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Study of microbiological runoff water quality from a green roof and in an open storm water system

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Acknowledgement

To the great woman Nimat my mother, my father`s sole, to my family in Sudan, my supervisor Justyna, all friends.

Ammar,,,

Abstract

Augustenborg is suburb city in Malmö south of Sweden. The climate is temperate with occasional snow during the winter. Open storm water is applied in Augustenborg since late 1990s and the storm water is disconnected from the combined sewer system in order to give the area a lift up value and to solve the flooding problems in basements after heavy rainfall events. The new system consists of combination of BMPs. Since the water in the open system is exposed in the surface and there is a risk for public health in the surrounding neighbourhood a microbiological study have been carried out in the area. The aim of the study was to assess the microbiological quality of the storm water within the system. Four locations have been selected to serve as sampling points in the system. These are: green roofs, pond 1, pond 2 and the open channel. `E-coli`, total coli forms, `clostridium perfringens`, and intestinal enterococci have been chosen as microbial indicators to evaluate the water quality. Grab water samples have been collected after heavy rain events three times in each sampling points in 6 May, 24 October and 26 November. The obtained results have been compared with bathing water standard for EU countries. The results from the green roofs have least microbial pollution load among all sampling sites. The samples taken from the ditch show the highest microbial concentrations. Pond1 and pond2 sampling points show less microbial pollution comparing with the ditch. The results from the ponds are affected by the addition of drinking water from mains supply, which has been added occasionally during dry periods. The process of adding drinking water affected the water quality in the ponds positively. Most of the collected samples did not meet the standards for bathing water quality. Around 80% of the investigated samples exceeded the standard value (1000/100 ml) for total coli form indicator while 33 % of the samples exceeded the standard value for `E. coli` indicator (500st/100 ml) and 66% of the samples exceeded the standard value for intestinal enterococci indicator. In general, the storm water in Augustenborg open system can be judged as polluted water from microbiological point of view and there is a need for further research for better linkage between rainfall intensity and microbial concentration in storm water.

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Objectives

The aim of the study is to investigate the microbiological water quality of green roof runoff and in an open storm water system to assess the potential health risks due to contact with storm water in an open storm water system and to identify potential needs for further studies. The research is carried out in Austenborg, Malmö, Sweden. Water samples were taken three times during autumn 2009, directly after precipitation events. Four samples were taken on each sampling occasion: green roof runoff, storm water runoff from an open channel, storm water from pond 1, and storm water from pond 2. Samples were analyzed for `E. coli`, total coli forms, `clostridium perfringens`, and intestinal enterococci.

1 .Introduction

Since humans started to live in dense communities (urban areas) household wastes, water used at households and runoff water originating from precipitation became an issue requiring management. Archeological evidence proves that ancient storm water systems established by human were found at Minoan (Crete) and ancient Roman Empire (Butler et al., 2002). Indus civilization and Mesopotamians (3000 BC) established drains to transport storm water from the streets to outside in other public place. The Greeks later reused these drains and reinstalled it in residential areas. In ancient Roman Empire in some cities, manholes and drains used for inspection purposes are found. Since Roman Empire falls, no progress is made in storm water management. Consequently, many cities suffered from pollution and the sanitation situation was the worst resulting in waterborne diseases outbreak. In 1800s, the cities became denser with population as result of industrial revolution. This in turn led to increase of pollution and water demand. The first well-designed sewer system was established in Hamburg in Germany in 1843 due to reconstruction of part of the city, which was destroyed by fire. In England, the major cities suffered from cholera epidemics, especially London. The sewer system was completed in the year 1865and the rainfall calculations were considered to estimate the storm water runoff (Villarreal, 2003).

This master thesis investigates microbiological storm water quality in an open water system. Storm water is defined here as the water, originating from precipitation or snow melt and creates runoff which is discharged through a drainage system to recipients. Storm water runoff is created on impervious surface. Increasing impervious surface in urban areas leads to decreased infiltration and consequently increased runoff volume and pollution load. The storm water management concerns two main factors: the volume of storm water and the contaminants load. Traditionally storm water infrastructures are established to remove water from surface (especially road) as soon as possible and dispose it off to the nearest watercourse through piping system (canal or ditch). Generally, the storm water can be handled by following systems: combined, separate and open system (Butler et al., 2002).

In the combined system, the storm water is carried together with wastewater in the same pipe to wastewater treatment plants. In dry weather condition, the system carries the wastewater only, but during rain, the flow is predominated by storm water flow. The pipes in the combined system carry only ten percent of the designed flow most of the time. The system only reaches its capacity during wet weather condition, which is economically ineffective. To prevent flooding from a combined storm water system, in case pipe capacity is exceeded during heavy rainfall a CSO (combined sewer overflow) structure is often provided. Trough this structure an excess flow is diverted into water recipients. The risk of flooding, high pump cost, pollution, construction cost and variation of the pollution load are the more obvious limitation of the combined system. However, the system offers some degree of treatment of storm water (smaller flow than those requiring CSO). Moreover, the combined system requires only one pipe, takes less space and money to install the pipe (comparing to separate system where two pipes are required). Furthermore, the solid waste deposited in pipes is washed out during storm events (Butler et al., 2002).

In the separate system, the storm water and the household wastewater are carried in separate pipes. Commonly the separate storm water pipe discharges directly to water course and storm water runoff is not treated, although the storm water from urban areas can be contaminated with many types of contaminants.

In an open storm water system, the storm water may be managed in more natural and sustainable manner. The open storm water system involves a numbers of BMPs (best management practice) techniques typically including wetland, ponds, swales, open channels, infiltration sites, percolation facilities, and porous surfaces. The system is totally separated from waste water system but sometimes may be connected to it at the discharge point. Villarreal et al. (2004) demonstrate that the use of BMPs can be successfully applied in housing development in Sweden. This is a part of international trend driven by public demand for sustainable development and integrated water managements. Such an open storm water system can be designed for multipurpose use including control of the water volume (reducing runoff volume and risk of flooding, slowing down the runoff), improvement of water quality, establishment of green areas for recreation, and enhancement of biodiversity in urban areas. However, the open system has many advantages but it has also some limitations and involves risks, which need to be considered. These include:

- Flood risks and properties damages in case of improper design and underestimation of runoff volume. The disadvantage can be avoided by careful design and maintenance.
- Bad water quality in ponds and wetlands. The pollutants accumulate in the wetlands and ponds and there is a risk that polluted water may percolate to ground water reservoir and contaminate it. The polluted water is a threat to aquatic ecosystem flora and fauna.

- During the dry period there is a risk for vegetation damage in the e.g. green roofs, moreover the ponds and swales can dry out which leads to creation of an unpleasant environment.
- The water in ponds and swales may represent health hazards for humans especially when human come in contact with water, as the water could be contaminated and potentially expose humans for infection risks.
- The ponds and swales can be habitats for undesirable insects' species (Czemiel Berndtsson, 2004).

2. Background – literature review

2.1 Storm water quality

The quality of water in open system depends on the source of water. The rainwater can be generally considered as non-polluted water but contamination takes place when the water reaches the roofs or in collection system or in the storage system. Heavy metals, pesticides, pathogenic microorganisms, nutrients, petroleum hydrocarbons and dissolved roofs materials are the majors' contaminants groups in the storm water (Czemiel Berndtsson, 2004). Many factors influence the storm water quality. Quality of roof runoff is influenced by:

- Roof material chemical and physical characteristic, roughness, type of surface coating.
- Boundary condition of the roofing system, area, slope, and age of the roof.
- Rain events, rain intensity, wind velocity, and concentration of pollutants in the rain.
- Chemical and physical properties of pollutants.
- Meteorological factors- weather characteristics, length of a dry period preceding a rain event.
- Location of the roof: storm water collected at industrial sites and areas with high traffic intensity tend to be highly contaminated (Förster, 1996).

The concentration of pollutants in storm water runoff tends to be higher in the first minutes of a storm event comparing with a deeper runoff depth. This process is known as a first flush phenomenon. The concentration of pollutants tends to decrease with time as the pollutants are washed away from hard surfaces. One of the following three factors or a combination of these can cause the first flush: (1) the matter deposited on roof during the dry period is washed by falling rain; (2) particles from weathering of roof materials are washed off; (3) the pollutant load decreases with increasing of rainfall depth (Meera et al., 2006).

Large and diverse types of pollutant can be found in storm water depending on many factors. Below the main contaminants, groups are reviewed.

Heavy metals. In storm water typically following metals are measured: zinc, cadmium, lead, copper, manganese, nickel, cobalt, vanadium, and chromium. These are largely found in storm water, especially the water collected from roofs and street surfaces. It is very important to study heavy metal in storm water due their toxicity for living organisms. Moreover, heavy metals cannot be easily transformed or removed from water. The potential sources of heavy metals in storm water are degradation of roof material itself, atmosphere fallout, exhaust emissions, industrial activates, road surfaces, and de-icing compounds. The content of heavy metals in storm water is varying depending on site and rain intensity and duration (Meera et al., 2006).

Organic compounds. About 640 xenobiotic organic compounds can be found in storm water as revealed by the literature review conducted by Ledin (Czemiel Berndtsson, 2004). Polycyclic aromatic hydrocarbons and pesticides are the most common and well studies parameters in this group. Several studies prove that the precipitation itself contain considerable amount of organic materials. Both roofs characteristic and chemical properties of organic matter have great affect on runoff water quality, which is collected from roofs. Major sources of organic pollutants to storm water are: heating, traffic, industrial activities, local emissions which pollute the atmosphere and construction materials.

Microbial contaminants. Normally the storm water harvested on roofs does not meet the standard quality for drinking water as showed by numerous studies conducted on rainwater harvesting systems. Different sources have been participated in fecal contamination of storm water. The main sources are animal feces, vegetation and street dirt. Microbiological quality of storm water depends on many factors including roof materials and contamination of roof itself. It also depends on rain intensity and the length of dry periods between rain events. Some studies prove that the microbial contamination increased as the dry period increased between rainfalls events. That can be explained by increased load of deposition materials on the top of roofs. Fecal coli form, fecal streptococci and E. coli are the common indicators used to assess the microbiological water quality. Further discussion about these indicators is given in the next chapter.

The quality of water in open storm water system, in particular those that are recently being constructed in urban areas, as a part of sustainability trend is still not well investigated. Earlier studies of storm water in urban streams that receive urban storm water runoff show that the storm water from urban areas - especially after heavy rain events - contains substantial microbiological pollution. Eventually there has been growing recognition that storm water runoff from urban areas contributes with considerable amount of pathogens and microorganisms to water recipients (Ellis, 1993). The open storm water systems, especially such including numerous shallow channels lead to increase potential of exposure of people for contact with storm water runoff. Open storm water systems located in housing areas potentially expose inhabitants for contact with storm water, which may create potential health risks, especially regarding children.

Indeed, storm water runoff from impermeable surfaces is a major source of microorganisms and pathogens in urban receiving waters. Most of recreational sites in UK do not meet the standards value of recreational water. Furthermore, about 87 % of recreational water, which receives urban discharge, fails to meet the regularity value for fecal coli form bacteria. Urban surface water is often of the same quality as sewage effluents (Ellis, 1993). Ellis (1993) argues that where water is used for recreational activities a reasonable public expectation is such that water is safe and clean and at the very least should comply with minimum standards.

A number of microbial pathogenic organisms can be found in storm water including bacteria, viruses, and protozoa. These microbes are the main reasons of waterborne diseases. Contaminated storm water can be a cause of many bathing related illnesses including eye, ear, nose and reparatory thickness (Kurz, 1998).

In Table (1) a major pathogenic bacteria that may be found in polluted water, the related diseases and survival time are presented (Dean et al., 1981).

Table 1. Pathogenic bacteria found in polluted water, related diseases and survival time (Dean et el., 1981).

Bacterium	Disease	Survival time in water
E .coli (pathogenic strain)	Infantile enteritis, Traveler diarrhea	Several weeks
Shigella dysenteriae, shigella flexneri and other types	Bacterial dysenteri	Few hours to few days

Salmonella typhi, salmonella paratyhi, salmonella typhimurium and other types	Typhoid fever, paratyphoid fever, enteritis	Several weeks
Yersinia enerocolitica	Enteritis (arthritis)	Survive for prolonged periods at low temperature
Vibrio cholera Vibrio cholera NAG Vibrio parahaemmolyticus	Cholera disease, enteritis	Several weeks, especially with appropriate salt concentration and alkaline pH
Campylobacter jejuni (previously vibrio fetus)	enteritis	Probably like vibrio
Leptospira	Leptospirosis (Wiel disease)	months
Mycobacterium tuberculosis	Tuberculosis	May survive for prolonged periods (several weeks)

2.1.1 Indicator organisms of microbial pollution

Many microorganisms group have been used in water microbiology as indicators' or tracers for fecal pollution in water. The purpose of use of such indicators is either to assess the treatment efficiency of a particular water system or evaluate the water quality in general. The search for suitable and adequate indicators has been linked with the organisms present in human feces. Major microbiological health hazard are related to consumption or contact with fecally contaminated water. Dean et al. (1981) suggests that the ideal indicator of fecal pollution should:

- be universally present in feces of human and animals in large numbers
- persist in water in a similar manner to fecal pathogen
- exist in higher number than fecal pathogens
- be detected in water in simple and inexpensive way
- respond in the same way to treatment process as fecal pathogens.

According to the above criteria the total coli form, fecal coli form and fecal streptococci are the best indicators, which meet most of the above listed criteria. Besides coli form group, other kind of indicators can probably be used (Dean et al., 1981). Coliphage viruses which infect and replicate in coli form bacteria and can be correlated with coli form bacteria are also widely used as indicators in drinking water treatment and groundwater recharge. A fluorescent bead has been widely used as tracer for `oocysts` of `Cryptosporidium parvum` pathogen that causes many waterborne diseases throughout the world (Kurz, 1998).

Total coli form, `Clostrium perfringens`, `intestinal enterococci` and `E.coli` are the indicators used in this study. Below follows description of these indicator organisms.

Clostrium perfringens: `Clostridium perfringen`s is Gram-positive, anaerobic sulfite –reducing bacilli. C. p`erfringens` is a member of the normal intestinal flora of 13-35 % of human and other warm-blooded animals. C. does not multiply in water environments and is considered an excellent indicator of fecal pollution. Due to the exceptional resistance of C. `perfringens` to disinfection process, it is proposed as an index of enteric viruses and protozoa in treated drinking water. `C. perfringens` is not recommended as a routine monitoring due to their long survival time. However, it can be used to indicate pollution that took place long time ago. This group of organisms is present in feces of animals and humans. Membrane technique is used to detect C. `perfringens` in water (WHO, 2010).

Total coli form bacteria: Total coli form bacteria include a wide range of aerobic and facultatively anaerobic gram-negative, not-spore-forming bacilli capable of growing in the presence of relatively high concentration of bile salts with fermentation of lactose and production of acid or aldehyde within 24 h at 35-37 °C. Traditionally coli form bacteria were regarded as belonging to the genera `Escherichia`, `Citrobacter klebsiella`, and Enterobacter, but this group is more heterogeneous and includes a wider spectrum of genera such as Serratia and Hafnia. The total coli form group includes both fecal and environmental species. Total coli form includes organisms, which can survive and grow in water. The group is used as an indicator of water treatment efficiency. The group of total coli form excluding `E.coli` occurs both in natural and sewage water and some of bacteria is excreted in faeces of animals and humans (WHIO, 2010).

Intestinal enterococci bacteria: Intestinal enterococci are a subgroup of the larger group of organisms defined as fecal enterococci. These bacteria are gram-negative and relatively tolerant of sodium chloride and alkaline pH levels. They are facultative anaerobic and occur singly in pair of short chains. These bacteria are found in feces of warm-blooded animals and in other sources such as soil and water environment. The intestinal enerococci can be used widely as index of fecal pollution of raw water due to its longer survival time in water comparing with `E.coli` group. There are different methods of measuring content of this indicator organism in water including membrane filtration and most probable number technique. Detection of intestinal enterococci in water is an evidence of recent fecal pollution (WHO, 2010).

Escherichia coli and thermo tolerant coli forms (E. coli bacteria): Total coli form bacteria that are able to ferment lactose at 44-45 °C are known as thermo tolerant coli form. Escherichia coli (`E. coli`) belongs to that group. In most polluted water the predominant genus is Escherichia coli. It can be differentiated from the other thermo tolerant coli form by it's' ability to produce enzyme `b-glucuronidase. E. coli` is present in a large number in human and animal feces and present in water it is always a strong evidence of fecal pollution. `E. coli` is the most preferable index to detect fecal pollution. Membrane filtration and most probable number are the common methods to detect `E. coli` in water (WHO, 2010).

2.1.2 Recreational water quality guidelines

There are no standards for microbial quality in storm water and storm water recipients. In case there is a risk for human contact with storm water runoff directly after the storm event, like for example in open storm water systems, the recreational water quality standard can be used as a reference in assessing water quality. Setting recreational water standards have been successful in improving water quality and increasing public awareness about water quality and related risks. Those in turn contributed to improving public health (WHO, 2001). The bathing water has been since long recognized as carrying potential health risks due to water contamination with microorganisms originating in feces (Kay, 2007). The first standards for recreational water quality are dated to 1974 and are the recommendations of WHO. The microbiological term of these recommendations suggests guidelines based on the presence of bacterial indicators organisms in bathing water. The guidelines suggest less than 100 E.coli per 100 ml for highly satisfactory bathing water. For bathing, water to be accepted as such `E. coli` should not be greater than 1000 per 100 ml. These standards are given in Table (2).

Table (2). EC microbiological quality requirements as per council Directive 76-160-EEC December 1975 (Kamizoulis et al., 2004).

Parameters	Guide value	Mandatory value	Minimum sampling frequency	Method of analysis and inspection
Total coli form Per 100 ml	500	1000	Fortnightly	Fermentation in multiple tubes. Sub culturing of the positive tubes on a Confirmation medium. Count according to MPN (most probable number)or membrane filtration and culture on an appropriate medium such asTergitol actose agar, endo-agar, 0.4% Teepol broth, subculturing and identification of the suspect colonies.
Fecal coli form Per 100 ml	100	200	Fortnightly	For coli form. MPN (most probable number), filtration membrane in appropriate medium.
Fecal streptococci Per 100 ml	100	-	Concentration must check by the competent authorities when there is tendency towards the eutrophication of the water.	
Salmonella per liter	-	-	Concentration must check by the competent authorities when there is tendency	Concentration by membrane filtration

			towards the eutrophication of the water.	

These standards (Table 2) had been widely criticised because there was no transparent evidence based on epidemiological studies. Many epidemiological studies have been carried out in UK in order to determine scientific evidence and to develop new standards based on practical measurements. The studies were aiming to quantify the potential health risk of bathing in recreational water. These studies brought out a scientific basis for developing new standards. The studies prove that the previous standards were insufficient to protect the health of bathers. WHO used the UK studies to develop new standards however, WHO concluded that there is still a need for more information regarding not temperate climate conditions. WHO utilized the results of UK and similar studies, which provided a link between the pathogen presence in bathing water and the health of bathers. The outcome of all these studies is the new guideline for safe recreational water environment as presented in table (3). The guideline expressed the relationship between exposures to recreational water with risk of getting a mild gastrointestinal illness using enterococci as indicator organism (Kay, 2007).

Table (3). WHO standards for bathing water quality stablished on 2003 (WHO, 2003).

Grade 95th percentile[4] value of Enterococci /100 ml	Basis of derivation	Estimated risk
A = 40	This range is below the NOAEL[2] in most of epidemiological studies.	Less than 1 % GI[1] illness risk; Less than AFRI[3] risk. The upper 95th percentile value of 40/100 ml relates to an average probability of less than one case of gastroenteritis in every 100 exposure to water. The AFRI burden would be negligible.

B (41 to 200)	The value 200/100 ml is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL.	1-less than 5% GI illness risk; 0.3- less than1.9% AFRI illness risk The upper 95th percentile value of 200/100 ml relates to an average probability of one case gastroenteritis in 20 exposures. The AFRI illness rate at this upper value would be less than 19 per 100 exposure, or less than approximately I in 50 exposure.
C (201 to 500)	This range represents substantial elevation in the probability of all adverse health outcomes for which dose- response data available.	5- 10 % GI illness risk; 1.9-3.9% AFRI illness risk. This range of 95th percentile represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19- 39 per 1000 exposures, or a range of approximately 1 in 50 1 in 25 exposure.
D (above 500)	Above this level, there may be a significant risk of high levels of minor illness transmission.	More than 10% GI illness risk; More than 3.9% AFRI illness risk. There is a greater than 10% chance to gastroenteritis per single exposure. The AFRI illness rate at the 95th percentile point of more than 500/100ml would be greater than 39 per 1000 exposure, of greater than approximately 1 in 25 exposures.

GI= Gastrointestinal, [2]NOAEL =no observed effect level, [3]AFRI=acute febrile respiratory illness. [4]The 95th percentile is the 95% confidence limit of the range of values found in epidemiological studies and provides s suitably protective value (Kay , 2007).

The EU has developed guidelines (Table 4) based on more epidemiological studies such as those performed in Germany in fresh watersides (Kay, 2007). In these studies, it was allowed to follow up children health after bathing, which gave better results and more accurate standards could have been developed. The EU standards classify the water quality in three categories excellent, good and sufficient.

Table (4). Microbiological criteria outlined in the EU bathing water directive (EC, 2006)

In land water				
A	B	C	D	E
Parameter	Excellent quality	Good quality	Sufficient quality	Reference method of analysis
Intestinal enterococci (cfu/100 ml)	200*	400*	330**	ISO 7899-1 or ISO 7899-2
Escherchia coli(cfu/100 ml)	500*	1000*	900*	ISO 7899-1 or ISO 7899-2
For coastal waters				
Intestinal enterococci (cfu/100 ml	100*	200*	185*	ISO 7899-1 or ISO 7899-2
Escherchia coli(cfu/100 ml)	250*	500*	500**	ISO 7899-1 or ISO 7899-2

Explanation for table (4)

- * Based on * 95th percentile
- ** based on 90th percentile

2.2 Green roofs

Green roofs are roofs covered with soil and vegetation. In the past, the main purpose behind the green roofs was the benefit of insulation. Sod used in green roofs was easily available and cheap. During the industrial revolution in 19th century, the cities became denser and people moved from rural areas to cities. Invention of new and cheap building materials including isolation materials lead to gradual disappearance of green roofs. In recent decades, as the trend of sustainability increases the green areas including green roofs become recognized as essential for the quality of life and the ecosystem.

The main purpose for establishing green roofs in Sweden is probably the aesthetics. However, recently green roofs are recognized as playing an important role in the management of storm water (Bengtsson et al., 2004). Vegetated roofs become more and more used as storm water BMPs often in combination with open storm water system. Many cities, for example New York, Berlin, and Toronto started to increase the area of green roofs seeking for better city environment. Modern green roof systems were first applied in Switzerland in 1960, then in Germany in the 1970s (Bernstad, 2009).

The main construction materials of green roof are waterproof membrane, growing medium (soil) and plants. There are different ways of constructing green roofs. For example, they can be prefabricated or constructed on site. The method of construction depends upon the purpose of green roofs. Figure (1) shows a simple green roof cross section with construction materials. The green roofs have many advantages, for example, they may:

- Green roofs improve the environmental image of companies owning the buildings;
- Green roofs block solar radiation and enhance the thermal protections of the buildings;
- Green roofs improve the climate by reducing the heat island effect;
- Green roofs can be prime habitats for many plants and animals (including the protected species) and thus contribute to enhancing biodiversity;
- Green roofs reduce noise pollution;
- Green roofs slow down and reduce the runoff volume;
- Green roofs reduce the urban flooding in the combined sewer, as the soil and the vegetation in the green roof can store water;
- Green roofs contribute to mitigating air pollution as well as improving storm water runoff quality.

The risks linked with the establishment of green roofs include:

- Green roofs can be source of pollutants that are released from soil, plants and fertilizers.
- Green roofs may require regular maintenance; the construction costs may be high.

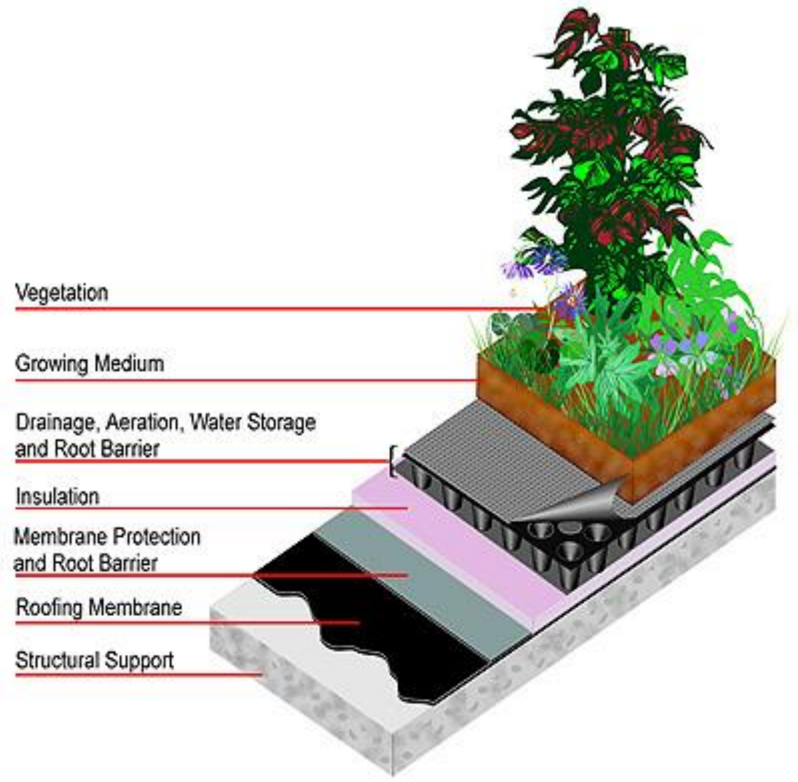


Figure1. Construction layers of a green roof (American Wick Drain Corp).

3. Study site at Augustenborg, Malmö, Sweden

Augustenborg is an inner city suburb in Malmö, Sweden. Malmö is the third largest city in Sweden in term of population. The climate is temperate with occasional snow during the winter. The average precipitation is about 600 mm per year. An open storm water system is applied in Augustenborg since late 1990s and the storm runoff is disconnected from combined sewer system (Villarreal et al., 2004). The Augustenborg housing area was built in 1950. Since late 1970, this area was experiencing problems with flooding basements during heavy rain events. At the same time, the surroundings worn down and the apartments became old, out of fashion, and people began to move away from the area. In order to solve problems with flooding and give the area lift up Malmö municipality decided to renovate the area and among others to build a new open drainage system using a number of storm water BMPs. The main purpose of the new system was to reduce the peak flow from the storm water and make the area more attractive by creating recreational sites. In the new system, the storm water is kept on the surface in the city environment. Storm water runoff from the green roofs as well as from the hard roofs and other impermeable surfaces is collected through gutters into system of channels, vegetated ditches and ponds. In a case the capacity of the system would be exceeded the excess water will be discharged to conventional sewer.

3.1. Drainge system in Augustenborg

The new open system consists of ponds, infiltration surfaces, canals, and green roofs combined to function as one unit. The drainage system in Augustenborg was designed to drain an area of 48 664 m^2 divided into four sub areas. Area A (28 092 m^2) consist of a school and a parkland. The area A represents the final part of BMPs in Augustenborg. The water flows from the parkland and asphalt towards the grass swale, which divides parkland and transports the water to the combined sewer inlet. Two different BMPs are applied in area A: infiltration surfaces and swale. In early 2000s, green roofs have also been installed on the school roofs. Area B consists of apartments and buildings separated by paved yards while area C consist of council property offices and buildings. The storm water flows from upstream to downstream (from area B to area D) through series of BMPs including wet ponds, gardens, meandered channel, wetland and dry pond. Those two areas (B and C) consist mainly of apartment buildings and parking areas. The storm water enters the main channel in area C and from there water flows to the large pond in area B. Area B has two parts: one part is drained directly to the main pond while the other part drains first to the main channel before it enters the main pond (Villarreal et al., 2004). The large pond in the area B has been reconstructed and replaced with two smaller ponds linked with a dry pond. That was done due to the fact that the original capacity of the big pond was overestimated: the pond was empty or half empty most of the time and created aesthetically unpleasant site.

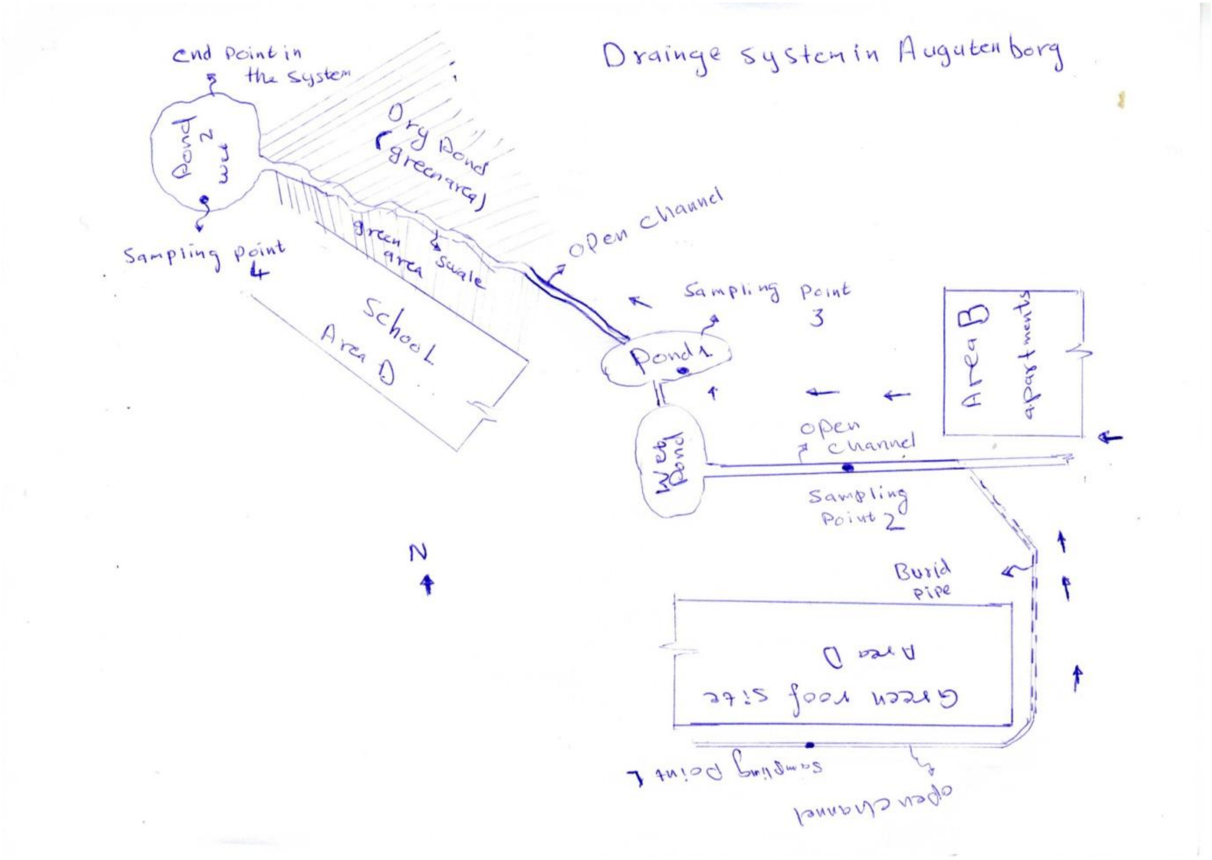


Figure (2). Drainages system in Augustenborg with sampling points.

3.2 Green roofs in Augustenborg

The green roofs in Augustenborg (Figure. 2) were constructed in 1998-2000 as a part of the Eco-city Augustenborg project. The main objective with green roofs construction was to contribute to mitigating the flooding problem but also to make the area more attractive for residents by enhancing the aesthetic view. Hard roofs have been converted to extensive green roofs with area about 9 500 m^2. Different types of vegetated roofs were used and different establishment methods apply, as the area was also to serve for research and development purposes. Major vegetation groups are grasses, sedum, and mosses. The roof section used in this study for water sampling is 4.0 m long and 1.25 m wide with total area 5.0 m^2. The substrate is 3 cm thick and is a mixture of clay 5 %, crushed lime stone 5 %, crushed ceramic roof tiles 43 %, sand 37 % and 10 % organic matter (Bengtsson et al., 2004).

Picture (1). View on the green roofs in Augustenborg.

3.2.1 Hydrological properties of extensive green roofs at Augustenborg

Bengtsson et al. (2004) performed study on hydrological function of the extensive green roof in Augustenborg. The results show that the green roofs retained a substantial amount of water. The water balance has been measured from mid July 2001 through December 2002; the annual precipitation during the study period was 705 mm while the annual runoff was 378 mm. The evaporation was 327 mm, which means that the green roofs reduced the runoff by 50%. Monthly precipitation, runoff, and evapotranspiration are given in Table 6. The daily runoff was also measured the runoff was always less than the precipitation except for few days when soil in the roof reached the field capacity. In such a situation, runoff was equal or close to precipitation. The study measured also the hourly runoff. The results show that there was no runoff in the first 3 hours of a precipitation event; the runoff starts after the hour 4. The maximum observed rainfall was 11.5 mm in 2002 while the runoff was 11 mm. The study confirmed the ability of the soil on the roofs to store the water and the drier the roof the smaller the runoff; for instance for 13 mm rainfall on a dry roof only 1 mm runoff was generated. Similar study was conducted by Köhler et al. (2001) in Berlin where he measured the runoff from a 360-m2 extensive green roof, which were 12 and 5 cm thick. The soil of the 5 cm thick green roof was able to retain 30 mm and of 12 cm thick green roof retain 40 mm rain respectively. The precipitation occurred in 3 days and was 55 mm. It can be concluded from those studies that the green roof can detain and reduce the runoff; moreover, the runoff in many cases does not occur until the soil reached the field capacity (Bengtsson et al., 2004).

Table (5). Monthly water balance for extensive green roof in Augustenborg and the runoff for small water rural basin for 12 months. (Bengtsson, et al., 2004)

Month	Precipitation (mm)	Runoff (mm)	Evapotranspiration
August-01	89	48	41
September-01	110	76	34
October-01	43	17	26
November-01	50	29	21
December-01	37	25	12
January-02	76	62	14
February-02	69	56	13
March-02	29	13	16
April-02	28	5	23
May-02	52	13	16
June-02	64	8	56
July-02	58	26	32
12 month	705	378	327

3.2.2 Extensive green roofs at Augustenborg influence on runoff water quality

Only few studies investigated the runoff water quality from green roofs. Currently there are no studies investigating micobiological quality of green roof runoff are published in English language. Existing studies on green roof runoff quality show that green roofs can act as a source and a sink for different polutants at different time. Some studies perfromed in Germany showed that green roofs reduce the load of heavy metals and nutrients in urban runoff. This are however often linked to the fact that the runoff volume is reduced in green roof, as in Köhler et al., (2002). The green roofs retantion capability of heavy metals, besides the water retention, depends on the season, roofs’ materials, and roofs’age .

Czemiel Berndtsson, (2005) studied the seasonal changes of runoff water quality from extensive vegetated roofs in Augustenborg. The study investigated heavy metals and nutrients in precipitation water and green roof runoff water. About five samples of runoff and five samples of precipitation water were collected on each sampling campaign; a number of sampling campaigns were performed during different seasons between autumn 2003 and spring 2007. The samples were analyzed for potassium (K), nitrate nitrogen (NO3-N), total nitrogen (Tot-N), phosphate phosphorus (PO4-P), and dissolved organic carbon (DOC). Heavy metals were also studied.

The results of the water quality analyses of green roof runoff water show that the concentrations of PO4-P, Tot-P, K and DOC in runoff water are higher than in precipitation water. In autumn seasons PO4-P, Tot-P, K increase more than in spring seasons. The concentration of NO3-N and Tot-N decrease in runoff comparing with rainwater. The results showed also the influence of the age of the roof. The ability of adsorption of nitrogen is decreasing with the age of the roof, while the releasing of K, Tot-P, PO4-P and total organic carbon is decreasing. It can be concluded that the green roof can be both a sink and a source of pollutants. This depends on many factors but generally, the rainwater has less contaminant than storm water except nitrogen. With regard to heavy metals, the runoff quality from green roofs is considered good (Czemiel Berndtsson, 2005). The microbiological quality of the runoff from green roofs has not previously been studied.

4. Methodology

In order to evaluate the microbiological quality of storm water in Augustenborg open system and to assess the health risk for public in the area an investigation of microbiological water quality has been carried out. Four microbial indicators have been chosen to serve as a tracer for fecal contamination: `E. coli`, total coli forms, `clostridium perfringens`, and intestinal enterococci. All these parameters have been measured in grab storm water runoff samples. The samples have been collected during/after three different precipitation events taking place in 6 May, 26 October and 24 November 2009. The water samples were taken at the following four locations from the Augustenborg storm water systems: green roof (picture 1), pond 1 (picture 2), pond 2 (picture 3), and the ditch, one sample at each location and event. The runoff from the green roof was collected in a plastic barrel of capacity 25 l that was connected by a plastic hose with a green roof section. The plastic barrel has been emptied and cleaned with tap water after each collection event. One grab water sample was taken from the barrel after each of the sampled precipitation events. At other, three sites (two ponds and ditch), the water samples were collected manually in plastic bottles by submerging the bottles under the water surface until the sampling bottle fills up. Sampling bottles (300 ml) were sterile and they were prepared at the laboratory according to the requirements for sampling equipment for collecting water for microbiological analysis. The samples have been taken after storms, which generated enough runoff for the system to allow water sampling. The water samples were delivered to the (VA SYD) water laboratory in Malmö immediately after collection. Concentration of `E. coli`, total coli forms, and intestinal enterococci have been measured by number of each individual parameter per 100 ml water sample (st/100 ml) while the `clostridium perfringens` was measured by a colony forming unit (CFU) in 100 ml water sample. The obtained results from each collection site are compared with recreational water quality standards for EU in order to assess the microbiological water quality.

Picture (2). Pond 2 (sampling point 3**).**

Picture (3). Pond 2 – the end of the Augustenborgs open storm water system (sampling point 4)

Picture (4).Ditch (sampling point 2).

5. Results

The results are presented in Tables 6-9.

Table (6). The concentration of microbial indicators for the green roof site.

parameter	Unit	Date /090506	Date/091026	Date/091124
Total coliform	st/100 ml	5730	1764	5940 l
E. coli	st/100 ml	8	10	10
clostridium perfringens	CFU/100 ml	1	1	7

Intestinal entrococci	st/100 ml	2	3920	3010

Table (7). The concentration of microbial indicators for the pond 1 site.

parameter	unit	Date /090506	Date/091026	Date/091124
Total coli form	st/100 ml	1040	2070	710
E. coli	100st/100 ml	10	10	10
Clostridium perfingens	CFU/100 ml	16	2	2
Intestinal entrococci	st/100 ml	20	450	10

Table (8). The concentration of microbial indicators for the pond 2 site.

parameter	Unit	Date /090506	Date/091026	Date/091124
Total coli form	st/100 ml	241900	3420	610
E. coli	st/100 ml	730	10	36
Clostridium perfingens	CFU/100 ml	140	24	56

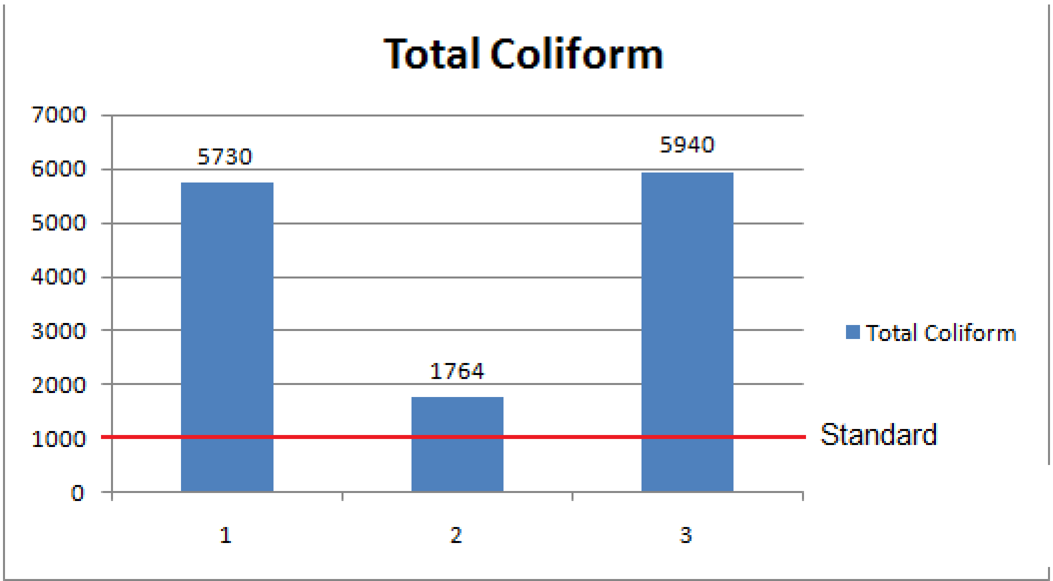
Intestinal entrococci	st/100 ml	2330	540	18

Table (9). The concentration and of microbial indicators for the ditch site.

parameter	unit	Date /090506	Date/091026	Date/091124
Total coli form	st/100 ml	64880	21400	51700
E. coli	st/100 ml	9330	12545	11450
Clostridium perfingens	CFU/100 ml	210	410	270
Intestinal entrococci	st/100 ml	13170	68700	2640

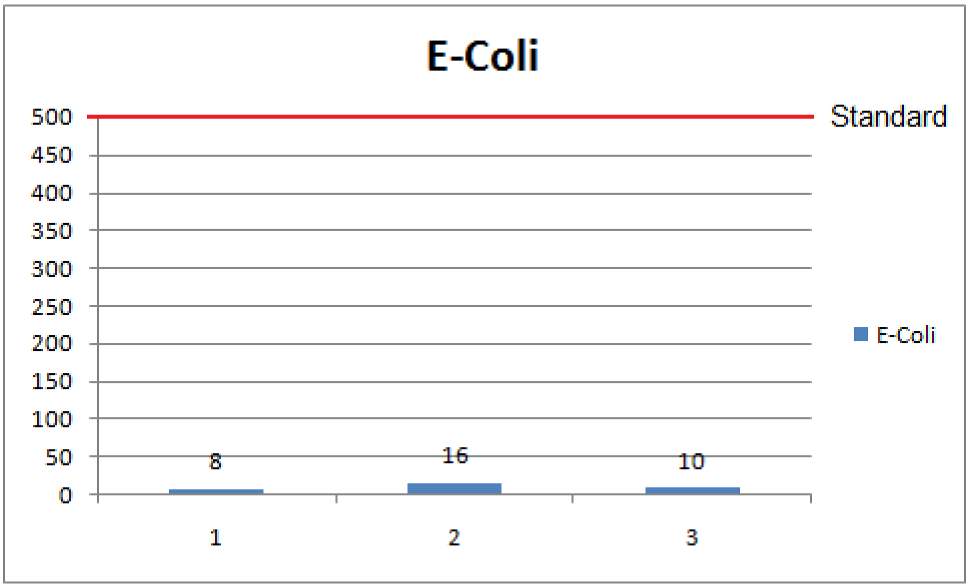
The figures (3) to (13) illustrate the obtained results in comparison with the standards value as according to microbiological criteria outlined in the EU bathing water directive (EC, 2006) for each microorganism indicators. The red horizontal lines represent the obligatory value.

Figure (3). The total coli form bacteria in the green roofs site. The histograms represent the concentration of total coli from in (st/100 ml) each sample while the red horizontal line is the standard value (1000/100 ml).



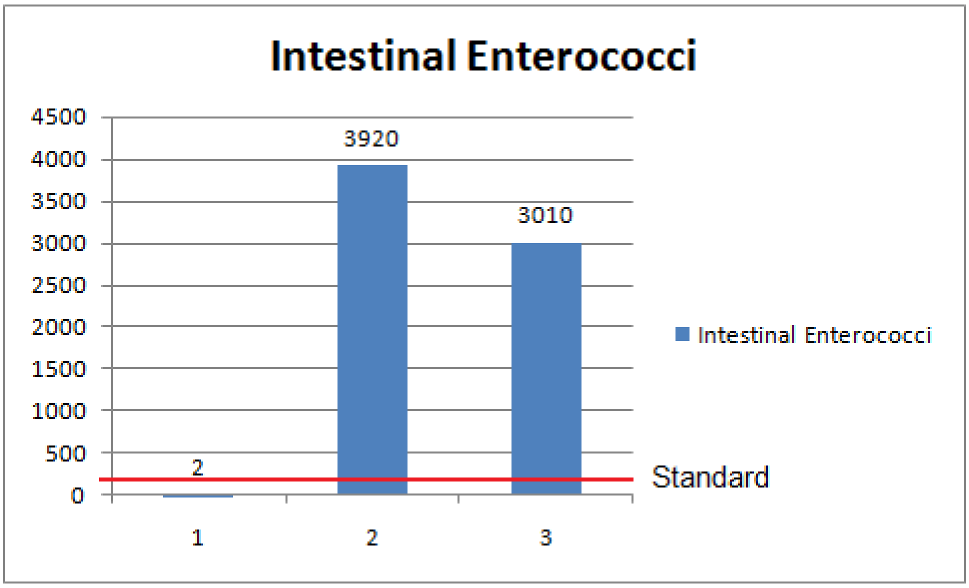
In figure (3), horizontal concentration of total coli form in all the samples exceeded the standard value for total coli form. Vertical samples collected in May, October and November.

Figure (4). The E. coli bacteria in the green roofs site. The histograms represent the concentration of E. coli in each sample while the red horizontal line is the standard value (500/100 ml) for EU countries.



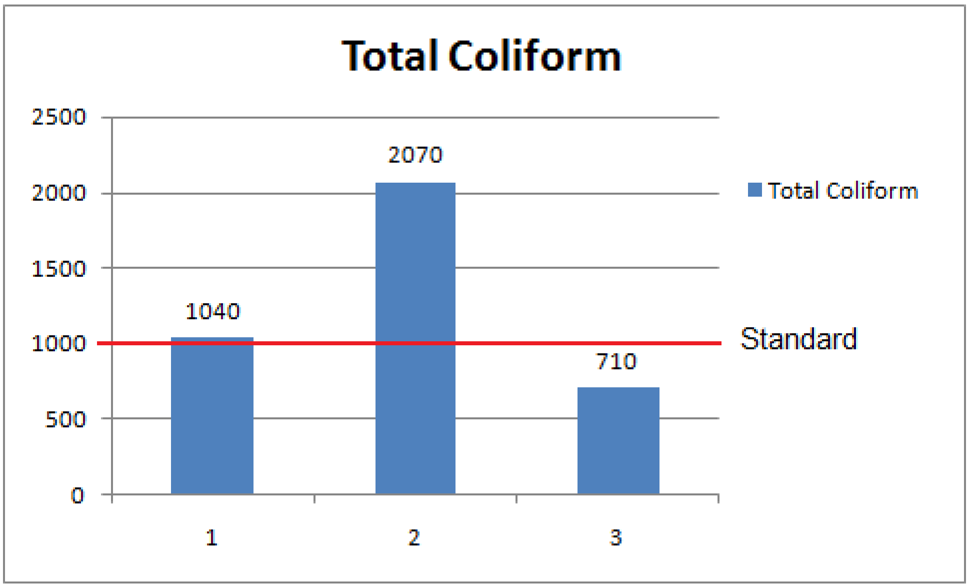
The measured E. coli concentrations in samples taken from green roofs were all below the standard value.

Figure (5). The intestinal Enterococci in the green roofs site. The histograms represent the concentration of intestinal Enterococci in each sample while the red horizontal line the standard value (200/100 ml) for EU countries.



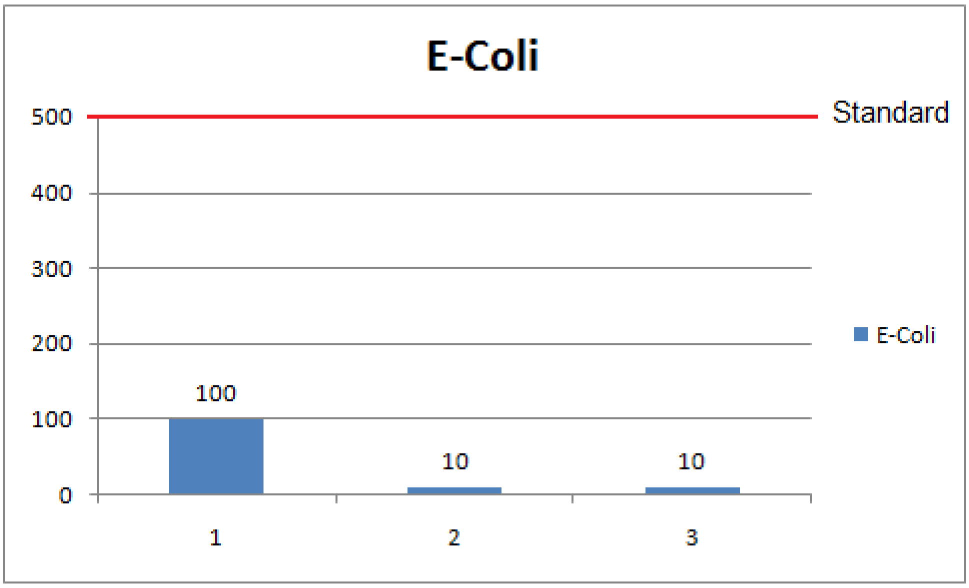
In figure (5) above two of three samples exceeded the standard value.

Figure (6). The total coli form bacteria in the pond 1 site. The histograms represent the concentration of total coli form in each sample while the red horizontal line is the standard value (1000/100 ml) for bathing water quality in EU countries.



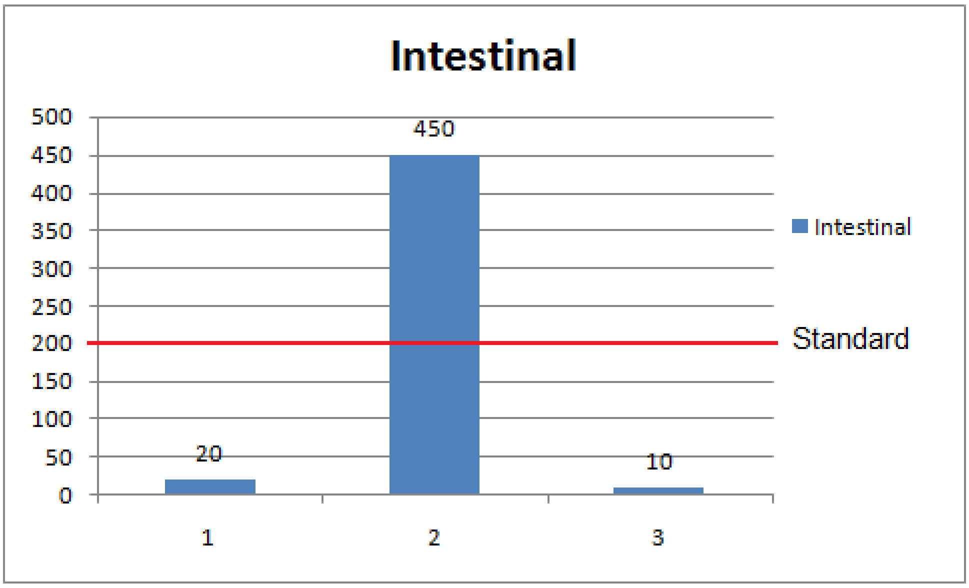
In figure (6) two samples exceeded the standard value.

Figure (7). The `E. coli` bacteria in the pond 1 site. The histograms represent the concentration of total coli form in each sample while the red horizontal line is the standard value (500/100 ml) for bathing water quality in EU countries.



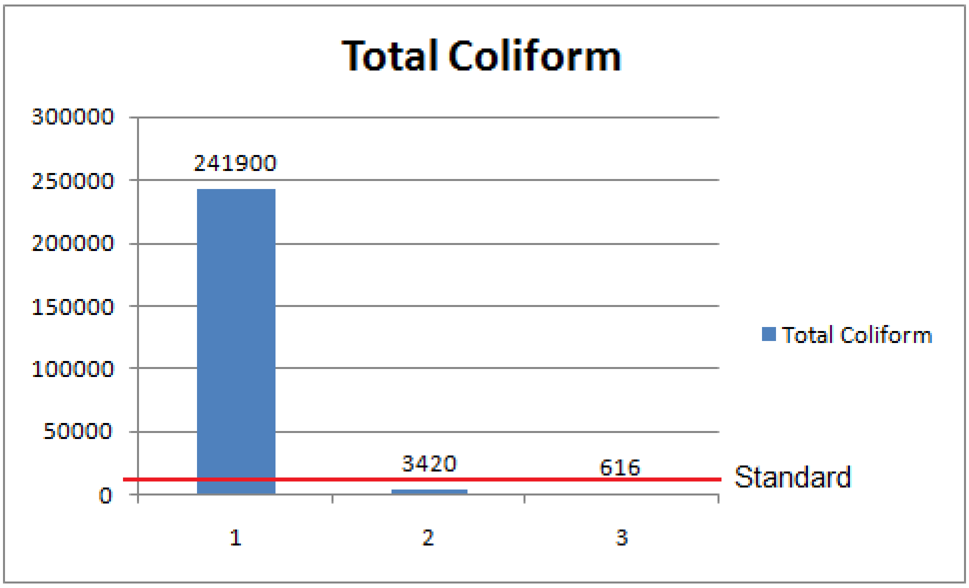
In figure (7) above non of the three samples exceeded the standard value.

Figure (8). The Intestinal Enterococci in the pond 1-site. The histograms represent the concentration of Intestinal Enterococci in each sample while the red horizontal line is the standard value 200/100 ml for bathing water quality in EU countries.



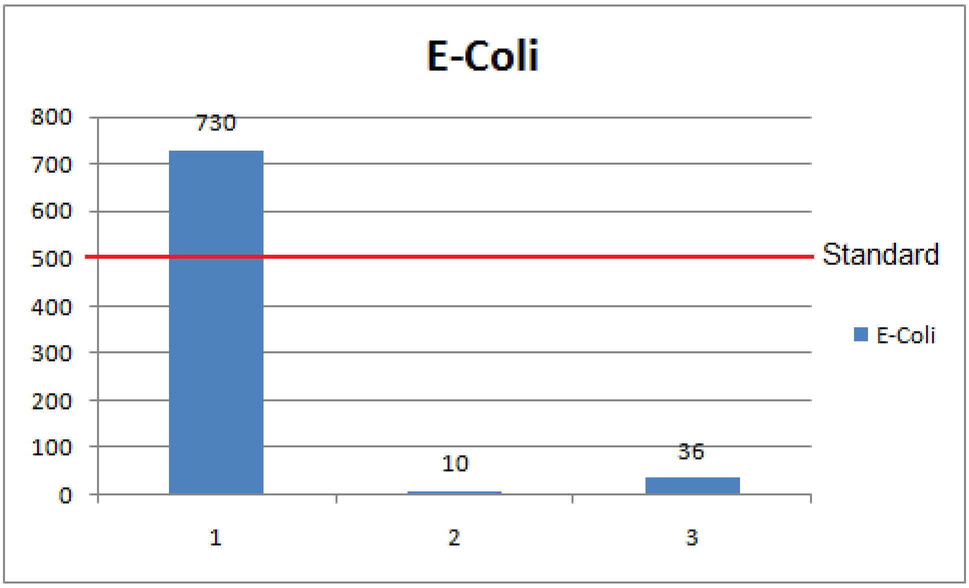
In figure (8), one sample taken on 26 October exceeded the standard value.

Figure (9). The total coli form bacteria in the green pond 2. The histograms represent the concentration of total coli form in each sample while the red horizontal line the standard value 1000/100 ml for bathing water quality in EU countries.



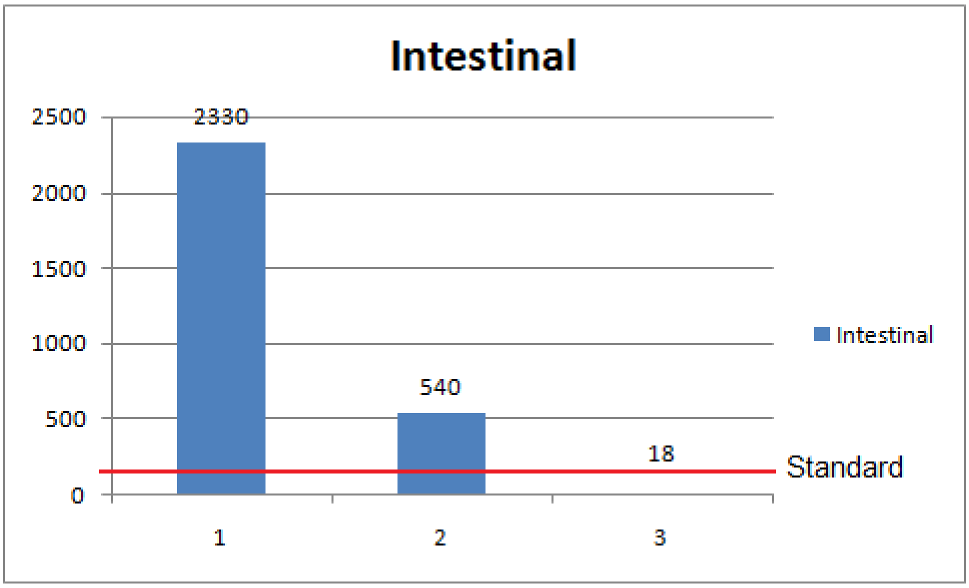
In figure (9) two samples were taken on 6 May and 26 October exceeded the standard value. The sample, which took on 6 May, is very high comparing with other two samples, the second sample (3420 st100 ml) also exceeded the standard.

Figure (10). The `E. coli` bacteria in the pond 2 site. The histograms represent the concentration of `E. coli` in each sample while the red horizontal line is the standard value 500/100 ml for bathing water quality in EU countries.



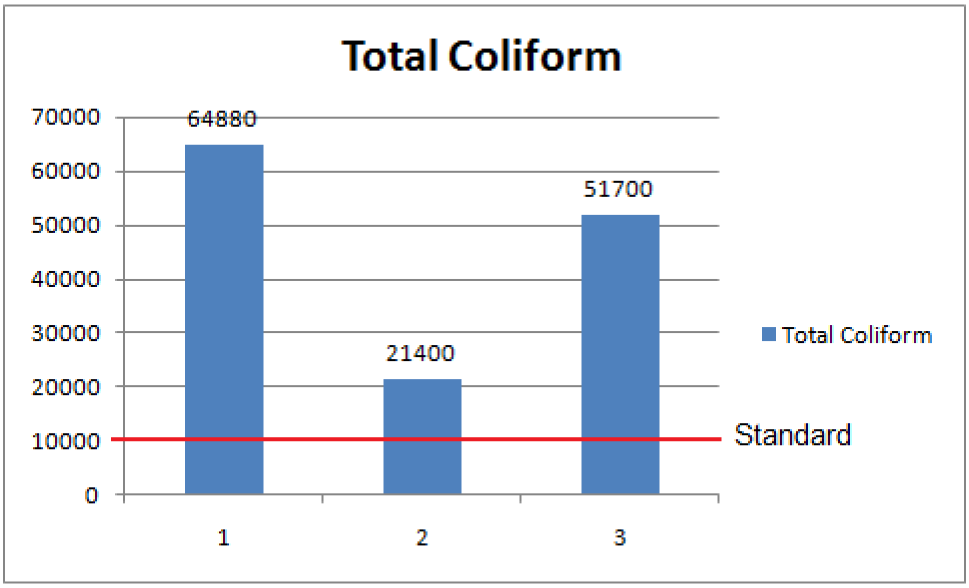
In figure (10) above only one sapmle took on 6 May from three exceeded the standard value .

Figure (11). The Intestinal enterococci bacteria in the pond 2 site. The histograms represent the concentration of Intestinal enterococci in each sample while the red horizontal line the standard value 200/100 ml for bathing water quality in EU countries.



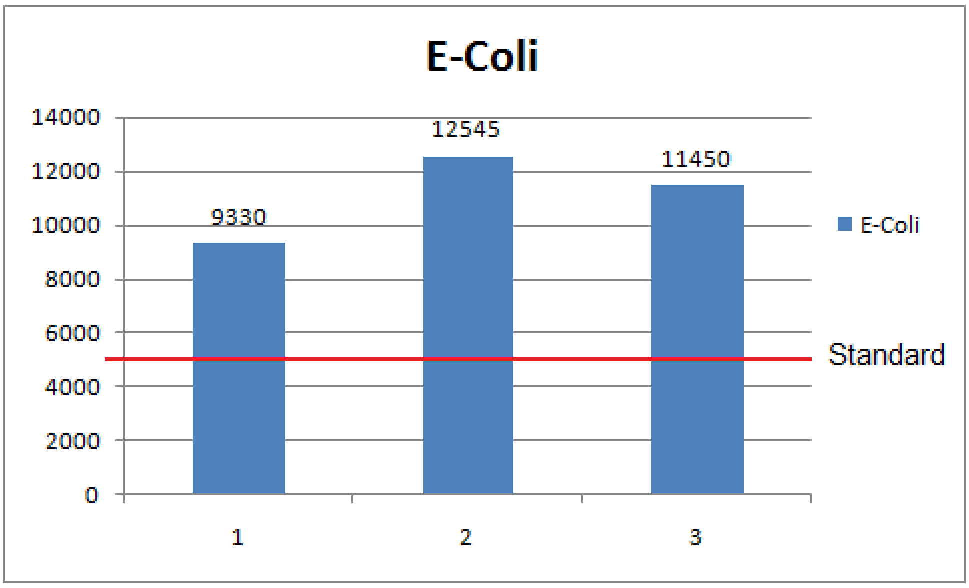
In figure (11) two samples exceeded the standard value .

Figure (12). The total coli from bacteria in the ditch site. The histograms represent the concentration of total coli from in each sample while the red horizontal line the standard value 1000/100 ml for bathing water quality in EU countries.



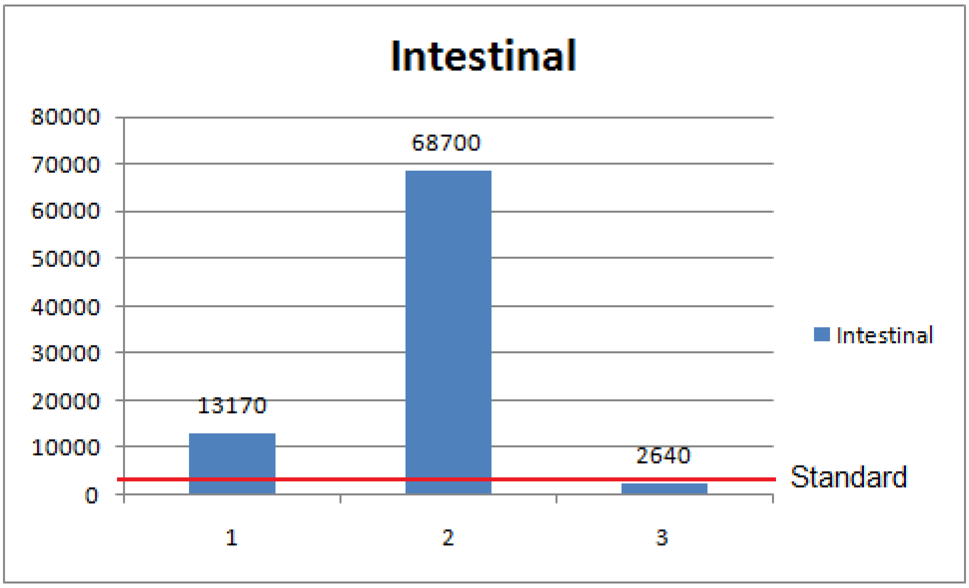
In figure (12) all the samples exceeded the standard value .

Figure (13). The `E. coli` bacteria in the ditch site. The histograms represent the concentration of `E. coli` in each sample while the red horizontal line the standard value 500/100 ml for bathing water quality in EU countries.



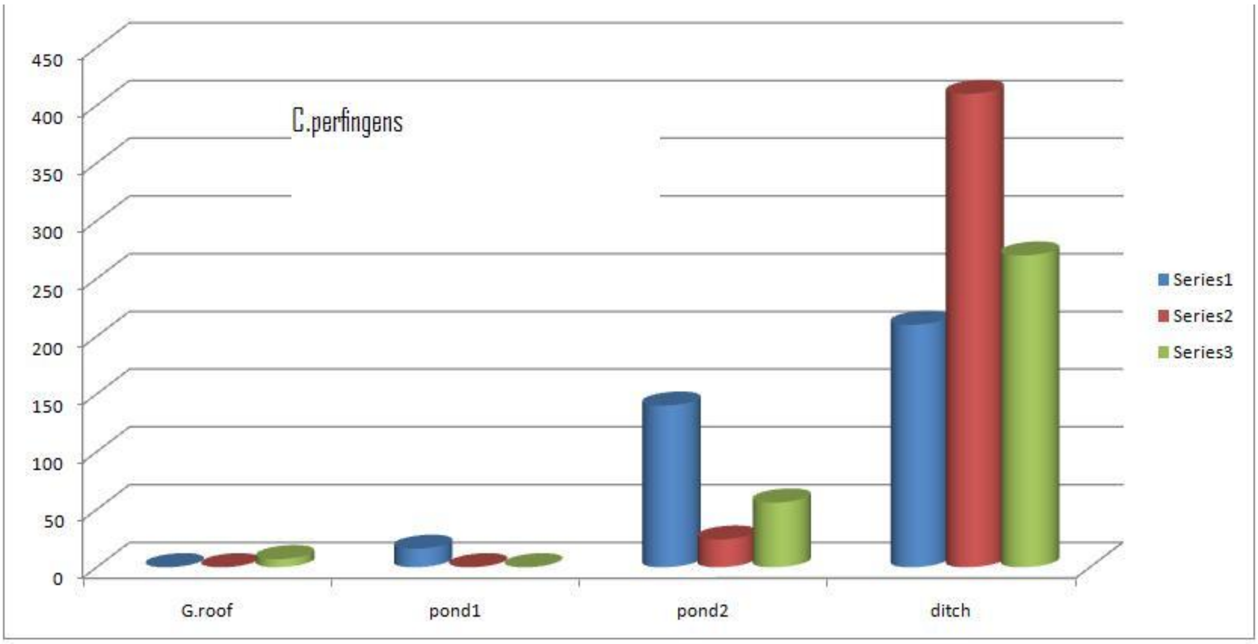
In figure (13) all the three samples exceeded the obligatory value.

Figure (14). The intestinal enterococci bacteria in the ditch site. The histograms represent the concentration of intestinal enterococci in each sample while the red horizontal line is the standard value 200/100 ml for bathing water quality in EU countries.



In figure (14) all the samples exceeded the standard value.

Figure (15) shows the clostridium perfringens indicator in all sampling sites.



In figure (15) the results for clostridium perfringens indicators in the four sampling points are shown. Vertical axis shows concentration of clostridium perfringens in (CFU/100 ml). Horizontal axis shows the four sampling points. The clostridium perfringens concentration increased as the storm water flows from upstream to down stream except the sample from the ditch site which has the highest concentrations of studied indicator among all the other sampling sites. The increase of clostridium perfringens concentration from upstream to downstream is due to the increased storm water pollution during surface runoff. The bacteria can easily be washed off from hard surfaces to the storm water. Dog feces may be the major source of clostridium perfringens in the ditch. Some studies linked the abundance of clostridium perfringens in storm water with the presence of dogs waste. The dog feces contain abundance of clostridium perfringens spores, which are thermo tolerant (Leeming et el., 19989 There is no standard for clostridium perfringens for recreational water. The recommended standard for drinking water is that the water should be free from clostridium perfringens (WHO, 2003). The concentration of clostridium perfringens in the ditch and pond 2 are higher than in other two sampling points.

Figure (16). The monthly precipitation in Augustenborg 2009

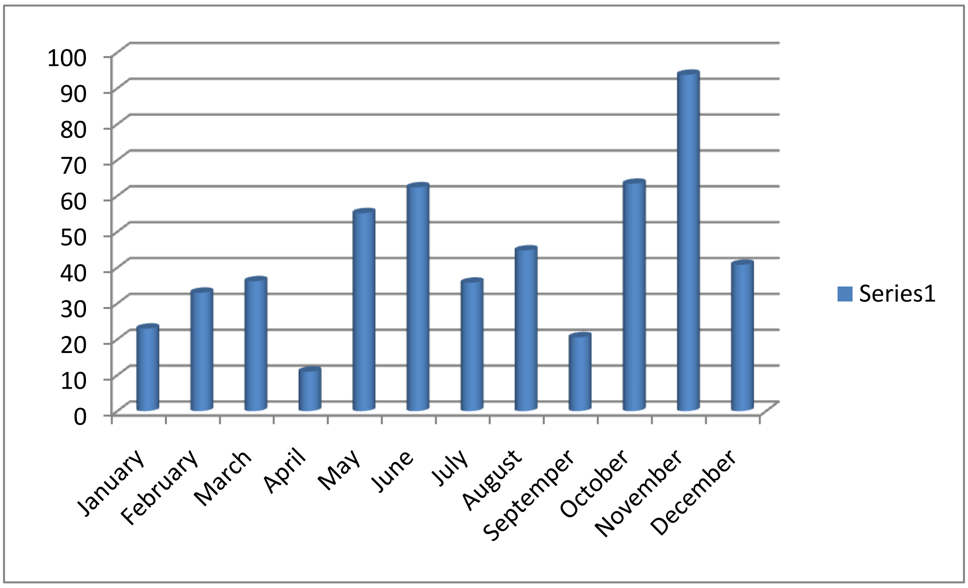
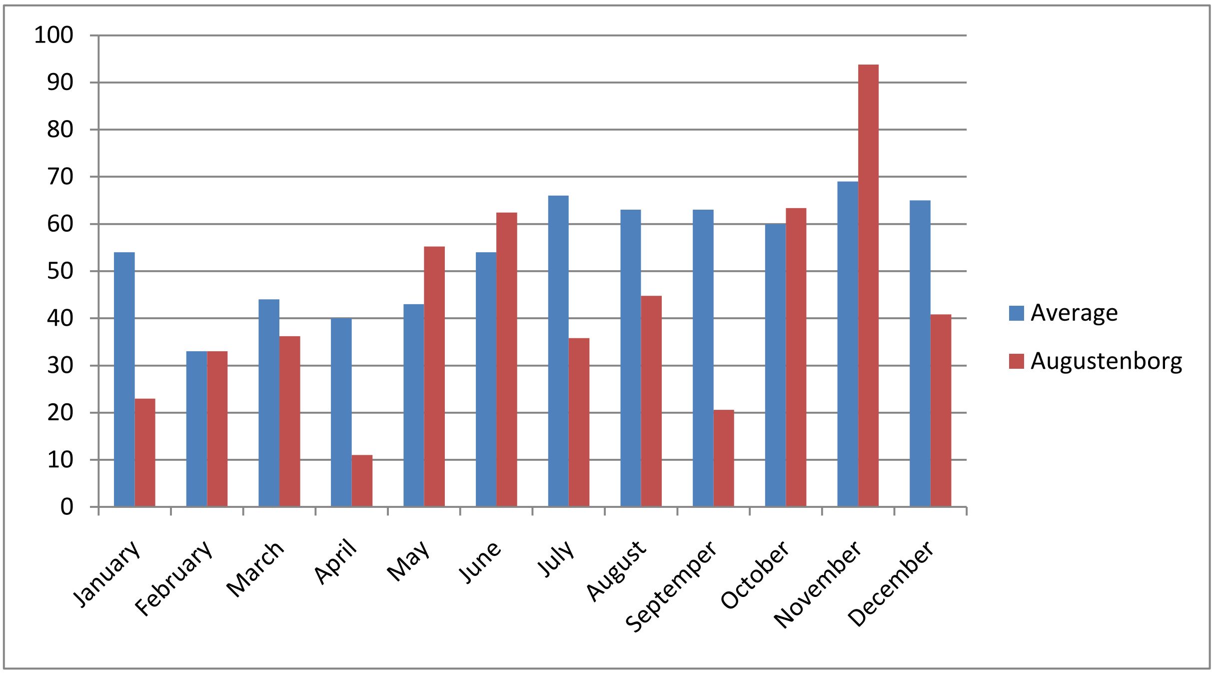


Figure (17). Illustrates the monthly precipitation in (mm) in Augustenborg comparing with the average precipitation in Lund between years 1960-1990 (SCB, 2010).



In figure (16), the monthly precipitation in Augustenborg 2009 is presented. Figure (17) shows the average monthly precipitation in Lund 1960-1990 comparing with the monthly precipitation in Augustenborg 2009 .The average precipitation was about 655mm in Lund while it was about 520mm in Augustenborg 2009. In the sampling months the precipitation in Augustenborg was 55.2 in May, 63.2 in October and 93.8 in November while the average precipitation in Lund 1960-1990 was 43 mm in May , 60 mm in October and 69 mm in November. The average precipitation in sampling months is higher than the average in Lund 1960-1990. The higher precipitation could increase concentration of bacteria in the runoff. Since the rain depth is higher which, leads to wash out more bacteria from surfaces consequencely more bacteria will exist in the runoff.

Figure (18). Rainfall depth in Augustenborg from 22 April 2009 to 6 may 2009 prior to the first sampling day (06-05-2009).

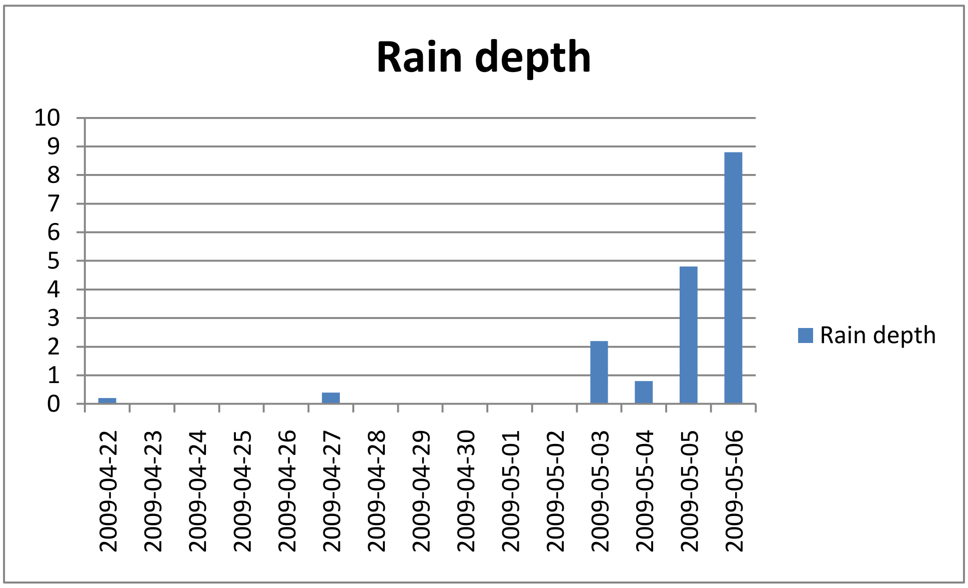


Figure (18) shows that the precipitation during sampling day was 8.8 mm which is highest during two weeks. The procceding days before sampling were almost dry.

Figure (19) shows the rain fall before two weeks from sampling day 26-10-2009, horizontal axis is the rain fall depth in (mm), the vertical axis is a corresponding day.

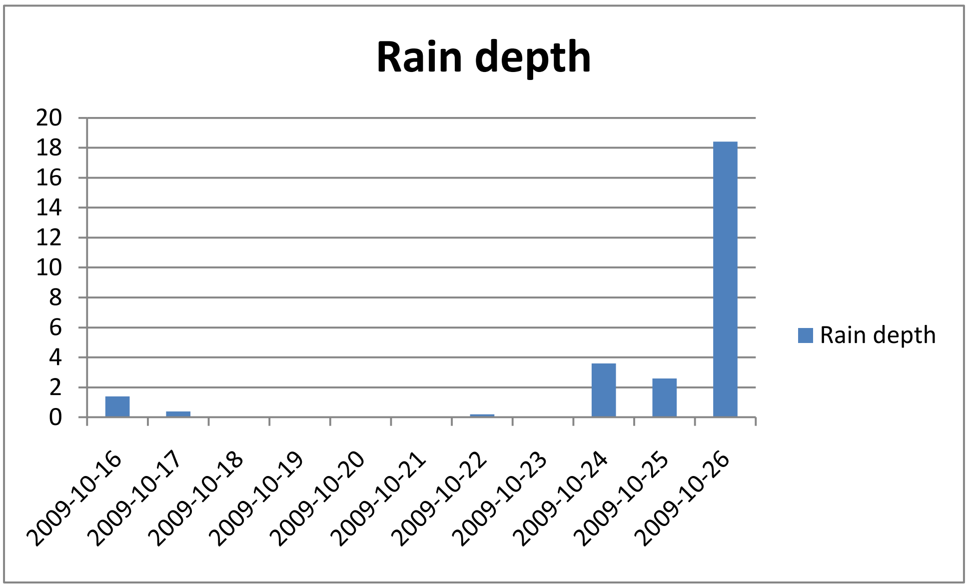


Figure (19) shows that the precipitation during the sampling day was 18.4 mm. The high precipitation during sampling day came after some minor rainfall events during two days preceding the sampling.

Figure (20) shows the rainfall depth prior to the the third sampling day 24-11-2009. Horizontal axis is rain depth in (mm) while the vertical axis is the coresponding day.

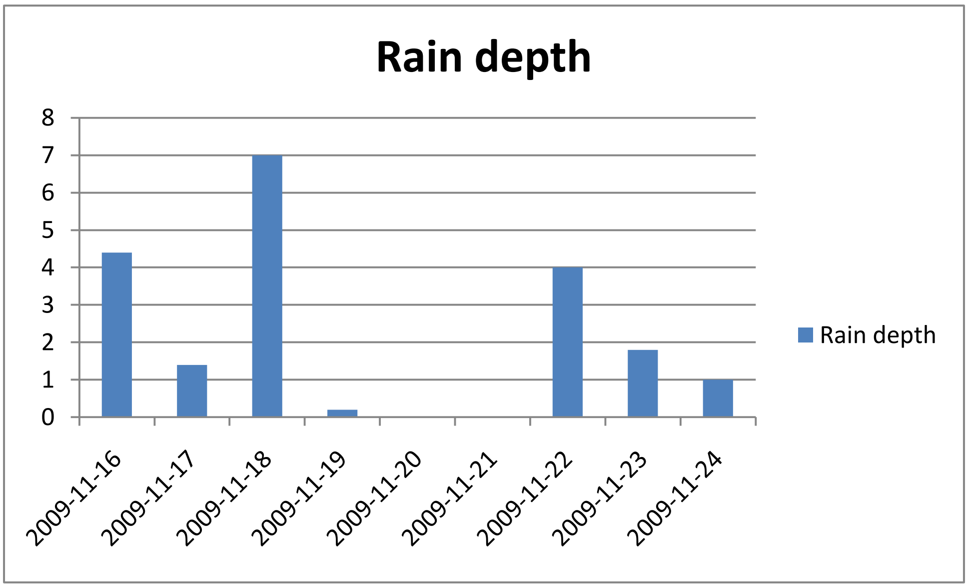


Figure (20) shows that the precipitation during sampling day was only 1mm, but the precipitation occurred during preceding days. The storm water system was in wet condition.

Figure (21). The houry precipitation in first sampling to sampling hour. Samples ware taken at 11oclock 05-06-2009.

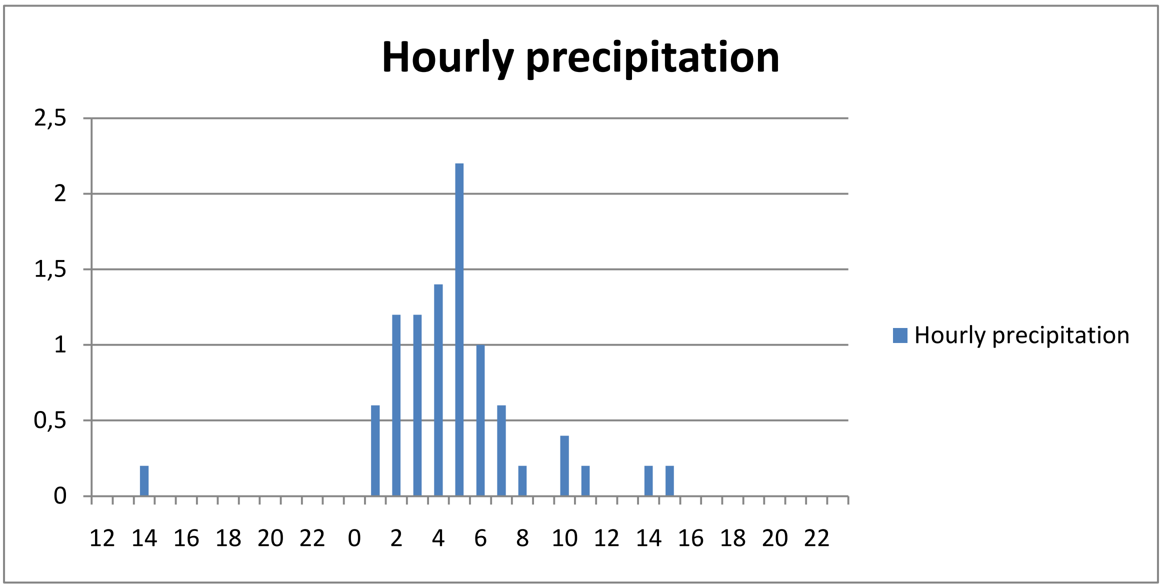
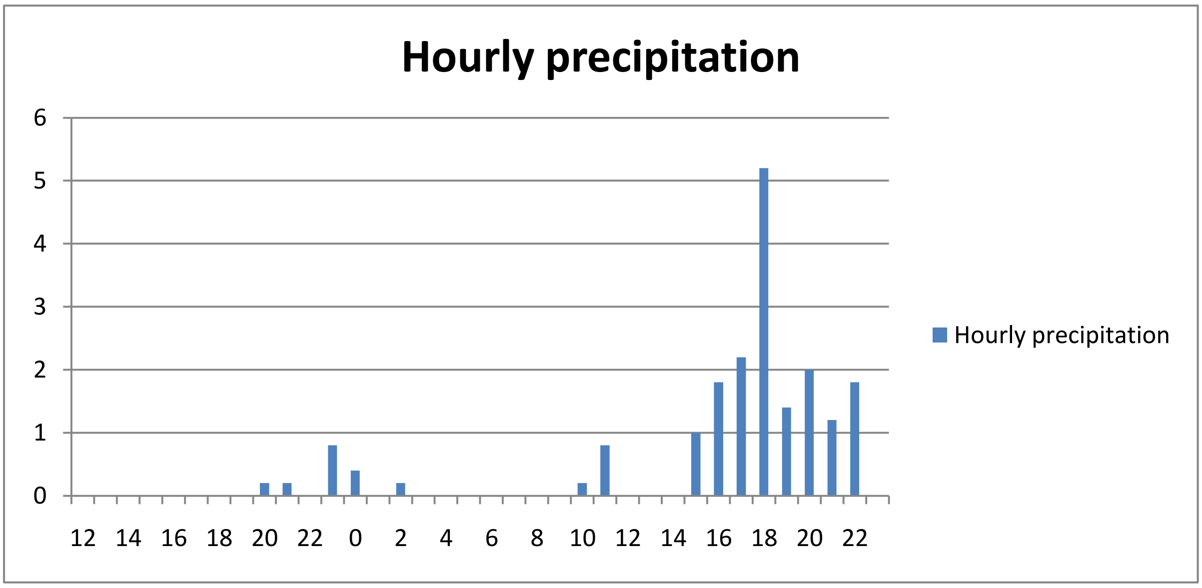


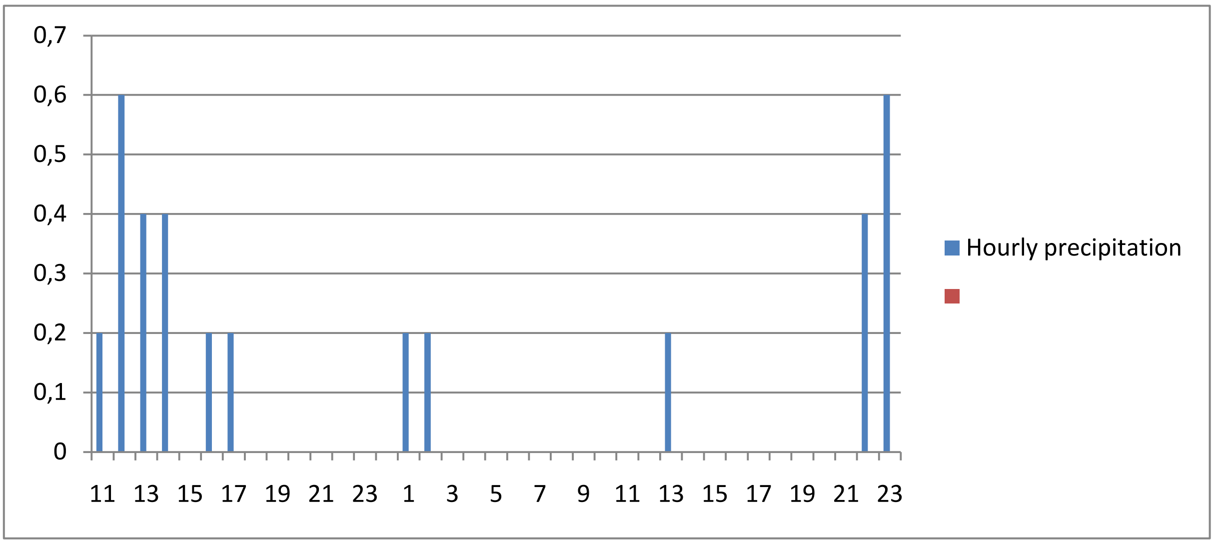
Figure (21) shows that the precipitation on sampling hour was less than 0.5 mm, but the precipitation in the previous hours generated enough water in the sytem for sampling.

Figure (22). The hourly precipitation during the second sampling ocassion. Samples weretaken at 12 oclock 26-10-2009.



In figure (22) the the preciptation in sampling hour was less than 1 mm.

Figure (23). The hourly precipitation before and after sampling hour on the third sampling ocassion. Samples weretaken at 8 oclock on 24-11-2009.



In figure (23) it can be seen that the preceding precipitation before the sampling hour generated enough runoff ton the open system to collect samples.

The results obtained for the green roof site (figure 2) regarding content of total coli form bacteria indicate the contamination exceeding 1000 st/ml which is the EU recommendation for acceptable bathing water quality. Source of these bacteria can be soil but most likely birds waste as birds are nesting on the green roofs. The water samples which have been taken during May and November show higher total coli from concentration than the sample, which was taken in October. The reason can be because of May`s samples were taken after proceeding long dry period (Figure 18). The long dry period may have resulted in accumulation of deposition materials on the green roofs and consequently more bacteria present in the runoff from the roofs. Figure (16) shows, that April was the driest month during 2009 while figure (18) illustrates the rainfall depth before sampling day (6 May). Figure (16) shows the `E. coli` bacteria in the green roofs site. All the three samples have low concentration of `E. coli` bacteria. The results of tested samples were all below the standard value (500 st per 100 ml) for `E. coli` bacteria. Figure (17) shows the results for intestinal enterococci in the green roof site, two samples have very high concentration comparing with the standard value for EU that is (200 st/100 ml) and even comparing with the first sample collected in May. Those two samples have a concentration of (3010 &2310) st/100ml intestinal enterococci and were collected during October & November. The two samples exceeded the standard value (200/100 ml) while the third sample was below it. Two possible explanations of the high concentration of intestinal enterococci in the green roof runoff water samples can be the length of the dry period between rain events and the bird waste. In general, the green roofs results have less bacteria concentration comparing with other collection points except for intestinal `enterococci` bacteria, which is higher in the green roof than in the two ponds. The green roofs represent the upstream of the drainage system in Augustenborg (first sampling location) so, the source of bacteria is only from soils in the green roofs and from birds. The samples from green roofs were taken before the water contacts the ground, which means that, the potentials for water to be polluted, is very low comparing with the other sampling points where the water is exposed to the surface. Most of results from green roofs had less bacteria concentration comparing with the other locations.

The results obtained from main channel (ditch) showed the highest microbiological contamination. The ditch represents the second collection location in the drainage system from upstream to downstream (figure 2). Figures (11), (12) and (13) show each microbial indicator for the ditch site comparing with the standard value. All the samples from the ditch exceeded the standard values. The samples exceeded the standard value with an order of magnitude. The contamination of water in the ditch was the highest among the other sites. The main reason of getting very high bacteria concentration in the main channel is that the main channel is exposed to direct runoff from the hard surface. Storm water runoff is washing dirt from the streets and pavements to the channel and as a result, the water in the channel can be highly contaminated by microorganisms. The water quality results for samples taken in the channel (also called ditch) show very high contamination and the need for further investigations.

The results obtained for pond 1 water show that water quality in the pond can be considered as good except for total coli from bacteria since, the obtained results for `E. coli` were all bellow standards (500/100 ml) and only sample of intestinal enterococci above standard (200/100 ml). The exceedance of the standard value was less than an order of magnitude. Only one sample, which was collected on 24 October, exceeded the standard value (200/100 ml) for intestinal enterococci bacteria in pond 1 figure (8). The others two samples have low concentration of intestinal enterococci bacteria below (200/100 ml). The bacteria indicators showed better results in pond1 comparing with pond 2, see figures (6), (7), (8,) 9, (10) and 11. The reasons behind the fact that the water quality in pond 1 is better than on other sampling sites is that Pond 1 occasionally receives drinking water from mains supply. This water is added to the pond when the system turns dry in order to keep wet conditions in the pond, also for aesthetical reasons. In addition, the water in the pond is circulated through a channel using a pump. During the circulation water, gets aerated which has a positive effect on water quality. The results obtained for pond 2 (end in the open system) show higher bacteria concentrations comparing with pond 1 and green roofs and less concentration comparing with open channel, see figure (3) to (14). The samples, which have been collected on 6 May, show extremely high bacteria concentration for all four microbial indicators. `E. coli`, total coli forms, and intestinal enterococci in this sample have much exceeded the standard value. Two samples of total coli from bacteria in pond 2 have exceeded the standard value while the third sample was below it (figure 9). Two samples of `E. coli` and one sample of intestinal enterococci have exceeded the standard value (see figure 10 and 11). The long dry period before sampling on 6 May can be the reason of having high bacteria concentration in pond 2. It could have been expected that pond 2 would show the worst water quality in the whole system since it is located in the end of the system and exposed to different sources of pollution from the entire catchment. However, addition of drinking water from mains supply to the system as well as some degree of water treatment that may take place in the open storm water system may contribute to improved water quality.

The results of microbial indicators show fluctuation with rainfall events and intensity. The bacteria concentration in most of the samples collected on 6 May can be considered high comparing with other two sampling occasions. This high concentration can be linked with long dry period in April and first four days in May. Some studies linked the increase of microbiological load of storm water with the increase of dry periods between rain events. Figure (17) shows that April was the driest month in 2009. Figure (18) shows that the first four days in May were almost dry. The first flush phenomena can be the reason behind fluctuation of bacteria concentration during the three sampling occasions. Establishing a link between rainfall and bacteria concentration in the open storm water system needs further investigation.

6 .Discussion

Little attention has been paid so far to the microbiological quality of storm water, particularly in open storm water systems although the runoff from storm water may contain diverse microorganisms and can be harmful for humans. Kurz (1998) showed that little information was available about effectiveness of the current storm water treatment systems in the removal of microbial pathogens. The lack of information can be explained by the fact that most of research conducted in storm water field was focuses on physical and chemical contaminants such as suspended solids and nutrients rather than microbial contaminants. However, the microbial contaminants always represent potential immediate health risk (Kurz, 1998). Some studies have determined that a large proportion of microbial contaminants originate from non-point sources such as storm water. One study performed by U.S.EPA in 1984 found that about 90% of fecal coli form pollution to surface water originated from storm water (Kurz, 1998). In Tampa Bay in Florida, it was found that about 45% of the tributaries that receive storm water runoff from surrounding areas do not meet the standards for water quality for shellfish harvesting and recreational exposure in United States. Kurz (1998) estimated that total and fecal coli form were often exceeding (10000cfu/100ml) in Tampa Bay, Florida. In our study, only the ditch sampling point exceeded this value. The result obtained from the ditch in our study of total coli from bacteria were in the four order of magnitude (10^4st/100ml), while the concentration of total coli from for the other sampling points was all below (10000cfu/100m) except one sample from pond 2 which was (241900) collected on 6 May. The American standards for recreational water that has been established in 1968 restrict the maximum concentration of fecal and total coli form should not exceed 200 colony-forming units per 100 ml, which is similar to EU mandatory value table (2). All the investigated water samples within Augustenborg have exceeded this coli from limiting value. Some studies estimate that the fecal pollution is two to five times more in storm water than in the secondarily treated wastewater (Kurz, 1998). Characklis et al. (2005) conducted a study on microbial partitioning in the water column of storm water runoff. The aim of the study was to estimate the fraction of organisms that can associate with settable particles in storm water. It was done by using centrifugation process. The study was conducted in Chapil Hill North Carolina, USA. Grab samples were collected in three different locations: Eno River (ER) classified as a law density residential land use, Meetings of the Waters Creek (MWC) classified as institutional land use and Booker Creek classified as a combination of commercial and residential area. The water samples were collected in both dry and wet conditions during storm events. The results of the raw water samples (wet condition) in the three locations as found by Characklis et al. (2005) are presented in Table (10) and compared with three locations in our study pond 1, pond 2 and ditch. Table (10) average microbial concentration in storm water in dry and wet condition as found by Characklis et al. (2005) and results from our study for ponds 1 and 2 and the ditch (average).

location	Fecal coli form(CFU/100	E.coli (CFU/100 ml	Enterococci

	ml)		(CFU/100 ml)
Eno river (dry condition)	893	63	45
Eno river (wet condition)	9790	2112	2601
BC (dry condition)	1233	523	134
BC (wet condition)	39982	7937	5575
MWC (dry condition)	4504	208	106
MWC (wet condition)	72285	24376	14390
Ditch (Augustenborg)	45993	1110	28170
Pond 1 (Augustenbrog)	1115	40	160
Pond 2 (Augustenborg)	81976	258	962

The values for Eno river, MWC and BC is the mean value of water samples collected.

The results from Chapil Hill study can be compared with our study since they concern the microbiological quality of storm water runoff, however, there are different climate conditions on both study sites. The results from Chapil Hill study show the influence of storm event on the bacteria concentration. If we compare results of bacteria indicators after and before storm event (wet and dry weather), we find that, the storm event causes considerable loads of bacteria into water recipients. The analyzed samples in Chapil Hill during the wet weather condition have higher bacteria concentration than the one during the dry weather condition. The results from dry weather condition are much closer to guidelines value for bathing water quality while the results obtained after storm events have high bacteria concentration comparing with the guidelines. The results from wet weather condition are similar order to those obtained from the ditch sampling point in our study. On the other hand, the results from pond 1 and pond 2 are in the same order as the results for dry weather in the Chapil Hill study. For example the first location in the Chapil Hill study (Eno river) had (839/100ml) total coli from in the dry weather condition and (9790/100ml) in the wet weather condition while the results from pond 1 and pond 2 vary from 710 to 34200 (table 10). The wet weather samples show one-order higher concentrations than the samples taken in dry weather conditions. The storm water quality in Augustenborg is of similar quality comparing with storm water from Chapil Hill study.

In table (11) the microbial quality of water collected from roofs as report by different studies in different parts of the world and summarized by Meera et al. (2006) is shown.

no	Location	samples collected from	No of samples tested	Parameter tested	Salient findings	References
1	Rural areas of Auckland New Zealand	Water faucet	125	HPC ,TC,FC ,ENT ,sammonella ,areomonas, Crytospridduim	56% samples exceeded microbiological criteria for drinking water ,Aeromnas found in 16%samples , salmonella in one samples	Simmons et el 2001
2	Port Harcourt Nigeria	Rain tanks	100	HPC ,pseudomonas, salmonella,shigella,vibro	High Hpc. Pseudomonas present in all except Zink roofs,high number of pathogenic bacteria like salmonella present	Upa & Aghogho (2000)
3	Rural area of south of Australia	Rain tanks	100	HPC, TTC, FC,TC ,E.coli	59% contaminated with TTC 84% contaminated with FS ,high HPC	Plaznka (2001)
4	Palestine	Roof catchments		TC. FC	All samples contaminated with	Ghanayem (2001)

		&water tanks			TC,FC with less bacteria contamination from metal roofs	
5	Thailand	Roofs catchment &point of consumption	709	FC.FC	76% samples exceeded the WHO standards	Appan (1997)
6	New Dalhi, India	Roof runoff	54	FC,TCHPC,FS	All indicators bacteria were present, rough surface carried more contaminants .13%only met WHO standards	Vasudevan et el (2001)
7	US Virgin Island	Rain water system	13	Giardia ,`Cryptosporidium`	45% samples positive for Giardia ,23% positive for Cryptosporidium	Crabtree et el (1996)
8	Kerala India	Rain water tanks	30	FC	93% samples contaminated with FC,FC more than MPN/100ml in 13% of samples	Pushpangadan & sivanandan (2001)

Kurz (1998) performed study in Tampa, Florida about removal of microbial indicators from storm water in a treatment system consisting of sand filter, wet pond and alum coagulation. Grab Water samples have been collected from raw storm water and from treated storm water prior and after the control structure during simulated storm event using urban runoff in order to assess the removal efficiency. The water samples have been compared with guideline standards for recreational water for state of Florida, USA table (12).

Table (12). The microbiological quality of storm water in a sand filter and wet detention pond comparing with guideline value of State of Florida.

Locations of sample	Tested parameters	Comparison of the result with the standard
	coli form, fecal coli	TC &FC exceeded the standard value in all

Sand filter	form and other parameters	inflow samples,40% of the outflow samples exceeded the standard when the sand filter was saturated and 65% when the sand filter unsaturated
Wet detentions ponds	coli form, fecal coli form	TC &FC exceeded the standard values in 33% of the inflow samples .FC&TC exceeded 83%3, 60%and 40 the standard value of the outflow samples in different sampling locations and time in the ponds.

A study by Moe et al. (1991) investigated bacterial indicators in drinking water in Cebu, Philippinces. Four bacterial indicators were used to evaluate the relationship between presence of these indicators in the drinking water sources and diarrhea outbreaks among the children who consume the water. The indicators selected were fecal coli form, fecal enterococci and fecal streptococci. The study found strong connection between presences of bacterial indicators in water sources with prevalence of diarrhea between children. Table (13) presents some results found in this study.

Table (13). Microbiological quality of drinking water source (Moe et al., 1991)

Water sources	Number of sample tested	Samples with concentration more than 1000 indicators /100 ml
Springs	123	21 for FC, 20 for E .coli,18 for EN and 16 for FS
Open dug well	131	21 for FC,13 for E.coli,26 for EN,25 for FS
Wells with pumps	52	14 for FC,8 for E.coli,16 for EN and 16 for FS
Boreholes	751	6 for FC, 4 for Ecoli,3 for EN and 5 for FS

Explanations for table:

FC= fecal coli form bacteria, EN= enterococci, FS= fecal streprococci.

Column 3 in the table shows the water samples that have more than 1000/100 ml concentration for each microbial indicator.

Jacobs et al. (1991) have studied the bacterial water quality in Silk stream catchment in UK, which receive storm water runoff from an urban area. The results prove increasing of microbiological load as the water flows from upstream to downstream. The results have also shown that water contamination in the catchment exceeded the recommended quality for fecal coli form, total coli form and salmonella during the storm events. The study concluded that the water in the catchment seems to be unsafe for recreational use with recommendation for further investigation.

7. Conclussions

- The water quality in Augustenborg can be judged as polluted water when microbiological pollution is concerned. However, the direct health risk can be considered low if the humans are not accidently exposed for contact with that water. The water in open storm water system would not satisfy the bathing water quality standards.

- The water quality seems to be in the common range found by other studies in storm water. Further investigation is required to access risked involved for humans coming in contact with that water. Information about the potential risks of getting ill after contact with storm water in the open system shall be made available for the residents.

- In general, the water runoff green roofs has less bacteria concentration comparing with storm water runoff from other locations (ponds and open channel).

- The storm water in Augustenborg should not be used for bathing purposes and not to be used for drinking purposes.

- Further research is required for better understanding of microbiology of storm water as linked to the rainfall events.

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