	0.023
S7	WWF	weekend	23.00	-4.60	0.00	night	6.57	534.00	11.70	20.00	5.55	0.03	62.40	0.67	0.93	7.85	469.23	469.92	1.781	0.022
S7	WWF	weekend	0.00	-5.90	0.00	night	6.56	515.00	8.03	0.00	2.90	0.01	34.60	0.30	0.37	7.86	470.18	485.68	1.759	0.021
S7	WWF	weekend	1.00	-6.40	0.00	night	6.70	511.00	10.90	20.00	1.84	0.00	30.20	0.04	0.17	7.89	468.94	519.89	1.742	0.021
S7	WWF	weekend	2.00	-6.90	0.00	night	6.67	504.00	4.48	40.00	0.98	0.00	171.00	-0.04	0.13	7.90	464.87	596.80	1.733	0.020
S7	WWF	weekend	3.00	-7.90	0.00	night	6.59	506.00	4.33	0.00	0.94	0.00	186.00	-0.09	0.05	7.91	464.37	545.85	1.722	0.020
S7	WWF	weekend	4.00	-8.20	0.00	night	6.64	509.00	3.46	80.00	1.06	0.01	19.30	-0.03	0.13	7.93	461.74	508.03	1.720	0.020
S7	WWF	weekend	5.00	-6.50	0.00	night	6.70	510.00	2.87	40.00	0.75	0.01	15.20	-0.08	0.07	7.94	455.92	517.22	1.710	0.020
S7	WWF	weekend	6.00	-6.30	0.00	day	6.55	513.00	4.16	40.00	1.06	0.02	15.80	-0.03	0.15	7.94	450.62	538.17	1.740	0.020
S7	WWF	weekend	7.00	-6.60	0.00	day	6.52	527.00	12.30	80.00	4.12	0.04	44.60	0.50	0.89	7.91	448.68	504.96	1.768	0.021
S7	WWF	weekend	8.00	-6.60	0.00	day	6.53	541.00	26.00	160.00	7.49	0.05	181.00	0.80	0.92	7.87	446.73	490.85	1.792	0.022
S7	WWF	weekend	9.00	-4.40	0.00	day	6.51	522.00	31.30	0.00	5.96	0.05	163.00	0.51	0.86	7.87	457.97	477.29	1.793	0.022

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S7	WWF	weekend	10.00	-2.20	0.00	day	6.43	513.00	26.10	100.00	7.11	0.05	157.00	0.72	0.79	7.86	464.39	452.07	1.789	0.022
S8	WWF	weekday	11.00	2.70	0.30	day	7.68	455.00	21.40	36.00	3.22	1.51	67.10	0.14	0.53	7.79	392.79	165.64	2.307	0.047
S8	WWF	weekday	12.00	3.10	1.00	day	7.83	442.00	20.00	40.00	3.20	1.34	60.80	0.13	0.53	7.73	384.59	162.80	2.359	0.050
S8	WWF	weekday	13.00	3.40	1.00	day	7.76	450.00	31.60	46.00	4.06	1.21	76.20	0.34	0.70	7.73	379.83	157.40	2.386	0.053
S8	WWF	weekday	14.00	4.70	1.30	day	7.75	432.00	36.50	48.00	2.96	1.14	65.50	0.31	0.77	7.70	374.83	150.46	2.407	0.055
S8	WWF	weekday	15.00	4.70	0.10	day	7.70	422.00	19.60	42.00	2.40	1.02	55.10	0.13	0.57	7.71	371.60	145.69	2.432	0.057
S8	WWF	weekday	16.00	3.90	0.00	day	7.71	459.00	31.00	54.00	4.30	0.93	77.20	0.24	0.72	7.69	368.21	143.37	2.421	0.057
S8	WWF	weekday	17.00	3.70	0.00	day	7.66	448.00	22.20	60.00	2.78	0.74	112.00	0.46	1.19	7.69	370.04	138.84	2.452	0.060
S8	WWF	weekday	18.00	4.80	0.10	day	7.76	443.00	20.00	56.00	2.80	0.75	81.90	0.20	1.24	7.65	371.22	136.99	2.453	0.060
S8	WWF	weekday	19.00	3.70	0.00	day	7.76	445.00	18.60	34.00	2.28	0.59	76.80	0.16	0.53	7.66	372.56	134.88	2.469	0.060
S8	WWF	weekday	20.00	3.10	0.00	day	7.95	460.00	23.20	44.00	3.60	0.56	90.60	0.49	0.71	7.67	374.09	128.64	2.463	0.060
S8	WWF	weekday	21.00	1.60	0.00	day	7.82	457.00	21.00	56.00	2.91	0.50	106.00	0.38	0.86	7.67	376.16	127.21	2.441	0.059
S8	WWF	weekday	22.00	0.70	0.00	day	7.81	448.00	15.60	18.00	2.51	0.35	49.30	0.25	0.39	7.69	377.25	126.40	2.433	0.057
S8	WWF	weekday	23.00	1.80	0.00	night	7.80	443.00	11.10	20.00	1.95	0.38	57.70	0.18	0.39	7.71	379.87	125.16	2.408	0.055
S8	WWF	weekday	0.00	1.10	0.10	night	8.02	453.00	9.94	18.00	2.23	0.41	40.70	0.31	0.43	7.75	379.06	123.29	2.390	0.053
S8	WWF	weekday	1.00	0.40	0.10	night	7.97	452.00	6.77	8.00	1.70	0.27	20.00	0.18	0.24	7.77	375.58	122.47	2.375	0.053
S8	WWF	weekday	2.00	1.10	0.20	night	8.10	445.00	5.83	8.00	1.06	0.12	24.90	-0.02	0.12	7.78	369.17	124.41	2.360	0.051
S8	WWF	weekday	3.00	1.80	0.00	night	8.02	443.00	4.02	2.00	0.83	0.00	10.40	-0.08	0.02	7.79	369.10	121.58	2.344	0.050
S8	WWF	weekday	4.00	1.70	0.00	night	7.99	453.00	7.09	6.00	1.31	0.00	25.60	0.18	0.35	7.79	365.77	121.17	2.347	0.050
S8	WWF	weekday	5.00	1.40	0.00	night	7.99	454.00	4.37	4.00	1.13	0.00	14.90	0.08	0.25	7.78	366.36	120.68	2.369	0.052
S8	WWF	weekday	6.00	1.40	0.00	day	7.99	457.00	10.60	24.00	1.96	0.00	48.20	0.41	0.64	7.74	369.01	121.06	2.412	0.055
S8	WWF	weekday	7.00	1.80	0.00	day	7.88	453.00	11.40	22.00	3.28	0.00	60.30	0.93	1.08	7.72	392.76	122.84	2.365	0.051
S8	WWF	weekday	8.00	2.00	0.00	day	7.98	465.00	17.00	60.00	3.89	0.00	112.00	0.95	1.35	7.74	414.52	121.33	2.354	0.050
S8	WWF	weekday	9.00	2.00	1.50	day	7.82	652.00	32.20	74.00	7.16	1.55	83.40	0.86	1.49	7.76	407.57	202.11	2.266	0.044
S8	WWF	weekday	10.00	2.30	0.80	day	7.71	450.00	25.40	40.00	2.87	1.46	50.90	0.22	0.77	7.75	394.75	177.09	2.273	0.044
S9	WWF	weekend	11.00	11.60	0.00	day	7.36	435.00	17.40	46.00	3.70	2.08	80.10	0.41	0.36	7.56	308.28	141.53	2.463	0.060
S9	WWF	weekend	12.00	13.40	0.00	day	7.35	425.00	11.00	24.00	1.83	2.12	54.40	0.23	0.15	7.51	303.14	142.09	2.488	0.060
S9	WWF	weekend	13.00	13.00	0.00	day	7.30	417.00	16.70	40.00	2.51	1.99	69.20	0.24	0.32	7.47	300.95	143.53	2.503	0.062

Sample ID	Category	Type	Time	Atm Temp°C	Precipitation (mm)	day	pH lab	conductivity lab(µS/cm)	Turbiditylab (NTU)	TSS(mg/l)	NH_4 (mg/l)	NO_2 (mg/l)	COD (mg/l)	O-P (mg/l)	T-P (mg/l)	pH sensor	Conductivity sensor (µS/cm)	Turbiditysensor (FNU)	flow(m/s)	discharge (m^3/s)
S9	WWF	weekend	14.00	14.60	0.00	day	7.35	413.00	9.03	16.00	1.95	2.15	30.90	0.24	0.13	7.47	295.38	139.63	2.527	0.066
S9	WWF	weekend	15.00	14.30	0.00	day	7.17	400.00	9.45	20.00	1.02	2.06	38.20	0.09	0.20	7.45	294.42	138.03	2.566	0.071
S9	WWF	weekend	16.00	15.20	0.00	day	7.27	397.00	9.16	44.00	1.34	2.19	58.90	0.46	0.24	7.48	288.04	134.58	2.593	0.076
S9	WWF	weekend	17.00	15.80	0.00	day	7.24	400.00	18.90	50.00	2.10	2.15	130.00	0.30	0.38	7.49	280.90	147.70	2.622	0.079
S9	WWF	weekend	18.00	15.50	0.00	day	7.29	385.00	12.60	40.00	1.13	2.21	63.10	0.27	0.20	7.52	282.18	155.39	2.631	0.081
S9	WWF	weekend	19.00	13.10	0.00	day	7.34	394.00	12.80	26.00	1.80	2.06	37.80	0.41	0.35	7.55	290.03	146.65	2.637	0.082
S9	WWF	weekend	20.00	10.50	0.00	day	7.36	395.00	12.40	24.00	1.13	2.19	61.70	0.27	0.25	7.54	300.69	140.12	2.646	0.081
S9	WWF	weekend	21.00	6.60	0.00	day	7.39	389.00	8.01	8.00	0.86	2.17	25.00	0.20	0.72	7.54	303.74	146.59	2.639	0.080
S9	WWF	weekend	22.00	6.30	0.00	day	7.41	396.00	8.86	16.00	0.97	2.14	29.80	0.28	0.37	7.53	300.93	159.24	2.605	0.077
S9	WWF	weekend	23.00	4.20	0.00	night	7.45	394.00	7.26	16.00	1.12	2.07	32.90	0.31	0.39	7.55	309.59	166.53	2.611	0.076
S9	WWF	weekend	0.00	4.10	0.00	night	7.50	398.00	3.88	16.00	1.01	2.09	22.90	0.29	0.65	7.55	312.42	155.14	2.588	0.072
S9	WWF	weekend	1.00	5.60	0.00	night	7.52	394.00	5.07	10.00	0.65	2.06	26.10	0.16	0.28	7.55	311.95	148.09	2.570	0.071
S9	WWF	weekend	2.00	6.00	0.00	night	7.56	399.00	4.43	8.00	0.60	2.01	14.30	0.14	0.29	7.56	312.56	148.92	2.542	0.069
S9	WWF	weekend	3.00	5.70	0.00	night	7.57	395.00	3.45	8.00	0.47	2.16	14.00	0.13	0.81	7.56	309.55	146.05	2.552	0.067
S9	WWF	weekend	4.00	5.80	0.00	night	7.57	398.00	3.23	8.00	0.39	2.08	23.00	0.08	0.39	7.56	313.91	154.74	2.527	0.065
S9	WWF	weekend	5.00	5.40	0.00	night	7.58	400.00	2.63	10.00	0.40	2.07	10.10	0.13	0.09	7.57	316.67	178.19	2.517	0.064
S9	WWF	weekend	6.00	5.50	0.00	day	7.60	404.00	1.61	6.00	0.50	1.95	9.22	0.22	0.15	7.56	322.83	251.34	2.511	0.064
S9	WWF	weekend	7.00	5.40	0.00	day	7.58	406.00	3.32	6.00	0.90	2.23	27.80	0.28	0.15	7.56	331.38	332.41	2.506	0.064
S9	WWF	weekend	8.00	6.00	0.00	day	7.53	417.00	10.40	22.00	1.51	2.29	53.40	0.58	0.32	7.55	342.92	401.58	2.504	0.064
S9	WWF	weekend	9.00	8.60	0.00	day	7.53	418.00	10.10	32.00	1.92	2.13	52.40	0.52	0.28	7.55	344.71	446.31	2.509	0.063
S9	WWF	weekend	10.00	9.80	0.00	day	7.40	469.00	26.40	82.00	4.35	2.08	135.00	0.62	0.55	7.59	313.55	143.18	2.468	0.060

Table 14 Excel Data sheet for the quantification of the pollutant loads.

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S1	11.00	526.00	22.225	0.005	979	6.874	12.208	0.011161	40179.6	21134469.6	892991.61	200.898	39335828.4	276194.57	490504.521
S1	12.00	316.00	21.162	0	548	4.302	7.121	0.011435	41166	13008456	871154.89	0	22558968	177096.132	293159.552
S1	13.00	154.00	1.316	0.239	413	2.721	4.176	0.010458	37648.8	5797915.2	49545.821	8998.0632	15548954.4	102442.385	157206.329
S1	14.00	240.00	1.85	0.014	394	2.085	4.052	0.011001	39603.6	9504864	73266.66	554.4504	15603818.4	82573.506	160489.629
S1	15.00	270.00	27.603	0.08	470	3.266	5.203	0.011070	39852	10760040	1100034.8	3188.16	18730440	130156.632	207349.956
S1	16.00	164.00	19.793	0.071	408	1.699	3.115	0.011019	39668.4	6505617.6	785156.64	2816.4564	16184707.2	67396.6116	123575
S1	17.00	158.00	16.06	0.119	262	1.621	3.291	0.011991	43167.6	6820480.8	693271.66	5136.9444	11309911.2	69974.6796	142073.205
S1	18.00	260.00	17.585	0.126	535	3.106	4.554	0.012525	45090	11723400	792907.65	5681.34	24123150	140049.54	205339.86
S1	19.00	228.00	13.997	0.012	529	1.151	3.535	0.014172	51019.2	11632377.6	714115.74	612.2304	26989156.8	58723.0992	180373.28
S1	20.00	152.00	22.908	0.062	313	2.469	3.731	0.013473	48502.8	7372425.6	1111102.1	3007.1736	15181376.4	119753.413	180973.647
S1	21.00	152.00	17.128	0.079	320	1.677	3.023	0.013392	48211.2	7328102.4	825761.43	3808.6848	15427584	80850.1824	145732.815
S1	22.00	142.00	23.743	0.129	346	2.347	3.670	0.012496	44985.6	6387955.2	1068093.1	5803.1424	15565017.6	105581.203	165079.158
S1	23.00	126.00	24.879	0.13	235	2.526	3.560	0.011423	41122.8	5181472.8	1023094.1	5345.964	9663858	103876.193	146380.719
S1	0.00	90.00	19.032	0.152	138	1.756	2.352	0.009882	35575.2	3201768	677067.21	5407.4304	4909377.6	62470.0512	83665.7554
S1	1.00	82.00	14.838	0.181	90.7	0.965	1.500	0.008802	31687.2	2598350.4	470174.67	5735.3832	2874029.04	30578.148	47543.4749
S1	2.00	58.00	12.391	0.123	67.7	0.81	0.981	0.009169	33008.4	1914487.2	409007.08	4060.0332	2234668.68	26736.804	32387.8421
S1	3.00	30.00	10.168	0.178	31.3	0.702	0.843	0.009387	33793.2	1013796	343609.26	6015.1896	1057727.16	23722.8264	28474.1503
S1	4.00	52.00	9.401	0.063	53.4	0.4	0.682	0.009621	34635.6	1801051.2	325609.28	2182.0428	1849541.04	13854.24	23621.4792

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S1	5.00	42.00	10.475	0.154	51.3	1.006	0.942	0.009112	32803.2	1377734.4	343613.52	5051.6928	1682804.16	33000.0192	30887.4931
S1	6.00	88.00	20.25	0.243	106	2.073	3.241	0.012582	45295.2	3985977.6	917227.8	11006.7336	4801291.2	93896.9496	146783.625
S1	7.00	290.00	30.32	0.246	141	5.246	8.307	0.015644	56318.4	16332336	1707573.9	13854.3264	7940894.4	295446.326	467848.212
S1	8.00	168.00	35.286	0.165	327	4.766	6.074	0.012922	46519.2	7815225.6	1641476.5	7675.668	15211778.4	221710.507	282566.925
S1	9.00	164.00	26.091	0.152	209	3.175	4.853	0.012119	43628.4	7155057.6	1138308.6	6631.5168	9118335.6	138520.17	211737.351
S1	10.00	134.00	18.042	0.13	299	1.571	2.567	0.011861	42699.6	5721746.4	770386.18	5550.948	12767180.4	67081.0716	109626.953
						S1	**Total per day**		**996181.2**	**176075107**	**18744550**	**118324.472**	**310670398**	**2521685.26**	**4063380.93**
S2	10.00	100.00	11.074	0.223	125	1.426	2.684	0.0203	73162.8	7316280	810204.85	16315.3044	9145350	104330.153	196368.955
S2	11.00	116.67	9.64	0.087	126	1.095	1.749	0.0193	69393.6	8095920	668954.3	6037.2432	8743593.6	75985.992	121369.406
S2	12.00	66.67	6.597	0.086	184	0.948	1.709	0.0195	70218	4681200	463228.15	6038.748	12920112	66566.664	120030.649
S2	13.00	66.67	8.305	0.182	180	0.954	1.657	0.0196	70408.8	4693920	584745.08	12814.4016	12673584	67169.9952	116639.218
S2	14.00	166.67	10.16	0.125	234	1.052	2.092	0.0202	72860.4	12143400	740261.66	9107.55	17049333.6	76649.1408	152438.529
S2	15.00	200.00	14.446	0.157	171	1.784	2.682	0.0213	76680	15336000	1107719.3	12038.76	13112280	136797.12	205640.424
S2	16.00	140.00	10.869	0.234	155	1.318	2.055	0.0242	87062.4	12188736	946281.23	20372.6016	13494672	114748.243	178895.82
S2	17.00	66.67	9.712	0.184	200	1.193	2.075	0.0260	93542.4	6236160	908483.79	17211.8016	18708480	111596.083	194063.063
S2	18.00	66.67	7.392	0.143	320	1.24	2.647	0.0293	105415.2	7027680	779229.16	15074.3736	33732864	130714.848	278991.868
S2	19.00	166.67	10.26	0.205	231	1.511	3.045	0.0318	114411.6	19068600	1173863	23454.378	26429079.6	172875.928	348360.44
S2	20.00	166.67	6.626	0.236	188	0.975	1.923	0.0332	119574	19929000	792297.32	28219.464	22479912	116584.65	229916.887
S2	21.00	166.67	8.031	0.24	223	1.261	2.396	0.0347	124869.6	20811600	1002827.8	29968.704	27845920.8	157460.566	299162.588

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S2	22.00	100.00	6.868	0.293	193	0.934	2.147	0.0365	131335.2	13133520	902010.15	38481.2136	25347693.6	122667.077	282002.941
S2	23.00	133.33	6.282	0.317	176	0.998	1.654	0.0372	134042.4	17872320	842054.36	42491.4408	23591462.4	133774.315	221759.747
S2	0.00	133.33	3.671	0.408	73.8	0.434	0.913	0.0370	133092	17745600	488580.73	54301.536	9822189.6	57761.928	121512.996
S2	1.00	66.67	2.533	0.411	27.1	0.298	0.425	0.0373	134413.2	8960880	340468.64	55243.8252	3642597.72	40055.1336	57071.8447
S2	2.00	33.33	3.791	0.438	60.7	0.388	0.486	0.0375	134848.8	4494960	511211.8	59063.7744	8185322.16	52321.3344	65563.4866
S2	3.00	0.00	1.964	0.417	33	0.231	0.275	0.0377	135838.8	0	266787.4	56644.7796	4482680.4	31378.7628	37355.67
S2	4.00	-33.33	1.774	0.421	30.9	0.175	0.249	0.0371	133686	-4456200	237158.96	56281.806	4130897.4	23395.05	33234.3396
S2	5.00	0.00	2.427	0.462	29	0.311	0.308	0.0368	132418.8	0	321380.43	61177.4856	3840145.2	41182.2468	40784.9904
S2	6.00	0.00	2.919	0.467	44.1	0.369	0.510	0.0395	142074	0	414714.01	66348.558	6265463.4	52425.306	72514.5696
S2	7.00	0.00	6.436	0.467	98	1.217	1.846	0.0418	150451.2	0	968303.92	70260.7104	14744217.6	183099.11	277702.825
S2	8.00	66.67	6.597	0.467	177	1.606	2.488	0.0388	139838.4	9322560	922513.92	65304.5328	24751396.8	224580.47	347945.907
S2	9.00	66.67	4.917	0.517	163	0.939	2.077	0.0386	138787.2	9252480	682416.66	71752.9824	22622313.6	130321.181	288233.257
						S2	**Total per day**		**2718424.8**	**213854616**	**16875697**	**894005.975**	**367761561**	**2424441.3**	**4287560.42**
S3	15.00	62.00	8.687	1.94	92.8	0.456	1.397	0.0188	67647.6	4194151.2	587654.7	131236.344	6277697.28	30847.3056	94503.6972
S3	16.00	40.00	8.759	2.14	58.2	0.502	1.221	0.0193	69652.8	2786112	610088.88	149056.992	4053792.96	34965.7056	85046.0688
S3	17.00	42.00	9.547	1.94	98.1	0.703	1.901	0.0196	70477.2	2960042.4	672845.83	136725.768	6913813.32	49545.4716	133963.062
S3	18.00	92.00	11.947	1.96	204	0.863	2.334	0.0187	67345.2	6195758.4	804573.1	131996.592	13738420.8	58118.9076	157197.166
S3	19.00	66.00	8.658	1.994	137	0.523	1.302	0.0183	65851.2	4346179.2	570139.69	131307.293	9021614.4	34440.1776	85764.6029
S3	20.00	76.00	9.01	2.081	116	0.527	1.485	0.0177	63741.6	4844361.6	574311.82	132646.27	7394025.6	33591.8232	94656.276

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S3	21.00	152.00	11.876	1.869	180	0.981	2.706	0.0165	59540.4	9050140.8	707101.79	111281.008	10717272	58409.1324	161116.322
S3	22.00	114.00	10.593	2.039	163	0.711	1.872	0.0163	58568.4	6676797.6	620415.06	119420.968	9546649.2	41642.1324	109651.758
S3	23.00	80.00	9.569	2.055	118	0.578	1.555	0.0159	57182.4	4574592	547178.39	117509.832	6747523.2	33051.4272	88941.505
S3	0.00	62.00	9.555	2.208	81	0.815	1.712	0.0154	55335.6	3430807.2	528731.66	122181.005	4482183.6	45098.514	94712.413
S3	1.00	80.00	6.992	2.359	82.9	0.499	1.188	0.0142	51285.6	4102848	358588.92	120982.73	4251576.24	25591.5144	60927.2928
S3	2.00	96.00	6.568	2.198	68	0.483	1.126	0.0137	49341.6	4736793.6	324075.63	108452.837	3355228.8	23831.9928	55578.3782
S3	3.00	46.00	4.21	2.355	63.5	0.44	0.702	0.0136	48830.4	2246198.4	205575.98	114995.592	3100730.4	21485.376	34269.1747
S3	4.00	58.00	3.258	2.498	71.2	0.333	0.587	0.0134	48240	2797920	157165.92	120503.52	3434688	16063.92	28336.176
S3	5.00	60.00	2.496	2.487	30.9	0.269	0.449	0.0132	47473.2	2848392	118493.11	118065.848	1466921.88	12770.2908	21305.9722
S3	6.00	54.00	2.753	2.474	25	0.327	0.506	0.0134	48196.8	2602627.2	132685.79	119238.883	1204920	15760.3536	24387.5808
S3	7.00	70.00	6.01	2.401	55.8	0.638	1.252	0.0139	50022	3501540	300632.22	120102.822	2791227.6	31914.036	62617.5396
S3	8.00	124.00	10.331	2.197	99.5	1.38	4.649	0.0158	56955.6	7062494.4	588408.3	125131.453	5667082.2	78598.728	264763.802
S3	9.00	188.00	10.487	1.676	223	1.469	3.590	0.0182	65394	12294072	685786.88	109600.344	14582862	96063.786	234790.618
S3	10.00	144.00	9.89	2.099	208	0.964	2.708	0.0195	70340.4	10129017.6	695666.56	147644.5	14630803.2	67808.1456	190495.871
S3	11.00	124.00	11.848	2.143	130	1.432	4.149	0.0186	66859.2	8290540.8	792147.8	143279.266	8691696	95742.3744	277412.193
S3	12.00	208.00	11.448	1.99	233	1.462	4.380	0.0190	68349.6	14216716.8	782466.22	136015.704	15925456.8	99927.1152	299384.918
S3	13.00	196.00	9.075	1.755	280	1.114	3.447	0.0187	67201.2	13171435.2	609850.89	117938.106	18816336	74862.1368	231669.417
S3	14.00	92.00	9.182	1.939	198	0.961	2.306	0.0184	66106.8	6081825.6	606992.64	128181.085	13089146.4	63528.6348	152415.838
						S3	**Total per day**		**1439938.8**	**143141364**	**12581578**	**3013494.76**	**189901668**	**1143659**	**3043907.64**

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S4	11.00	276.70	13.507	0.945	418	1.144	2.517	0.0148	53424	14782420.8	721597.97	50485.68	22331232	61117.056	134457.523
S4	12.00	136.70	12.192	1.26	436	1.275	2.805	0.0147	52999.2	7244990.64	646166.25	66778.992	23107651.2	67573.98	148662.756
S4	13.00	100.00	17.275	1.654	622	1.737	3.821	0.0148	53280	5328000	920412	88125.12	33140160	92547.36	203604.192
S4	14.00	120.00	14.122	1.674	283	1.697	3.733	0.0145	52178.4	6261408	736863.36	87346.6416	14766487.2	88546.7448	194802.839
S4	15.00	40.00	13.528	2.15	683	1.031	2.268	0.0141	50767.2	2030688	686778.68	109149.48	34673997.6	52340.9832	115150.163
S4	16.00	200.00	19.682	1.447	213	1.75	3.850	0.0143	51552	10310400	1014646.5	74595.744	10980576	90216	198475.2
S4	17.00	70.00	15.036	1.9	530	1.572	3.458	0.0155	55951.2	3916584	841282.24	106307.28	29654136	87955.2864	193501.63
S4	18.00	186.70	15.35	1.596	302	1.837	4.041	0.0157	56667.6	10579840.9	869847.66	90441.4896	17113615.2	104098.381	229016.439
S4	19.00	130.00	15.029	1.72	258	1.432	3.150	0.0162	58269.6	7575048	875733.82	100223.712	15033556.8	83442.0672	183572.548
S4	20.00	126.70	15.405	1.933	159	1.935	4.257	0.0161	57934.8	7340339.16	892485.59	111987.968	9211633.2	112103.838	246628.444
S4	21.00	90.00	12.429	2.097	273	1.468	3.230	0.0159	57088.8	5137992	709556.7	119715.214	15585242.4	83806.3584	184373.988
S4	22.00	80.00	12.066	2.1	124	1.685	3.707	0.0157	56635.2	4530816	683360.32	118933.92	7022764.8	95430.312	209946.686
S4	23.00	93.30	14.349	2.207	142	1.887	4.151	0.0142	51019.2	4760091.36	732074.5	112599.374	7244726.4	96273.2304	211801.107
S4	0.00	60.00	12.66	2.328	184	2.104	4.629	0.0121	43549.2	2612952	551332.87	101382.538	8013052.8	91627.5168	201580.537
S4	1.00	20.00	8.226	2.421	101	0.86	1.892	0.0104	37573.2	751464	309077.14	90964.7172	3794893.2	32312.952	71088.4944
S4	2.00	113.30	3.911	2.301	94.7	0.376	0.827	0.0102	36666	4154257.8	143400.73	84368.466	3472270.2	13786.416	30330.1152
S4	3.00	16.70	5.221	2.409	95.5	0.882	1.940	0.0100	35978.4	600839.28	187843.23	86671.9656	3435937.2	31732.9488	69812.4874
S4	4.00	16.70	4.969	2.331	44.2	0.736	1.619	0.0101	36435.6	608474.52	181048.5	84931.3836	1610453.52	26816.6016	58996.5235
S4	5.00	20.00	5.302	2.365	53	0.776	1.707	0.0105	37814.4	756288	200491.95	89431.056	2004163.2	29343.9744	64556.7437

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S4	6.00	46.70	7.734	2.465	33.5	1.736	3.819	0.0150	53989.2	2521295.64	417552.47	133083.378	1808638.2	93725.2512	206195.553
S4	7.00	130.00	15.786	2.39	104	4.3	9.460	0.0191	68896.8	8956584	1087604.9	164663.352	7165267.2	296256.24	651763.728
S4	8.00	163.30	15.875	2.225	189	2.719	5.982	0.0163	58608	9570686.4	930402	130402.8	11076912	159355.152	350581.334
S4	9.00	180.00	16.16	2.267	322	2.032	4.470	0.0151	54378	9788040	878748.48	123274.926	17509716	110496.096	243091.411
S4	10.00	140.00	12.073	2.215	367	1.735	3.817	0.0150	53917.2	7548408	650942.36	119426.598	19787612.4	93546.342	205801.952
						S4	**Total per day**		**1225573.2**	**137667909**	**15869250**	**2445291.8**	**319544695**	**2094451.09**	**4607792.39**
S5	11.00	176.70		0.626	397	2.208	4.325	0.0163	58600.8	10354761.4	0	36684.1008	23264517.6	129390.566	253460.18
S5	12.00	236.70		0.333	255	2.605	5.256	0.0160	57549.6	13621990.3	0	19164.0168	14675148	149916.708	302469.188
S5	13.00	153.30		0.704	236	1.892	3.766	0.0150	53877.6	8259436.08	0	37929.8304	12715113.6	101936.419	202924.593
S5	14.00	143.30		0.665	202	0.773	3.307	0.0145	52347.6	7501411.08	0	34811.154	10574215.2	40464.6948	173092.574
S5	15.00	166.70		0.596	111	1.073	0.836	0.0150	53845.2	8975994.84	0	32091.7392	5976817.2	57775.8996	45014.5872
S5	16.00	93.30		0.999	466	0.633	1.467	0.0151	54266.4	5063055.12	0	54212.1336	25288142.4	34350.6312	79630.5154
S5	17.00	136.70		1.148	184	1.365	3.606	0.0154	55278	7556502.6	0	63459.144	10171152	75454.47	199321.412
S5	18.00	176.70		0.88	270	1.158	1.984	0.0159	57135.6	10095860.5	0	50279.328	15426612	66163.0248	113379.885
S5	19.00	90.00		1.034	107	2.109	-0.015	0.0144	51980.4	4678236	0	53747.7336	5561902.8	109626.664	-800.49816
S5	20.00	56.70		1.328	116	1.629	2.202	0.0141	50659.2	2872376.64	0	67275.4176	5876467.2	82523.8368	111561.69
S5	21.00	110.00		1.573	269	1.273	1.740	0.0132	47386.8	5212548	0	74539.4364	12747049.2	60323.3964	82462.5094
S5	22.00	50.00		1.727	193	1.346	1.481	0.0130	46933.2	2346660	0	46933.2	9058107.6	63172.0872	69489.2959
S5	23.00	63.30		1.882	222	2.435	2.939	0.0133	47844	3028525.2	0	90042.408	10621368	116500.14	140623.085

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S5	0.00	110.00		2.091	159	2.268	2.688	0.0125	45126	4963860	0	94358.466	7175034	102345.768	121316.738
S5	1.00	20.00		1.759	65.2	1.072	1.399	0.0108	38754	775080	0	68168.286	2526760.8	41544.288	54224.5968
S5	2.00	43.30		1.964	35	1.412	1.597	0.0101	36205.2	1567685.16	0	71107.0128	1267182	51121.7424	57826.9454
S5	3.00	20.00		2.084	68.5	0.575	0.541	0.0100	35845.2	716904	0	74701.3968	2455396.2	20610.99	19399.4222
S5	4.00	3.30		2.139	27.3	0.828	0.741	0.0100	35877.6	118396.08	0	76742.1864	979458.48	29706.6528	26599.6526
S5	5.00	10.00		2.126	32	0.748	0.770	0.0096	34506	345060	0	73359.756	1104192	25810.488	26569.62
S5	6.00	3.30		2.089	91	0.436	0.407	0.0098	35233.2	116269.56	0	73602.1548	3206221.2	15361.6752	14339.9124
S5	7.00	46.70		1.986	187	2.025	2.416	0.0112	40298.4	1881935.28	0	80032.6224	7535800.8	81604.26	97344.815
S5	8.00	100.00		2.047	447	2.73	3.412	0.0131	47145.6	4714560	0	96507.0432	21074083.2	128707.488	160870.216
S5	9.00	170.00		1.725	238	2.793	3.711	0.0152	54828	9320760	0	94578.3	13049064	153134.604	203488.639
S5	10.00	180.00		1.52	331	3.671	4.723	0.0162	58446	10520280	0	88837.92	19345626	214555.266	276063.836
						S5	**Total per day**		**1149969.6**	**124608148**	**0**	**1553164.79**	**241675431**	**1952101.76**	**2830673.41**
S6	10.00	266.00	13.756	1.643	463	1.671	4.347	0.0129	46299.6	12315693.6	636897.3	76070.2428	21436714.8	77366.6316	201273.621
S6	11.00	192.00	32.005	1.03	336	3.475	5.060	0.0123	44179.2	8482406.4	1413955.3	45504.576	14844211.2	153522.72	223546.752
S6	12.00	296.00	15.775	2.71	414	2.087	4.145	0.0119	42724.8	12646540.8	673983.72	115784.208	17688067.2	89166.6576	177085.751
S6	13.00	214.00	18.803	2.104	326	1.872	3.949	0.0129	46562.4	9964353.6	875512.81	97967.2896	15179342.4	87164.8128	183874.918
S6	14.00	156.00	14.682	2.059	333	1.774	3.564	0.0134	48211.2	7520947.2	707836.84	99266.8608	16054329.6	85526.6688	171824.717
S6	15.00	136.00	10.167	3.234	381	1.651	3.346	0.0153	55126.8	7497244.8	560474.18	178280.071	21003310.8	91014.3468	184465.298
S6	16.00	264.00	15.153	2.54	390	2.395	4.129	0.0158	56894.4	15020121.6	862120.84	144511.776	22188816	136262.088	234939.735

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S6	17.00	150.00	16.588	2.704	314	1.903	3.065	0.0162	58377.6	8756640	968367.63	157853.03	18330566.4	111092.573	178903.993
S6	18.00	158.00	15.775	3.302	305	2.293	3.755	0.0169	60663.6	9584848.8	956968.29	200311.207	18502398	139101.635	227816.083
S6	19.00	124.00	12.449	2.425	279	1.589	3.489	0.0163	58748.4	7284801.6	731358.83	142464.87	16390803.6	93351.2076	204984.917
S6	20.00	114.00	12.848	3.136	202	1.782	2.831	0.0175	62992.8	7181179.2	809331.49	197545.421	12724545.6	112253.17	178357.814
S6	21.00	94.00	12.23	3.138	244	1.73	3.443	0.0174	62560.8	5880715.2	765118.58	196315.79	15264835.2	108230.184	215396.834
S6	22.00	68.00	9.265	3.198	219	1.383	2.075	0.0171	61689.6	4194892.8	571554.14	197283.341	13510022.4	85316.7168	127981.244
S6	23.00	62.00	10.857	3.107	155	1.653	2.070	0.0149	53481.6	3315859.2	580649.73	166167.331	8289648	88405.0848	110717.608
S6	0.00	50.00	9.16	2.831	107	1.419	1.736	0.0128	46065.6	2303280	421960.9	130411.714	4929019.2	65367.0864	79960.6685
S6	1.00	42.00	4.845	2.719	88	0.791	1.188	0.0113	40543.2	1702814.4	196431.8	110236.961	3551584.32	32069.6712	48165.3216
S6	2.00	28.00	0.582	2.928	50	0.496	0.539	0.0114	40982.4	1147507.2	23851.757	119996.467	2061414.72	20327.2704	22089.5136
S6	3.00	14.00	0.149	2.813	24	0.576	0.596	0.0104	37605.6	526478.4	5603.2344	105784.553	883731.6	21660.8256	22420.4587
S6	4.00	10.00	1.475	2.875	29	0.804	0.926	0.0106	38304	383040	56498.4	110124	1095494.4	30796.416	35477.1648
S6	5.00	40.00	2.811	2.877	111	1.503	1.767	0.0110	39495.6	1579824	111022.13	113628.841	4384011.6	59361.8868	69772.927
S6	6.00	40.00	4.792	3.076	83	1.401	1.769	0.0158	56743.2	2269728	271913.41	174542.083	4726708.56	79497.2232	100367.372
S6	7.00	202.00	20.014	2.875	413	3.499	5.379	0.0211	75891.6	15330103.2	1518894.5	218188.35	31343230.8	265544.708	408220.916
S6	8.00	308.00	32.347	2.883	600	5.382	9.308	0.0157	56635.2	17443641.6	1831978.8	163279.282	33981120	304810.646	527171.769
S6	9.00	270.00	12.368	2.898	485	2.228	4.358	0.0148	53226	14371020	658299.17	154245.4	25814610	118587.528	231969.553
						S6	**Total per day**		**1244005.2**	**176703682**	**16210584**	**3415763.67**	**344178536**	**2455797.76**	**4166784.95**
S7	11.00	200.00	9.125	0.054	220	0.34	1.813	0.0217	78274.8	15654960	714257.55	4226.8392	17220456	26613.432	141896.557

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S7	12.00	60.00	12.839	0.015	82.7	0.292	0.693	0.0220	79131.6	4747896	1015970.6	1186.974	6544183.32	23106.4272	54838.1988
S7	13.00	60.00	5.326	0.029	193	0.222	0.790	0.0219	78685.2	4721112	419077.38	2281.8708	15186243.6	17468.1144	62145.571
S7	14.00	20.00	4.404	0	124	0.242	0.583	0.0231	83160	1663200	366236.64	0	10311840	20124.72	48482.28
S7	15.00	60.00	6.138	0.002	51.1	0.214	0.482	0.0237	85399.2	5123952	524180.29	170.7984	4363899.12	18275.4288	41145.3346
S7	16.00	0.00	4.927	0.002	60.3	0.256	0.524	0.0241	86778	0	427555.21	173.556	5232713.4	22215.168	45436.9608
S7	17.00	20.00	6.162	0.026	88.6	0.245	0.405	0.0243	87397.2	1747944	538541.55	2272.3272	7743391.92	21412.314	35378.3866
S7	18.00	40.00	6.158	0.022	86.8	0.371	0.704	0.0233	83800.8	3352032	516045.33	1843.6176	7273909.44	31090.0968	58995.7632
S7	19.00	100.00	4.447	0.006	63.6	0.204	0.343	0.0231	83156.4	8315640	369796.51	498.9384	5288747.04	16963.9056	28539.2765
S7	20.00	60.00	5.595	0	154	0.377	0.462	0.0229	82368	4942080	460848.96	0	12684672	31052.736	38054.016
S7	21.00	0.00	1.986	0	44.4	0.14	0.306	0.0223	80125.2	0	159128.65	0	3557558.88	11217.528	24502.2862
S7	22.00	60.00	5.855	0	81	0.273	0.449	0.0226	81388.8	4883328	476531.42	0	6592492.8	22219.1424	36527.2934
S7	23.00	20.00	5.546	0.029	62.4	0.667	0.931	0.0218	78523.2	1570464	435489.67	2277.1728	4899847.68	52374.9744	73073.6899
S7	0.00	0.00	2.902	0.01	34.6	0.304	0.372	0.0211	75906	0	220279.21	759.06	2626347.6	23075.424	28221.8508
S7	1.00	20.00	1.84	0	30.2	0.04	0.172	0.0206	74185.2	1483704	136500.77	0	2240393.04	2967.408	12730.1803
S7	2.00	40.00	0.979	0	171	-0.043	0.134	0.0204	73396.8	2935872	71855.467	0	12550852.8	-3156.0624	9849.85056
S7	3.00	0.00	0.94	0.003	186	-0.089	0.046	0.0201	72410.4	0	68065.776	217.2312	13468334.4	-6444.5256	3345.36048
S7	4.00	80.00	1.056	0.006	19.3	-0.029	0.130	0.0199	71586	5726880	75594.816	429.516	1381609.8	-2075.994	9291.8628
S7	5.00	40.00	0.747	0.008	15.2	-0.077	0.066	0.0199	71733.6	2869344	53584.999	573.8688	1090350.72	-5523.4872	4734.4176
S7	6.00	40.00	1.06	0.018	15.8	-0.026	0.152	0.0204	73278	2931120	77674.68	1319.004	1157792.4	-1905.228	11123.6004

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S7	7.00	80.00	4.123	0.037	44.6	0.501	0.889	0.0214	76914	6153120	317116.42	2845.818	3430364.4	38533.914	68361.1632
S7	8.00	160.00	7.493	0.053	181	0.798	0.922	0.0224	80586	12893760	603830.9	4271.058	14586066	64307.628	74284.1748
S7	9.00	0.00	5.963	0.047	163	0.51	0.865	0.0223	80276.4	0	478688.17	3772.9908	13085053.2	40940.964	69406.9754
S7	10.00	100.00	7.107	0.052	157	0.718	0.785	0.0217	78145.2	7814520	555377.94	4063.5504	12268796.4	56108.2536	61375.2401
						S7	**Total per day**		**1896606**	**99530928**	**9082228.9**	**33184.1916**	**184785916**	**520962.282**	**1041740.29**
S8	9.00	74.00	7.156	1.552	83.4	0.856	1.489	0.0441	158878.8	11757031.2	1136936.7	246579.898	13250491.9	136000.253	236634.085
S8	10.00	40.00	2.867	1.463	50.9	0.22	0.766	0.0441	158882.4	6355296	455515.84	232444.951	8087114.16	34954.128	121640.365
S8	11.00	36.00	3.222	1.507	67.1	0.142	0.530	0.0470	169059.6	6086145.6	544710.03	254772.817	11343899.2	24006.4632	89635.3999
S8	12.00	40.00	3.201	1.339	60.8	0.126	0.530	0.0504	181328.4	7253136	580432.21	242798.728	11024766.7	22847.3784	96140.3177
S8	13.00	46.00	4.055	1.21	76.2	0.338	0.700	0.0535	192492	8854632	780555.06	232915.32	14667890.4	65062.296	134667.403
S8	14.00	48.00	2.961	1.14	65.5	0.308	0.768	0.0547	196779.6	9445420.8	582664.4	224328.744	12889063.8	60608.1168	151087.377
S8	15.00	42.00	2.404	1.021	55.1	0.126	0.570	0.0573	206168.4	8659072.8	495628.83	210497.936	11359878.8	25977.2184	117474.754
S8	16.00	54.00	4.299	0.929	77.2	0.244	0.722	0.0571	205520.4	11098101.6	883532.2	190928.452	15866174.9	50146.9776	148303.521
S8	17.00	60.00	2.776	0.735	112	0.46	1.188	0.0600	215917.2	12955032	599386.15	158699.142	24182726.4	99321.912	256509.634
S8	18.00	56.00	2.801	0.747	81.9	0.199	1.243	0.0600	215874	12088944	604663.07	161257.878	17680080.6	42958.926	268331.382
S8	19.00	34.00	2.282	0.594	76.8	0.159	0.535	0.0603	216993.6	7377782.4	495179.4	128894.198	16665108.5	34501.9824	116004.779
S8	20.00	44.00	3.595	0.562	90.6	0.485	0.711	0.0604	217479.6	9569102.4	781839.16	122223.535	19703651.8	105477.606	154541.004
S8	21.00	56.00	2.913	0.501	106	0.376	0.858	0.0587	211460.4	11841782.4	615984.15	105941.66	22414802.4	79509.1104	181433.023
S8	22.00	18.00	2.507	0.346	49.3	0.25	0.392	0.0573	206125.2	3710253.6	516755.88	71319.3192	10161972.4	51531.3	80718.6283

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S8	23.00	20.00	1.954	0.378	57.7	0.182	0.389	0.0551	198471.6	3969432	387813.51	75022.2648	11451811.3	36121.8312	77284.841
S8	0.00	18.00	2.231	0.409	40.7	0.307	0.431	0.0533	192045.6	3456820.8	428453.73	78546.6504	7816255.92	58957.9992	82810.0627
S8	1.00	8.00	1.702	0.265	20	0.182	0.242	0.0526	189201.6	1513612.8	322021.12	50138.424	3784032	34434.6912	45786.7872
S8	2.00	8.00	1.057	0.12	24.9	-0.021	0.121	0.0508	182808	1462464	193228.06	21936.96	4551919.2	-3838.968	22119.768
S8	3.00	2.00	0.825	0	10.4	-0.082	0.020	0.0500	180136.8	360273.6	148612.86	0	1873422.72	-14771.218	3566.70864
S8	4.00	6.00	1.309	0	25.6	0.182	0.354	0.0497	178812	1072872	234064.91	0	4577587.2	32543.784	63335.2104
S8	5.00	4.00	1.132	0	14.9	0.084	0.249	0.0518	186631.2	746524.8	211266.52	0	2780804.88	15677.0208	46396.5163
S8	6.00	24.00	1.964	0	48.2	0.411	0.638	0.0550	197881.2	4749148.8	388638.68	0	9537873.84	81329.1732	126248.206
S8	7.00	22.00	3.277	0	60.3	0.926	1.076	0.0513	184525.2	4059554.4	604689.08	0	11126869.6	170870.335	198512.21
S8	8.00	60.00	3.89	0	112	0.952	1.353	0.0498	179168.4	10750104	696965.08	0	20066860.8	170568.317	242414.845
						S8	**Total per day**		**4622641.2**	**159192540**	**12689537**	**2809246.88**	**286865059**	**1414796.63**	**3061596.83**
S9	10.00	82.00	4.35	2.084	135	0.615	0.553	0.0600	215964	17709048	939443.4	450068.976	29155140	132817.86	119428.092
S9	11.00	46.00	3.704	2.083	80.1	0.412	0.356	0.0597	214941.6	9887313.6	796143.69	447723.353	17216822.2	88555.9392	76519.2096
S9	12.00	24.00	1.834	2.12	54.4	0.225	0.153	0.0603	217040.4	5208969.6	398052.09	460125.648	11806997.8	48834.09	33207.1812
S9	13.00	40.00	2.51	1.992	69.2	0.238	0.320	0.0620	223333.2	8933328	560566.33	444879.734	15454657.4	53153.3016	71466.624
S9	14.00	16.00	1.951	2.145	30.9	0.239	0.133	0.0665	239270.4	3828326.4	466816.55	513235.008	7393455.36	57185.6256	31822.9632
S9	15.00	20.00	1.022	2.063	38.2	0.094	0.200	0.0706	254311.2	5086224	259906.05	524644.006	9714687.84	23905.2528	50862.24
S9	16.00	44.00	1.343	2.189	58.9	0.46	0.236	0.0758	272959.2	12010204.8	366584.21	597507.689	16077296.9	125561.232	64418.3712
S9	17.00	50.00	2.102	2.149	130	0.301	0.382	0.0792	284972.4	14248620	599011.98	612405.688	37046412	85776.6924	108859.457

Sample ID	Time	TSS (mg/l)	NH_4 (mg/l)	NO_3 (mg/l)	COD (mg/l)	O-P(mg/l)	T-P(mg/l)	Discharge (m^3/s)	Discharge (L/hr)	TSS (mg/hr)	NH_4 (mg/hr)	NO_3 (mg/hr)	COD (mg/hr)	O-P (mg/hr)	T-P (mg/hr)
S9	18.00	40.00	1.125	2.206	63.1	0.271	0.202	0.0812	292384.8	11695392	328932.9	645000.869	18449480.9	79236.2808	59061.7296
S9	19.00	26.00	1.796	2.064	37.8	0.413	0.351	0.0818	294544.8	7658164.8	529002.46	607940.467	11133793.4	121647.002	103385.225
S9	20.00	24.00	1.127	2.185	61.7	0.27	0.251	0.0814	293202	7036848	330438.65	640646.37	18090563.4	79164.54	73593.702
S9	21.00	8.00	0.855	2.171	25	0.2	0.715	0.0801	288219.6	2305756.8	246427.76	625724.752	7205490	57643.92	206077.014
S9	22.00	16.00	0.971	2.142	29.8	0.278	0.368	0.0774	278582.4	4457318.4	270503.51	596723.501	8301755.52	77445.9072	102518.323
S9	23.00	16.00	1.118	2.074	32.9	0.307	0.386	0.0758	273006	4368096	305220.71	566214.444	8981897.4	83812.842	105380.316
S9	0.00	16.00	1.005	2.094	22.9	0.29	0.650	0.0724	260625.6	4170009.6	261928.73	545750.006	5968326.24	75581.424	169406.64
S9	1.00	10.00	0.646	2.058	26.1	0.155	0.283	0.0705	253843.2	2538432	163982.71	522409.306	6625307.52	39345.696	71837.6256
S9	2.00	8.00	0.6	2.009	14.3	0.137	0.289	0.0687	247186.8	1977494.4	148312.08	496598.281	3534771.24	33864.5916	71436.9852
S9	3.00	8.00	0.473	2.16	14	0.134	0.812	0.0672	241927.2	1935417.6	114431.57	522562.752	3386980.8	32418.2448	196444.886
S9	4.00	8.00	0.388	2.077	23	0.079	0.391	0.0653	234990	1879920	91176.12	488074.23	5404770	18564.21	91881.09
S9	5.00	10.00	0.402	2.068	10.1	0.126	0.088	0.0644	231696	2316960	93141.792	479147.328	2340129.6	29193.696	20389.248
S9	6.00	6.00	0.504	1.953	9.22	0.215	0.154	0.0636	228780	1372680	115305.12	446807.34	2109351.6	49187.7	35232.12
S9	7.00	6.00	0.9	2.234	27.8	0.277	0.153	0.0638	229532.4	1377194.4	206579.16	512775.382	6381000.72	63580.4748	35118.4572
S9	8.00	22.00	1.514	2.294	53.4	0.581	0.319	0.0644	231969.6	5103331.2	351201.97	532138.262	12387176.6	134774.338	73998.3024
S9	9.00	32.00	1.923	2.131	52.4	0.517	0.283	0.0634	228384	7308288	439182.43	486686.304	11967321.6	118074.528	64632.672
						S8	**Total per day**		**6031666.8**	**144413338**	**8382292**	**12765789.7**	**276133586**	**1709325.39**	**2036978.47**
							Grand Total for 216 samples		**21325006.8**	**1375187631**	**110435716**	**27048266.2**	**2521516851**	**16237220.5**	**29140415.3**

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