

Wastewater Management in Rural Human Settlements Using Village Ponds

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GURPRINDER KAUR

Roll No. 601101007

Under the supervision of

Dr. A.S. Reddy

Head of the department

School of Energy and Environment



School of Energy and Environment

THAPAR UNIVERSITY

PATIALA (PUNJAB)-147004

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CANDIDATE CERTIFICATE


This is to certify that the work done in this thesis report entitled "**Wastewater Management in Rural Human Settlements Using Village Ponds**" submitted by Gurprinder Kaur in partial fulfillment of requirement for the award of the **Master degree in Environment science and Technology** in "**School of Energy and Environment**", Thapar University, Patiala, is a record of the student's own work carried out by her under my supervision and guidance. The report has not been submitted for the award of any degree or certificate in this or any other university or institution.


The matter embodied in this report has not been submitted at any other university or institution for the award of any degree.

Date:

Place:


Dr. S.K. Mohapatra
Dean, Academic Affairs
Thapar University, Patiala


Dr. A.S. Reddy
Head, School of Energy and Environment
Thapar University, Patiala


Dr. A.S. Reddy
Head, School of Energy and Environment
Thapar University, Patiala

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation entitled “**Wastewater Management in Rural Human Settlements Using Village Ponds**” in partial fulfillment of requirement for the award of the **Master degree in Environmental Science and Technology** in the School of Energy and Environment, Thapar University, Patiala, in July 2013, is an authentic record of my own work carried out by me, under the guidance of **Dr. A.S. Reddy**, Head of Department, School of Energy and Environment , Thapar University, Patiala.

The matter embodied in this report has not been submitted in any other university or institute for the award of any degree.

Date:

(Gurprinder Kaur)

Place:

This is to certify that above declaration made by student concerned is correct to the best of my knowledge & belief.

Dr. A.S. Reddy

Head, School of Energy and Environment

Thapar University, Patiala

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Date:

(Gurprinder Kaur)

Roll no. 601101007

ABSTRACT

Village ponds, which once served as water sources in rural human settlements, have become dumping sites for waste and posing serious environmental and health problems. There is a need for the improved management of the rural sewage and storm waters, and improving the health of the village ponds so that the ponds can again become important water resource in the rural settlements. A study has been instituted in this direction. Two village ponds, located in village Chappa, Barnala district, Punjab state, have been selected for the study. The study involved quantification and characterization of both the village sewage and the storm water, modification of the village ponds into water treatment and storage systems, and developing structures for facilitating reuse of the treated pond water and disposal through groundwater recharging. The wastewater treatment technologies employed are supposed to be on-site, low cost, low technology, requiring no trained man power and conventional energy sources and using locally available agricultural skills. This paper describes the strategies followed, methods adopted and results obtained so far. Storm water samples and sewage samples collected at the inlets and at the different depths from different locations of the village ponds have been analyzed characterization in terms of total dissolved solids (TDS), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), nutrients (total, nitrate, nitrite, ammonical and organic nitrogen, and total phosphorus), chlorides, chlorophyll, sulfates, alkalinity, and coliform count. The results obtained are reported in this paper.

Keywords: village ponds, on-site wastewater treatment, rural sewage characterization, rural storm water characterization, ground water recharging.

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ABBREVIATIONS

COD -Chemical Oxygen Demand

BOD- Biological Oxygen Demand

DO-Dissolved Oxygen

TKN- Total Kjeldhal Nitrogen

NO_3^- - Nitrate

NO_2^- -Nitrite

Cl-Chloride

SO_4^{2-} - Sulphate

Alkal.-Alkalinity

Chlorp.-Chlorophyll

TSS -Total Suspended Solids

TDS -Total Dissolved Solids

TP -Total Phosphorus

Org. N_2 - Organic Nitrogen

Amm. N_2 -Ammonical Nitrogen

Total N_2 -Total Nitrogen

Turb.-Turbidity

MPN -Most Probable Number

IMD -Indian Metrological Department

NA- Not Avaliable

CN -Curve Number

P -Precipitation

L/day -Litre per Day

Q -Inflow Rate

mm-milli meter

mg/l- milli gram per litre

hec.- Hectare

Tc- Time of Concentration

OVERVIEW OF THE REPORT

Present thesis work on Wastewater Management in Rural Human Settlements Using Village Ponds includes altogether five chapters and a reference section.

Chapter-1 Introduction: This chapter includes general view about the background information, objective, study area and importance of the present study. This thesis work can prove very useful for managing the wastewater of the selected village.

Chapter-2 Literature review: Review of literature related to present study has been discussed. It includes literature related to Village ponds and their management, Stabilization pond systems, rural sewage & storm water management and Disposal of rural storm water for ground water recharging.

Chapter-3 Methodology: This chapter includes the stepwise approach followed to achieve the objective of this work. It identifies the work elements of the present study.

Chapter-4-Result: Results of the characterization and quantification of ponds covered in this chapter and village pond management system is briefly described.

Chapter- Conclusion: In this chapter outcomes of the study and conclusion are summarized. Need of further studies related to this problem are also discussed.

1.1 Introduction/Background information

Village ponds are an integral part of rural India. Unfortunately, ponds have become disposal site for human and animal waste which leads to pollution and eutrophication due to accumulation of excess nutrients (nitrates and phosphates) and converted almost into cess pools. Village waste like sewage, kitchen waste and detergents not only pollutes the water by affecting its quality but also cause nuisance for the villagers due to foul smell and disease outbreaks. Heavy infestation with aquatic weeds is common with the village ponds and become breeding places for flies and mosquitoes. Moreover during rainy seasons ponds get flooded and water often backs up into village lanes.

In rural areas sanitation scenario of wastewater management is very poor. There is no organized sewerage system instead the sewage is collected through roadside drains constructed itself and conveyed into the village ponds. Also, no separate system for collection of wastewater and disposal of garbage.

Although village ponds have immense potential as key water resources for villages by producing nutrient rich water for agricultural purposes, aqua culturing, ground water recharging. But due to poor management, full potential of these resources have been ignored. There is need to find some cost effective methods for rural populations, which is easy enough to be adopted by villagers. So in such locations it will be better to use effective wastewater treatment which preferably uses local resources and local agricultural skills. Hence the ponds may have to be structured in lines of rugged and easy to operated stabilized systems, that require low technology and can be maintained for both village sewage and storm water.

Waste stabilization ponds (WSP) are now regarded as the method of first choice for the treatment of wastewater in many parts of world (Ramadan, 2010).WSP are widely used for small rural communities, upto 2000 population but larger systems exist in Mediterranean France, and also in Spain and Portugal (Boutin et al: 1987). In the United States one third of all wastewater treatment plants are WSP, usually serving 1000 to 5000 populations (EPA, 1983). However in

warmer climates ponds are commonly used for large populations (up to around 1 million). In developing countries and especially the tropical and equatorial region sewage treatment by waste stabilization ponds has been considered an ideal way of using natural processes to improve sewage effluents (Ramadan,2010). Although WSP are being used in many parts of world but still this technology is lacked in India.

WSP is a large man-made basin in which greywater, blackwater and fecal sludge can be treated to an effluent of relatively high quality and application for reuse in agriculture. In WSP wastewater flows and from which, after certain retention time (time which takes the effluent to flow the inlet to the outlet) as well treated effluent is discharged. Many characteristics make WSP substantially different from other wastewater treatments. This includes design, construction and operation simplicity, cost effectiveness require, low energy requirements easily adaptive for upgrading and high efficiency.

Still there is an argument concerning the economic feasibility of using WSP due to their high land requirement. However Mara and Pearson (1998) contend that even at high land cost, WSP's are often the cheapest option over continuously high consumption of electricity, 1 to 2 day anaerobic pond and 3 to 6 day facultative pond can produce an effluent suitable for restricted irrigation. So conversion of village ponds into stabilization ponds can still be an option to solve the problem of wastewater management in rural area. Also, ground water recharge technology provides benefit to rise in water table, renovation of ponds and improved irrigation systems and reduction in groundwater salinity.

WSP's are in series of three ponds where the anaerobic pond to facultative pond and finally maturation pond. The anaerobic ponds reduce solids and BOD as a pre-treatment stage. Anaerobic ponds are built to deep of 2 to 5 m and have relatively short detention time 1 to 7 days. Anaerobic bacteria convert organic carbon into methane in the process and remove up to 60 % of BOD. Anaerobic ponds are capable of treating strong wastewaters. The effluent from anaerobic pond is transferred to the facultative pond, where further BOD is removed. A facultative pond is shallower than an anaerobic pond and both aerobic and anaerobic processes occur within the pond. The top layer of pond receives oxygen from natural diffusion, wind mixing and algae driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond the

aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%. The pond should be constructed to a depth 1 to 2.5 m and have detention time between 5 to 30 days. Maturation ponds are shallowest, usually constructed a depth 0.5 to 1.5 m deep to ensure that sunlight penetrates the full depth for photosynthesis. Maturation ponds are designed for pathogen removal. This type of pond is effective at removing of nitrogen and phosphorus from the effluent. It is referred as polishing or finishing ponds.

Present study includes the characterization and quantification of village pond water, to develop the strategy for wastewater management in rural human settlements using village ponds and modifications of village pond for serving as a sewage and storm water treatment system. So, the village pond may have to be structured in lines of stabilization ponds systems as a reuse system; for the disposal of rural storm water ground water recharging system.

1.2 Study area

The two village ponds under study are located in village Chappa, District Barnala, Punjab state.

Population in the village: This village has approximately population of 4500 human and 3000 cattle. The number of houses in the village are around 640. There are only two schools in the village. One governmental hospital is placed for health facilities. No industry placed near the village. The village covers an area of 0.141 Km² as residential area and 9.5 Km² as agricultural land.

Water supply at the village: In the village at household's level, tube wells and water taps (supplied from common water tank) are available. In an agricultural area, bore wells are used.

Sanitation at the village: Sanitation service is not much poor, about 85% of the population have well constructed toilets. Some people have only poorly constructed and unhygienic basic toilet structures. Approximately 450 toilets are well constructed in the village and 70 toilets poorly constructed.

Pond information: The pond 1 and pond 2 covers an area 0.012 Km² and 0.016 Km² respectively. Pond 1 has two inlets- 1) Drain-1 (Station 1A) 2) Drain-2 (Station 1B); and pond 2 has only one inlet point- Drain-3 (Station 2). Village ponds receive wastewater in the form of grey water (household wastewater) and black water (urinal wastewater). Domestic waste from

the rural settlements and storm water runoff from precipitation is also directed to these ponds. The amount of wastewater discharge varies with time periods.



Fig. 1.1: Detailed view of village map



Fig. 1.2: Showing inlets of pond 1 (left side) and pond 2 (right side)

1.3 Objectives of the study

1. To characterize and quantify both domestic wastewater and storm water for a selected village.
2. To critically analyze a few selected village ponds from the environmental angle.
3. To develop a water resources management system/strategy for the selected village.

1.4 Importance and usefulness of the work

This study includes characterization of qualitative parameters of village pond water, use of village ponds for the treatment of waste water and enhancement of their performance. Development of a water resource management system/ strategy for villages while using the village pond as the key water resource. Modification of the village pond will be suggested for serving as a sewage and storm water treatment system. The village ponds can be structured and maintained for receiving the rural sewage and storm waters and treating the received wastewater and stored excess water can be disposed off from the village ponds.

Village ponds has an immense potential as a key water resources. Water can be supplied for irrigation purposes in agricultural land, can be used in aqua culturing, ground water recharging, horticulture and also can supply water for cattle and various human requirements. So, this study concentrate on the present situation of the village ponds and on the basis of pollution loads will be suggest the ground water recharging in the village, which will help to raise the water level table of this area ,there would be cleanliness in the area, no foul smell and this will also help to improve the sanitation conditions in the village.

LITERATURE REVIEW

2.1 Waste stabilization ponds and their modifications for wastewater treatment

Waste stabilization ponds, have become one of the world's most used methods of treating wastewater in areas where there is sufficient space for their construction. In addition, they are one of the most economical and environment friendly ways of treating wastewater and producing a highly purified effluent. A world bank report (Shuval et al. 1986) endorsed the concept of stabilization pond as the most suitable wastewater treatment system for effluent use in agriculture stabilization. They create a natural environment and utilize natural processes to treat a wide range of wastewater contaminants and can include systems such as constructed wetlands, septic tanks, lagoons and others.

Wastewater treatment ponds are known to have advantages over other forms of wastewater treatment, especially in the ability to remove harmful pathogens and reduce organic pollutants (WHO,1987). High quantities of organic pollutants can cause eutrophication, a significant environmental problem, in natural water systems. The removal of the organic pollutants of wastewater is crucial in wastewater treatment (Spring, 2012).

Wastewater treatment ponds are designed to stabilize wastewater before it is released into a natural water body or recycled. The ponds involve biological and chemical processes where the effluent's organic pollutants, the organic loads, are broken down primarily through bacteria's of the organic matter as a source of food. Treatment ponds are also capable of removing heavy metals, harmful pathogenic organisms and nutrients like nitrogen and phosphorous (Sperling, 2007).

Waste stabilization pond systems are man-made shallow earthen (anaerobic, facultative, maturation) ponds mostly used in the domestic wastewater treatment for the removal of biodegradable organic matter, nutrients and pathogens. These are considered as best suited for the tropical and subtropical countries (Shammas et al., 2009).

Mara et al. (1992) demonstrated that intensity of sunlight and temperature are key factors of treatment in waste stabilization ponds. Climate particularly temperature also plays a key role in the design of waste stabilization ponds (Parawira, 2004).

Maiga et al. (2009) studied the impact of pond depth and environmental conditions on sunlight inactivation of E.coli and enterococci in wastewater in warm climate. They reported that in illuminated conditions, enterococci were inactivated more rapidly than E. coli. However, E. coli presented greater variability in the survival capabilities. They further suggested that the use of both indicators together should be advised for the assessment of effluent quality from WSP in Sahelain region.

Heaven et al. (2007) highlighted the influence of annual climate variability on design and operation of WSP for continental climates. A simple model based on first order kinetics for biochemical oxygen demand is used to consider some alternative design and operating protocols using long term climate records for cities across continental central Asia.

Rockne and Brezonik (2006) reported nutrient removal in the form of ammonia volatilization in cold region (Minnesota) waste stabilization pond. The study evaluated the fate and removal efficiency of the nutrient elements- nitrogen, phosphorus, and organic carbon in a three-stage cold weather WWSP. They found that system was surprisingly efficient at nitrogen removal (average 80%) primarily through volatilization of unionized ammonia during late spring when pH was above 8 and ammonia levels were still high.

Ramadan and Ponce (2010) highlighted designs and performance of waste stabilization ponds and advanced integrated ponds (AIWSP's) and high rate algal ponds.

WSP can be classified in respect to types of biological activity occurring in a pond. Three types are distinguished anaerobic, facultative and maturation ponds.

2.1.1 Anaerobic Ponds

Anaerobic ponds are deep treatment ponds that exclude oxygen and encourage growth of bacteria which break down effluent. It is in the anaerobic pond that the effluent begins break down in the absence of oxygen an “aerobically”. The anaerobic pond acts like an uncover septic

tank. Anaerobic bacteria breakdown the organic matter in the effluent releasing methane and carbon dioxide. Sludge is deposited on the bottom and a crust formed on the surface.

These ponds are generally 2-5 m deep and receive such a high organic loading usually >100 g BOD/m³.d equivalent to >3000 kg/ha/d for the depth of 3 m. They contain an organic loading that is very high relative to amount of oxygen entering the pond which maintains anaerobic conditions to the pond surface. Anaerobic ponds do not contain algae. They work extremely well in warm climate can attain 60-85% BOD removal and have relatively short detention time (BOD up to 300 mg/l, 1 day is sufficient at temperature more than 20⁰C) (Ramadan and Ponce , 2010).

Anaerobic ponds reduce N, P, K and pathogenic organism by sludge formation and release of ammonia into the air.

As a complete process, the anaerobic pond serves to:

- Separate out solid from dissolved material as solids settle as bottom sludge.
- Dissolve further organic material.
- Break down biodegradable organic material.
- Store undigested material and non-biodegradable solids as bottom sludge.
- Allow partially treated effluent to pass out.
- The fermentation processes and the activity of anaerobic oxidation throughout the pond remove about 70% of the BOD of effluent.

SO₄ is reduced to hydrogen sulphide under anaerobic conditions from the anaerobic decomposition of carbohydrates and proteins may contribute to obnoxious odors, too.

However, odor is not a problem if the recommended design loadings are not exceeded and if the sulfate concentration in raw wastewater is less than 300 mg SO₄/L (Gloyna and Espino,1969).

A small amount of sulphide is beneficial as it reacts with heavy metals to form insoluble metal sulphides, which precipitate out. In the case of typical municipal sewage, it is generally accepted that a maximum anaerobic pond loading of 300 g BOD/ m³.d at 20⁰C will prevent odor nuisance (Mara et al. 1992). Typical BOD removal efficiency for anaerobic ponds is of the order of 50-70% (Sperling, 2007). Typically an anaerobic treatment pond will be used as the first biological treatment step and followed by further treatment, such as a facultative pond (Pena, 2002). Using

an anaerobic pond in series with a facultative pond has advantages, as there is a reduction in the surface area required by the facultative pond, as there is removal of significant amounts of BOD in the anaerobic treatment step.

Pena (2002) observed that removal of organic matter in anaerobic pond follows the same mechanism that takes place in any anaerobic reactor. In natural treatment systems such as WSP, the pathogens are progressively removed along the ponds series with in the highest removal efficiency taking place in maturation ponds (Mara et al., 1992).

Knorr and Torella (1995) reported a higher removal efficiency of total coliforms in anaerobic ponds when compared to the facultative lagoons. This research carried out that the removal of one log unit for total coliforms in anaerobic pond. Meanwhile, the viral efficiency was very poor in anaerobic ponds.

Arridge et al. (1995) working on experimental WSP complex in Northeast Brazil found a one log unit removal in the AP for each of the following indicators : faecal coliforms, *Clostridium perfringens*. *Salmonellae* were reduced from 130 to 70 MPN/100 ml , *V. cholera* reduced from 40 to 10 MPN/100 ml .Anaerobic ponds appear to essential for high levels of *V. cholera* removal.

In anaerobic ponds organic nitrogen is hydrolyzed to ammonia, so ammonia concentrations in anaerobic pond effluents are generally higher than in raw wastewater .Volatilization of ammonia seems to be the only likely nitrogen removal mechanism occurring to some extent in anaerobic ponds.

Soares et al.(1996) carried found a very low removal of nitrogen in anaerobic ponds.

Picot et al. (2003) studied the biogas production, sludge accumulation and mass balance of carbon in anaerobic ponds. The anaerobic ponds constitute a good primary treatment with the removal of 55% of SS and 30% of BOD₅, with a small surface area. Due to intensive anaerobic degradation, the production of biogas (83% CH₄) was measured by gas collectors especially developed was also strongly dependent on temperature. The mass balance of carbon showed that 74% of the removed organic carbon was converted into CH₄, 13% into dissolved inorganic carbon and 15% was stored in sludge.

Yacob et.al. (2006) demonstrated that methane emission from anaerobic ponds of palm oil mill effluent treatment. Palm oil mill effluent (POME) as the source of renewable energy from the

generation of methane and establish the current methane emission from the anaerobic treatment facility. Total methane emission per anaerobic pond was 1043.1 kg/day.

Harerimana et al. (2011) developed a simple and practical model of bacterial sulphate reduction in anaerobic ponds. The basic microbiology of our model consists of three steps, namely, acidogenesis, methanogenesis, and sulphate reduction. This model includes multiple reaction stoichiometry and substrate utilization kinetics. He established the values of K_{SO_4} and V_{max} for SRB in an anaerobic pond. Results concluded that these parameters of sulfidogenic bacteria will be used in the Anaerobic Pond Model to describe the sulphate reduction processes and to evaluate the risk of odour generation.

McCabe et al. (2011) monitored the performance of covered anaerobic ponds in the treatment of abattoir wastewater.

Almasi et al. (2012) demonstrated that a new approach to anaerobic-anoxic stabilization pond to treating petroleum refinery wastewater and to describe the ability of the anaerobic-anoxic pond systems in treating domestic wastewater. He depicted that combination of these ponds affects petroleum wastewater treatment efficiency significantly. An important advantage of this pond is its land saving capability, comparing to a facultative pond. Thus, it could be said that the integration can be beneficial in assessing Anaerobic-anoxic waste stabilization ponds performance.

Mohammad et.al., (2012) highlighted the calculation of the release of total organic matter and total mineral using the hydrodynamic equations applied to palm oil mill effluent treatment by cascaded anaerobic ponds

2.1.2 Facultative ponds

Facultative ponds (1-2 m deep) are of two types : primary facultative ponds, which receive raw wastewater, and secondary facultative ponds, which receive settled wastewater ,usually the effluent from anaerobic ponds (Pena ,2004).They are designed for BOD removal on the basis of relatively low surface loading (100-400 kg BOD/ha.d temperature between 20⁰C and 25⁰C) to permit the development of healthy algal population as the oxygen for BOD removal by the pond bacteria is mostly generated by algal photosynthesis. Due to the algae facultative ponds are colored dark green, although they may occasionally appear red or pink due to the presence of

anaerobic purple sulfide-oxidizing photosynthetic bacteria. The algae that tend to predominate in the turbid waters of facultative ponds are the motile genera as these can optimize their vertical position in the pond water column in relation to incident light intensity and temperature. The concentration of algae in a healthy facultative ponds depends on the loading and temperature, is usually in the range of 500- 2000 μg chlorophyll a per litre. Effluent entering the facultative pond from anaerobic pond is converted into CO_2 , water and new bacterial and algae cells in the presence of oxygen.

Aerobic pond is more accurately termed “facultative”, as in practice the pond usually has an aerobic upper layer and anaerobic lower layer. This facultative condition occurs because high O_2 level cannot be maintained to the total depth of anaerobic ponds. So a fully aerobic surface layer develops, along with anaerobic /aerobic intermediate layer, and a fully anaerobic layer on the pond bottom. Oxygen is unable to be maintained at the lower layers if:

- The pond is too deep, and the color too dark, to allow light to penetrate fully.
- The demand for oxygen in the lower layer is higher than supply. Demand is increased with high levels of organic matter. The anaerobic layer will be deeper in an aerobic pond where there is extremely high organic matter content of the inflowing effluent.
- The surface layer, rich in oxygen, is not adequately mixed with bottom layer.
- There is a combination of these conditions.

As a result of the photosynthesis activities of the pond algae, there is a diurnal variation in the concentration of dissolved oxygen. For typical facultative pond, the water column will be predominantly aerobic at the time of peak sun radiation and predominantly anaerobic at sunrise. After sunrise, the dissolved oxygen level gradually rises to a maximum in the mid-afternoon, after which it falls to minimum during the night. The position of the oxy-pause similarly changes, as does the pH since at peak algal activity carbonate and bicarbonate ions react to provide more carbon dioxide for the algae, so leaving an excess of hydroxyl ions with the result that the pH can rise to above 9 which kills faecal bacteria. The wind has important effect on the behavior of FP, as it induces vertical mixing of the pond liquid. Good mixing ensures a more uniform distribution of BOD, DO, bacteria and algae and hence better degree of waste stabilization.(Mara et al.,1992).

Facultative pond will remove odour and kill more pathogenic microorganisms (Ramadan and Ponce 2010). Organic loading for facultative pond is decided empirically on the basis of average ambient air temperature for the coldest month of the year or by the incident solar radiation (McGarry and Pescod, 1970). Further the loading is temperature dependent and limited to 80-400 kg/ha (Ramadan and Ponce 2010). The activity of further anaerobic oxidation and the aerobic conversion of effluent to CO₂, water and new bacterial and algae cells can result in the removal of 80% of the effluent flowing into the facultative pond (which means in overall removal in order of 95% over the two ponds). When a facultative pond is used as a primary treatment, BOD removal may be very efficient.

Abis (2002) reported a BOD removal in a pilot-scale facultative ponds in United Kingdom to an average of 91%. These values include the contribution of algae in the effluent. With the algae solids removed from the effluent, the average removal was 97.2%.

Removal of the pathogens and nutrients (N₂ & P) in these ponds is coincidental. Higher pH, higher DO and solar radiations (specially UV radiation) incidence are responsible for pathogen removal (Curtis, 1994, Davis-Colley et al., 1999).

Some parasites can be removed as well. Protozoan cysts and helminth eggs are removed by sedimentation. Their settling velocities are quite high, and consequently most removal takes place in the anaerobic and facultative ponds. It has recently become possible to design WSP for helminth egg removal (Ayres et al., 1992).

Nitrogen removal is believed to occur mainly through its assimilative use by both algae and bacteria (Ferrara and Avci, 1982). Algal inhibition of nitrifiers and low population levels of nitrifying bacteria make nitrogen removal through nitrification and denitrification route insignificant (Reed, 1985). Higher pH values resulting from activity are suspected to result in volatilization removal of ammoniacal nitrogen. Phosphorus removal is believed to occur through both assimilation and precipitation-sedimentation routes. Precipitation-sedimentation removal is influenced by the pH of the pond water (Ramadan and Ponce, 2010). In the actual practice, nitrogen removal is estimated on the basis of surface hydraulic loading rate, pH of the pond water and temperature.

Soares et al. (2001) determined the reaction coefficient (K) evaluation for full-scale facultative pond systems to describe the organic matter removal of a facultative pond. A correlation between applied COD load and reaction coefficient (K) was obtained. He suggested design parameter for facultative ponds in this region in terms of domestic wastewater.

Senzia et al. (2002) presented a dynamic rational model for nitrogen transformation in primary facultative ponds. It showed the dominant mechanism for nitrogen removal was sedimentation of organic nitrogen (9.7%). The major nitrogen transformation route was through mineralization (19.2%) followed by ammonia uptake by microorganisms (17.4%) and nitrification (2.4%). Denitrification process was another possible route for removal of nitrogen (4.1%), but volatilisation played a negligible role (0.1%)

Giraldo et al. (2002) developed Compartmental model for organic matter digestion in facultative ponds. The internal loadings to facultative ponds due to solubilization and return of organic matter from the sediments to the aerobic layer greatly influence the soluble BOD effluent concentration. Aerobic degradation activity in the facultative pond does not affect significantly the effluent concentration. Anaerobic degradation activity in the facultative pond can more easily achieve increases in the removal efficiencies of BOD.

Meneses et al. (2005) studied the Variations in BOD, algal biomass and organic matter biodegradation constants in a wind-mixed tropical facultative waste stabilization pond. This was sufficient to cause mixing of the water column resulting in loss of stratification in terms of chlorophyll a, temperature and dissolved oxygen.

Johnson et al. (2005) reported that Aerated rock filters for enhanced nitrogen and faecal coliform removal from facultative waste stabilization pond effluents. It describes and compares aerated and unaerated rock filter performance for BOD, SS, nitrogen and faecal coliform removals, and highlights the land-saving opportunities as maturation ponds and reed beds become redundant.

2.1.3. Maturation pond

Maturation ponds are primarily designed for tertiary, i.e., the removal of pathogens, nutrients and possibly algae. They are very shallow, around 1 m depth. Although Mara et al.,(1997) believes that at this reduced depth emergent plant growth and mosquito breeding problems to allow light penetration to the bottom and aerobic conditions throughout the whole depth. The ponds follow a

secondary treatment as facultative pond. size and number of maturation ponds needed in a system is normally determined by the required retention time to achieve a specified effluent pathogen concentration (The Water Treatments, 2012). Maturation ponds also act as a buffer for facultative ponds in the case of failure (Spring, 2012).

These ponds receive the effluent from a facultative pond and its size and number depend on the required bacteriological quality of the final effluent. Maturation ponds are shallow and show less vertical stratification, and their entire volume is well oxygenated throughout the day. Their algal population is much more diverse than that of facultative ponds. Thus, the algal diversity increases from pond to pond along the series. The main removal mechanisms especially of pathogens and faecal coliforms are ruled by algal activity in synergy with photo-oxidation.

On the other hand, maturation ponds only achieve a small removal of BOD₅, but their contribution to nitrogen and phosphorus removal is more significant. A total nitrogen removal of 80% in all waste stabilization pond systems, which in this figure corresponds to 95% ammonia removal. It should be emphasised that most ammonia and nitrogen is removed in maturation ponds. However, the total phosphorus removal in WSP systems is low, usually less than 50% (Pena, 2004).

Detention time must be long enough to allow for sufficient settling and treatment, as well as to prevent the flushing out of algae. At temperatures of 20°C a detention time of at least 3 days is recommended. But in a colder, temperate climate that can have monthly average temperatures far below 20°C, detention time recommended varies from 4-5 day and 20-30 days. So based on this a longer period of detention is recommended to ensure no pollutants are allowed to be discharged from the wastewater treatment system into the natural water body. Also a series of maturation ponds can be useful, especially for the removal of faecal coliforms. For the maturation ponds it is assumed that 70% of BOD is removed during primary and secondary treatment. This allows for maximum light penetration and Ideal conditions for tertiary treatment (Spring, 2012).

Lloyd et al.(2003) reported the reducing hydraulic short-circuiting in maturation ponds to maximize pathogen removal using channels and wind breaks. This included the impact of four sequential maturation pond interventions on the removal ofthermotolerant "faecal" coliform bacteria at a full scale WSP system in tropical Colombia.

Sperling (2003) investigated the sensitivity to the Dispersion Number (d) of the effluent coliform concentration from facultative and maturation ponds. The Dispersion Number is one of the coefficients used in the dispersed-flow model for ponds. Influence of the dispersion number on the estimation of coliform removal in ponds.

Graeme et al. (2004) highlighted the application of the Jameson Cell technology for algae and phosphorus removal from maturation ponds. This new treatment process has been shown to be capable of achieving algal removal efficiencies of over 98% and residual levels of total phosphorus to below 0.3 mg/l in the treated effluent.

Stott et al. (2005) showed the effect of biofilm on the attenuation of pathogen-sized particles from wastewater was compared for biofilms cultivated in a surface flow constructed wetland (SFW) and maturation pond (MP). Results concluded that providing surfaces for attachment of photosynthetic biofilms offers potential to enhance pathogen removal in open water systems. In vegetated systems, linkage to more toxic open water zones may allow thicker and 'stickier' epiphytic biofilms to develop, improving pathogen interception and removal.

Tyagi et al. (2008) assessed the removal of fecal indicators in a full-scale facultative and maturation pond system. The results showed that the system was able to remove approx. 2.0 to 3.5 log units of fecal indicators and almost 100% of helminth eggs. Removal efficiency of fecal indicator bacteria was reported maximum during summers (3.4 to 4.0 log units) and minimum (1.9 to 2.0 log units) in winters. Correlated the key physicochemical w/w quality parameters (BOD, turbidity, and SS) and indicator m/o (total coliforms, fecal coliforms, and fecal streptococci). Among all these parameters, suspended solids showed the highest correlation coefficient (r^2). These correlations manifest that the improvement of microbiological quality of wastewater is strongly linked to the removal of suspended solids.

Camargo et al. (2009) studied that in maturation ponds molecular microbiology analysis showed that denitrification can be considered a feasible mechanism for permanent removal in WSP, which may be supported either by ammonia oxidizing bacteria or by methanotrops, in addition to nitrite-oxidizing bacteria.

Mara et al. (2009) reported the the influence of algal biomass on tracer experiments in maturation ponds. The importance of determining hydraulic regimes and retention times in wastewater treatment units.

2.1.4. Village pond

Water and wastewater management are still lacking in many countries. Whereas in most industrialized countries safe water is supplied to the population and wastewater pollution control has progressed substantially, in the low and middle income countries the situation is different, with lower coverage of both water supply systems and sanitation services. Still, water supply coverage is usually higher than the sanitation coverage. In developing countries, for example, 85% of the population has access to safe drinking water, whereas only 32% has access to sanitation services. Similar situation can be found in middle income countries where water supply coverage is higher than sewerage systems coverage. In middle-income countries, lower coverage of drinking water services in the poorer areas means that if they would succeed to provide their entire population with safe centralized drinking water services, it is not likely that sufficient additional financial resources will remain for proper wastewater collection and treatment. Thus, wastewater management seems to lag behind water supply management in low and middle income countries.

It is essential for several reasons:

- (1) protecting public health and the well-being of the communities;
- (2) protecting the water resources and the environment;
- (3) in water-scarce regions for reuse purposes in order to reduce the pressure from the potable resources (Bakir, 2001; Friedler, 2001).

Chawala et al. (2001) determined the quality of water stored in village ponds to develop a strategy for its optimum utilization. It revealed that the quality of pond water is not only suitable for irrigation and development of fisheries, but also rich in nutrients, which is an added advantage. The study has revealed that the renovation of village ponds will have positive affect on environment, rural economy and ground water regime in declining water table areas.

Hussain et al. (2001) studies that the suitability of wastewater for irrigation tomato and radish crops and effect on soil and health. He showed that wastewater irrigation with fertilizer gives yield comparable to freshwater with fertilizer. The results concluded that the tomato irrigation

with only wastewater is higher than the wastewater with fertilizer. It also gives hygienic quality of crops.

Yokota et al.,(2001) reported that the arsenic contamination of ground and pond water and water purification system using pond water in Bangladesh.

Sharon et al.,(2003) investigated that wastewater management strategies can be categorized as centralized or decentralized systems. The main challenges facing decision makers in areas that still lack adequate wastewater treatment, such as high costs and weak institutions are more severe as local authorities lack the capacity to manage and maintain such facilities.

Mapuskar et al.(2003) estimated and experienced that Of appropriate liquid waste management technologies for rural areas. The choice of technology will depend on the situation at each place. These technologies, if used extensively in rural areas will help change the face of villages. It will be a march towards clean, healthy and prosperous villages in India.

Shivashankara et al. (2004) discussed the quality status of water in village ponds for irrigation . It is important to know the acceptable limit of hazardous loads to crops so as to minimize the deviation from the normal growth. Showed that EC and residual sodium carbonate (RSC) of entire village ponds belong to the category of normal water and non-alkaline water respectively. Revealed that village ponds are free from hazards, and can be used continuously for irrigation on almost all types of crops and soils.

Menon et al. (2008) suggested that conservation of rural ponds is the key to health and nutritional well being of the poor. Showed that a strong tendency of eutrofication , high incidence of colliform bacteria, high probability of waterborne diseases.Preservation of ponds is a compulsory to use it alternative water sources for all purposes

Kaushal et al. (2009) discussed the groundwater is declining at a very fast rate in Punjab. In Sangrur, Moga, Jalandhar,Ludhiana water level goes down 15 cm, in Barnala its 27.5 cm . He suggested that renovation of village ponds should be carried out for preventing overexploitation of groundwater aquifers to regulate and control groundwater development and management.

Zheng et al. (2009) reported that the discharge features of rural domestic wastewater from different types of villages in water source protection area in Miyun reservoir of Beijing. Kitchen

wastewater, bath wastewater and laundry wastewater constituted major parts of rural wastewater. Results showed that the concentration of total phosphorus (TP), chemical oxygen demand (COD) and ammonia (NH_4^+ -N) were rather higher. The concentration of COD was related closely to the type of wastewater

Yang et al. (2010) studied on nitrogen, phosphorus and organic matter in ponds around Chaohu Lake. The nitrogen, phosphorus and organic matter in ponds mainly sourced farmlands and village land surface. The contents of nitrogen, phosphorus and organic matter in ponds were affected by location and runoff supply of ponds. By retaining nitrogen, phosphorus and organic matter in runoff, the ponds can effectively decrease nutrient content into Chaohu Lake.

Ansari et al. (2010) reported that an ecologically and economically viable integrated approach for rural development through aquaculture, duckweed based bio-remediation of village ponds. Studied duckweed based bio-remediation of village ponds. Affordable technology utilizing plants as environmental cleansers in wastewater management. He stated that wastewater-duckweed-aquaculture is a perfect eco-friendly integrated package for converting the waste water nutrients into high quality fish protein and augmenting rural economy through generating employment opportunities and additional food security.

Peter et al. (2011) studied the transport of fecal bacteria from ponds to aquifers in rural area of Bangladesh. Thus, whether ponds are point sources of fecal contamination depends sensitively on the grain size of sediments immediately adjacent to the ponds. He investigated that receiving fecal contamination from the densely populated rural areas with poor sanitation contributed to high rates of diseases.

2.1.5 Constructed wetland systems

Wetlands, either constructed or natural, offer a cheaper and low-cost alternative technology for wastewater treatment. A constructed wetland system that is specifically engineered for water quality improvement as a primary purpose is termed as a 'Constructed Wetland Treatment System' (CWTS).

Constructed wetlands can be used for the secondary or tertiary treatment of septic tank effluent and can achieve high contaminant removal. They are either surface flow or subsurface flow wetland that use processes such as biological, chemical, physical and microbial for the treatment

of wastewater. The surface flow wetlands are constructed to resemble natural wetland while the subsurface flow wetland is a bed of porous media, such as sand or gravel, usually vegetated and can either be vertical flow or horizontal flow by configuration. The removal of contaminant in a wetland depends on the wastewater type, organic and hydraulic loading, the constructed wetland configuration or design and the climate. The plants in a wetland are important for gas transfer such as oxygen into the wastewater and methane and other gases out of the wastewater. During plant growth also, there is removal of nutrients such as nitrogen and phosphorus by the wetland plants. The influent ammonium nitrogen and organic nitrogen into the surface flow wetland can be removed by the process of nitrification as the wetland is aerobic. However it is recommended for effective nitrogen removal, the design of a surface flow wetland, that it is not fully vegetated. (Hammer, 2004).

Hagendorf et al.(1994) studied the efficiency of a number of wetlands in Germany. They observed the best results in systems with a mixture of sand and gravel and vertical flow. Horizontal systems were by no means as efficient, although those with fine to medium sandy soil afforded better germ reduction than those with pebbly soil. However, systems with small-grained soils often resulted in hydraulic problems (clogging leading to surface flow), which drastically reduced efficiency.

Knight et al. (1994) studied that a nitrogen (N) data from 52 constructed and natural wetlands in the North American. On the basis of this confirmed that N removal was variable. He suggested that NH_4^+ loading (kg N/ha/day) could be used to predict effluent NH_4^+ values. Combinations of shallow water-emergent vegetation and deep water-submergent vegetation with low NH_4^+ (and TKN) loading rates can produce very low levels of discharged NH_4^+ .

Keffala et al.,(2005) studied that nitrogen removal in planted system was greater than in unplanted one especially for nitrogen kjeldahl (27 and 5%) and nitrogen ammonia (19 and 6%). Whereas, removal of nitrate-nitrite in planted system is less than in unplanted one (4 and 13%). However, bacterial removal in both planted and unplanted system was similar.

Stottmeister et al.,(2005) studied that the mechanisms of both plants in constructed wetlands and the microorganisms in the root zone which come into play when they remove contaminants from wastewater. The supply of oxygen plays a crucial role in the activity and type of metabolism

performed by microorganisms in the root zone. Plants involvement in the input of oxygen into the root zone, in the uptake of nutrients and in the direct degradation of pollutants as well as the role of microorganisms understanding of the complex processes caused by the plants, microorganisms, soil matrix and substances in the wastewater.

2.1.6 Rural sewage and storm water treatment

The best method of handling residential sewage is through a properly designed and operated community or municipal treatment system. Here are three generally recognized methods of handling wastes from a rural residence. They are the stabilization lagoon, the septic tank and the individual aerobic treatment plant (Charles ,1997). This will improve knowledge of agricultural and rural drainage function in a rural landscape. The ground breaking new model will acquire more detailed and precise information on to manage any storm water impact during spring time and heavy rainfall events. This increased understanding to effectively reduce and manage run-off. This will help benefit to the environment.

Bucksteeg et al. (1997) studied that most of the communities need regular sewage disposal systems. Sewage treatment plants have to be adapted to special situations in rural villages. Ponds fulfill the requirements in an excellent way, facultative ponds (more than 1000 plants) for serving. Artificially aerated ponds (more than 300 plants) for treating sewage wastewater.

Howard et al. (2003) studied that the health risks from the absence of improved excreta disposal are likely to exceed those posed by contamination of groundwater from sanitation. For managing groundwater pollution risks derived from sanitation, both for on-site and off-site methods are helpful. Reed-beds are also used to treat effluent prior to discharge and can provide significant improvements in wastewater quality. The major problem for groundwater will be leaching of contaminants into the sub-surface. The risk to groundwater can be controlled by locating reed beds with sufficient distance to abstraction points. This includes the planning, design and construction of facilities, as well as monitoring their safe operation.

Rasul et al. (2008) studied that to manage water resources in a sustainable manner and to help reduce the restrictions, developing methods to recycle and reuse the storm water and effluent water/wastewater and reuse techniques. He introduced a new technology known as 'Green Gully' that collects ,purifies and reuse throughout an automated network system. It is a device

that is installed in the roads to direct storm water from roadways to storm drainage system. It helps to minimize the storm water pollution by mixing with sewage water and directly stored in a system and then can reuse this water easily.

Jian et al. (2009) studied the capacity of sewage treatment with anaerobic and artificial wetland. The COD removal efficiency could reach 70%-80% and the value of COD could be reduced from above 300.00 mg/L to below 100 mg /L.

Tokich et al. (2009) discussed that in rural settlements to wastewater management strategies, centralized and decentralized solutions. Improved version of traditional on-site technologies and development can provide wastewater treatment. In rural areas both the strategies should be considered to select most feasible one.

Albauquerque et al. (2012) studied that in rural communities water discharged can be reused for irrigation and daily purposes. The use of wastewater as reduction of pollution loads and it provides the environmental benefits and economic benefits, especially in periods of water shortage.

Khan et al. (2012) discussed that treated water can utilized not only as irrigation water, but also as liquid fertilizer. The effect of treated effluent from waste stabilization ponds are nutritive. In rural areas can be used for unrestricted crops in water deficient areas thereby saving fresh water.

2.1.7 Disposal of rural storm water for ground water recharging

In rural areas most common use techniques to recharge ground water. Spreading techniques is possible when the water is spread in streams by making check dams, nala bunds, cement plugs, gabion structures or a percolation pond may be constructed.

David et al. (1990) discussed that the sources of water for recharge, including leaking water mains, septic tanks and soak ways. The net effect to increase recharge higher in dry climates and with high densities and large imported water supplies.

Godey et al. (1991) studied that the use of artificial recharge to store surplus surface water underground can be expected to increase as growing populations demand more water.

Groundwater recharge may also be used to mitigate or control saltwater intrusion into coastal aquifers. Artificial recharge is suitable for areas up gradient of an aquifer where there is significant water for recharge purposes and land area available for treatment of the runoff before recharge. Treatment consists primarily of settling suspended solids. In rural areas, improvements in the design of water traps to increase groundwater recharge efficiency.

Veries et al (2002) discussed on recharge of unconfined aquifers, often the most readily available and affordable source of water in (semi-) arid regions. These aquifers are also the most susceptible to depletion and contamination, with the recharge rate and dominant processes determining their level of vulnerability.

Rushton et al. (2007) considered that the groundwater conditions in the Permo-Triassic Sandstone aquifer of the Liverpool area. It is found that conventional rainfall recharge accounts for only one-third of the total recharge. Numerical model solutions were used to check the adequacy of the understanding of the flow processes and the solutions have confirmed that the rising water levels in Central Liverpool result from high recharge and a reduction in abstraction. Having validated the model by comparisons with field data, the model was then used to predict the probable future water level changes.

Roy et al. (2010) studied that the management water resources. He showed that the village level surface water reservoirs, which had supplemented irrigation in addition to providing water for all sorts of domestic needs. Management effectiveness of these ponds calculated by counting the ponds in village for repair, desalination. A higher value indicated the better management of sources due to their capacity to store rainwater and to recharge groundwater to some extent.

3.1 Introduction

This chapter presents the methodology followed for the study. For achieving the objectives of the study, the work was planned on the following work elements:

- Background information collection for the selected rural human settlement.
- Standardization of methods of analysis for water and wastewater.
- Characterization and quantification of the village sewage.
- Characterization and quantification of the village storm water.
- Environmental analysis of the village pond.
- Development of a water resources management plan for the village while considering the village pond as the focus.

3.2 Background information collection for the selected rural human settlement

3.2.1 Detailed survey of the village for demographical features (including cattle and other domesticated animals)

For this work element the village was surveyed. Current human and cattle population of the village were collected. The data collected from the village according to house number. The number of toilets in this village are 450. In this village, 2 ponds are there, which have the potential to be used as water resources. Past demographic information was collected from census data.

3.2.2 Demarcation of the village watershed and collecting information on the hydrological characteristics

Two sub-watersheds have been demarcated within the village each contributing storm water runoff to the village ponds (pond 1 and pond 2).

Delineation of the catchment boundary has been done with the help of Google Earth Pro software available online. For information collection on the characteristics, physical survey of the catchments, interviews with local people, maps available on net (Google maps etc.) were used.

Drainage area, Channel length, channel slope and land use details have been worked upon. The land use data for the catchments was divided into the following sub-categories:

1. Farmsteads (Farms alongside houses)
2. Impervious paved area (Roads) and houses
3. Fallow land
4. Pasture (based upon extent of grazing)

Based upon the above characteristics of the sub-watersheds, Runoff Coefficient and Curve number were calculated for both the catchments in order to depict rainfall- runoff relationship.

3.2.3 Collection of information on water supply and sanitation status of the village

Details on the water supply of the village, were obtained. Both household level and village level water supply systems including the sources of water, water storage, treatment and distribution were understood.

Similarly the sanitation scenario of the village was understood. Management of both black water and grey water and of wastewater from the animal husbandry were understood. Further, how the village ponds were used in the management of the sewage as well as storm water was studied.

3.3 Standardization of methods of analysis for water and wastewater

The onsite analysis involved measurement of temperature and pH. Besides this, chlorophyll is filtered and transported to the lab along with other samples. The samples were analyzed for the parameters indicated in Table- 3.1. The methods used are indicated in the Table-3.2. Prior to the case, of the methods were standardized and acquainted with in the laboratory.

Table 3.1: Parameters to be characterized at different sampling points

Parameters	Sampling points (Village ponds)		
	Sewage samples		Storm water samples
	Inlets	Different depths	Inlets
pH	✓	✓	✓
Temperature	✓	✓	
Turbidity	✓		✓
Alkalinity	✓	✓	✓
COD	✓	✓	✓
BOD	✓	✓	✓
TSS	✓	✓	✓
TDS	✓	✓	✓
Total-P	✓	✓	✓
TKN	✓	✓	✓
Amm. nitrogen	✓	✓	✓
Nitrite	✓	✓	✓
Nitrate	✓	✓	✓
MPN	✓	✓	✓
Sulphate	✓	✓	✓
Chloride	✓	✓	✓
Chlorophyll		✓	

Table 3.2: Analytical techniques for testing of wastewater parameter

S. no.	Parameter	Method	References
1	pH	Indicator method	APHA (2008)
2	Temperature	Laboratory and field method	APHA (2008)
3	Turbidity	HACH-Spectrophotometer	HACH-spectrophotometer Manual
4	Alkalinity	Titration method	APHA (2008) "Manual standard method" 22 nd edition ,Method no.2320B.
5	COD	Open reflux method	APHA (2008) Manual standard method" 22 nd edition, Method no.-5220B.
6	BOD	3 day BOD test	APHA (2008) Manual standard method" 22 nd edition, Method no.-5210B
7	TSS	Total suspended solids dried at 103°-105 °C	APHA(2008) "Manual standard method" 22 nd edition, Method no.-2540B
8	TDS	Total dissolved solids at 180 °C	APHA(2008) "Manual standard method" 22 nd edition, Method no.-2540C
9	Total-P	Vanado-molybedo phosphoric acid method	IS-3025 (PART 31)
10	TKN	Macro kjeldhal method	APHA(2008) "Manual standard method" 22 nd edition
11	Amm. nitrogen	Preliminary Distillation step, titrimetric method	APHA(2008) "Manual standard method" 22 nd edition
12	Nitrite	UV Spectrophotometry	APHA(2008)
13	Nitrate	Spectrophotometry	APHA(2008)
14	MPN	Serial dilution method	APHA(2008) "manual standard method"
15	Sulphate	Gravimetric method	APHA (2008) "manual standard method", 22 nd edition ,method no.-4500C
16	Chloride	Argentometric method	APHA (2008)

3.4 Characterization and Quantification of the village sewage

3.4.1 Sewage regular sample collection and analysis:

Grab samples at inlets of the ponds were taken. Samples of sewage were collected at 6 hours interval over one day after every 1.5 months (from Oct 2012 to June 2013). For each of the samples pH and temperature were recorded on-site. Samples were collected in acid washed glass and plastic bottles. Collected water samples were immediately transported to stored at 4°C the TU labs and until analysis.

Grab sewage samples were also collected one time (April 2013) from different locations and different three depths of the village pond.

3.4.2 Quantification of domestic sewage:

Sewage quantification was done by both actual measurements at the village pond and by the assessments from the water supply and village population data.

For actual quantification, water supply from the overhead water tank to the village was estimated. Initial water level in the tank was noted and the pump was switched on for a fixed duration and the final level was noted down for knowing the pumping rate.

Log book on the pump operation was maintained over a work time and this information was used for estimating the daily water supply.

For actual sewage quantification, inflow of wastewater to the village pond was measured. Dimensions of the inlet drain were noted. And, the inlet drain, two points were selected at measured distance and sewage flow velocity was noted on hourly basis over one week time period.

3.5 Characterization and Quantification of the village storm water

3.5.1 Storm water sample collection and analysis

The storm water sampling was done during three rains (29-09-2012, 02-02-2013 and 7-06-2013) at the inlets of the village ponds. The sampling was done at 30 minutes interval from the

beginning of the storm and continued till storm water was flowing into the pond. The samples were analyzed for the parameters given in the Table-3.2.

3.5.2 Quantification of storm water:

Using hydrological methods storm water quantification was done for the watershed of both village ponds. Past 5 years rainfall data was collected from the Indian Meteorological Department (IMD) and used in the quantification of the storm water. The Hydrological method/model used: US- SCS CN (NRCS) Method.

Table-3.3: Summarize the formulae of the methods

METHOD	FORMULA	NOMENCLATURE	UNITS
US-SCS/ NRCS CN METHOD	$1. s = \frac{25400}{CN} - 254$ $2. Q = \frac{(P-I_a)^2}{P-I_a+S}$ $3. V = Q * A$	S = Potential Maximum Retention in Soil CN = Curve Number Q = Daily Runoff from Catchment P = Daily Rainfall/ Precipitation Ia= Initial Abstraction	Ia - 0.2 S P - mm A - m ² V - m ³

3.6 Environmental analysis of the village pond

Detailed survey of the village ponds was carried out and maps of the village ponds were developed. The maps show inlets of the ponds.



Fig. 1.3: Showing different locations of sampling of pond1

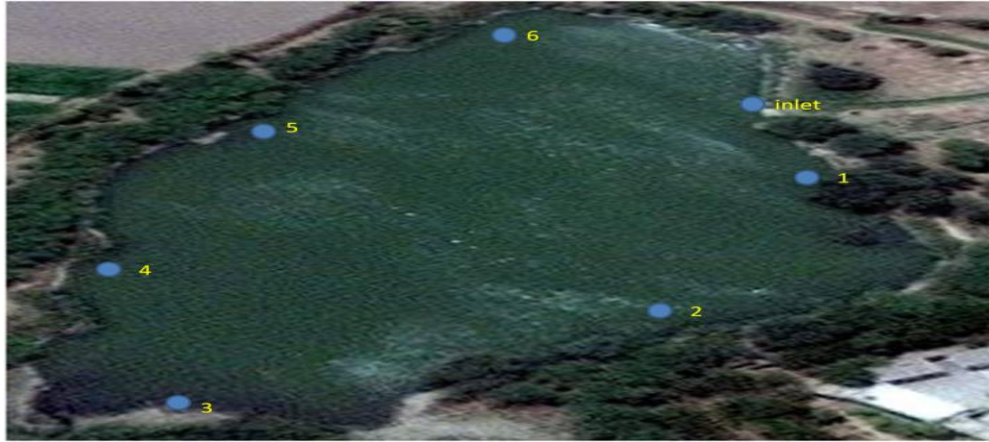


Fig. 1.4: Showing different locations of sampling of pond 2

The pond waters were sampled time in the month of April from different locations and different depths see in the figure- 1.4 & 1.5 and samples were analyzed for the parameters indicated in Table- 3.1.

3.7 Development of a water resources management plan for the village using village pond as the focus

The village ponds water management was worked out to the serve following purposes.

- Treatment and storage of both the storm water and village sewage.
- Making provision for the use of treated and stored pond for water various purposes within the pond premises.
- Making provisions for the disposal of excess of the treated ponds water through ground water recharging.

Capabilities and capacities of the ponds for the treatment of received wastewater was assessed and necessary suggestions were made for modifying the pond making it capable of handling and treatment of the received water. For this purpose the pond was viewed as if it was a waste stabilization pond system and due importance was given to vegetated ponds and constructed wetland system concepts in the pond modifications.

RESULTS AND DISCUSSION

This chapter includes the results obtained from the study. Characteristics and quantities of the sewage and of the storm water received by the village ponds and the existing pond water quality are summarized here. Based on the conditions village pond water management system was conceptualized and briefly described in this chapter.

4.1 Sewage and storm water from the village pond watersheds

The village is supplied with ground water pumped into overhead tank of 60 m³ capacity. Daily two overhead tank volumes of water is supplied. Human population of the village is 4500 and cattle population is 3000. Per capita water supply is 26.67 L/day. Area of the village is 14.1 hectares. Population density is about 320 per hectare. Almost all houses have independent tube wells for the parallel water supply. The village of about 640 houses has around 320 tube wells supplying water.

The village is having 450 new toilets and these toilets have septic tanks and overflows of the septic tanks are collected into open drains running on either sides wastewater generation by cattle sheds, washrooms, bathrooms and kitchens are also received into these open drain. There are about 70 old type toilets and these contribution no wastewater to the street drains.

The village has no roof top rainwater harvesting systems. All the rainwater is drained into the street side drains. The street side drains carry the wastewater (both domestic sewage and storm water) into two village ponds one of 1.2 hectare area and the other of 1.6 hectare respectively. Into pond 1, 9.38 hectares of village area drains through two drains. Into pond 2, 15.12 hectares of village area drains through one drain.

Drain-1 and Drain-2 of pond-1 and the one drain of pond-2 were sampled six day between October 2012 to June 2013 and sixteen samples were collected from each of the three ponds. The samples were analyzed for the parameters given in **Table-3.1**. The results obtained are given in **tables 4.1 to 4.3**.

The drains were also sampled during three rainfall events. The sampling was done at 30 min interval till all the storm water was drained out. The storm water samples were analyzed for the parameters indicated in **Table-3.1**. The results obtained are given in **tables 4.4 to 4.6**.

Wastewater flow rate in the drains to the two ponds was measured over 7 days of a week from morning 6:00am to evening 9:00 pm. Float velocity and depth of flow in the drain were monitored for estimating the flow rate. The results obtained are shown in **tables 4.7 to 4.9**.

Storm water flow rates to the ponds are highly variable and depend on the size of the rain fall event. Annual average rainfall of the region is 377 mm and the rainfall received highly variable (standard deviation of annual rainfall is 187 mm). The storm water and the sewage both are carried by the same drains to the ponds. Hence water carried by the drains during the storm events contain to storm water flow suspected over the sewage flow. Because of this every reason even very small rainfall events have been found to create significant storm water flows.

Background information (watershed characteristics) for the catchments of the two village ponds, needed for the storm water estimations, is presented in **table-4.12**. The curve number and the time of concentration for the sub-watersheds calculated are also given in this table. Rainfall data for the village region is presented in **figure-1.5** and percentile rainfall event size relationship obtained is presented in **figure-1.6**. Storm water flows to the ponds from the catchments were estimated using the **NRCS (US-SCS-CN) method**. The results obtained are presented in **table-4.13**. Storm water and sewage, both are carried by the same drains to the ponds.

4.2 The village ponds

There are two ponds, pond-1 of 12000 m² area and pond-2 of 16000 m² area, in the Chappa Village, receiving the village sewage and storm water. Please see **figures 1.3 and 1.4** for the village ponds. Catchment area for pond 1 is, 9.38 hectares and the catchments drain into the pond through two drains. Catchment area for village pond 2 is 15.12 hectares and the area is draining into the pond by a single drain. Pond -1 is heavily infested with water hyacinth and pond-2 is highly eutrophicated and showing algal bloom. There are no outlets to the ponds. Pond-1 was reported over flown a few years back and pond-2 is not known to overflow. From pond -2 the water is pumped and used for irrigation of the surrounding agricultural land. Water of both the

ponds were sampled (Pond-1 on 16-04-2013 and Pond-2 on 09-06-2013) at many places and at different depths and analyzed. Results obtained are presented in the **tables 4.10 to 4.11**.

Daily sewage loads, storm water loads during 90% rainfall event and pollution loads (BOD, COD, TSS, Total nitrogen, Total phosphorus and total coliform count) to the village ponds -1 and -2 are estimated and presented in **tables 4.14 to 4.15**. 90% rainfall event for the region is 35 mm and at this rainfall estimated storm water addition to pond-1 is 616 m³ and the addition to pond-2 is 511 m³. These flows are supposed to raise the water level in the pond-1 by 51 mm and in pond-2 by 32 mm. Sewage addition to the ponds -1 and -2 is 364.8 m³/day and 156 m³/day respectively. No pond water levels increase and no overflows from the ponds have been observed. This indicates that the percolation and evaporation losses from the ponds are quite sufficient to take care of the sewage flowing into the ponds. Influence of storm water addition to the ponds is not very significant.

4.3 Village pond water management system

4.3.1 The existing scenario

Water of both the village ponds is sufficiently polluted. Both BOD and MPN count are quite high for both the ponds. Pond -1 is heavily infested with water hyacinth, and pond-2 is highly eutrophicated and showing algal bloom.

The village ponds are daily receiving significant pollution loads from the village in the form of sewage. Pollution load received in the form of storm water is not very significant. Pond-1 and pond-2 receive 31.3 kg and 12.1 kg of BOD respectively from a 35 mm rainfall event, Total annual average rainfall is 377 mm. This indicates annual contribution of BOD by storm water to pond-1 and pond-2 is <300 kg and <120 kg respectively. Daily BOD contribution by the sewage from the village to pond-1 and pond-2 is 208 kg/day and 70.4 kg/day respectively.

Volumes of storm water received by the village ponds are also insignificant when compared with the volumes of sewage received. Pond-1 and pond-2 receive 496 m³ and 351 m³ of storm water respectively from a 35 mm rainfall event. This indicates that annual contribution of storm water to pond-1 and pond-2 is <4960 m³ and <3510 m³ respectively. On the other hand, contribution of sewage from the village to pond-1 and pond-2 is 365 m³/day and 156 m³/day respectively.

Water received by the village pond is mostly compensated by the water losses from the pond may be through percolation and evapo-transpiration. The village ponds have no history of getting flooded and overflowing.

4.3.2 Suggested actions for improving the environmental status of village ponds

Not allow the black water (septic tank overflows) from the multitude of new toilets installed in the village. Water consumption in the toilets can be minimized and septic tank overflows may be allowed to percolate into soil on-site. This can dramatically reduce the MPN count in the village pond water and make the village pond water may be fit for unrestricted irrigation that requires the MPN <1000/100 mL.

Allow incoming sewage and storm water to pass through a peripheral wetland system of the pond. This wetland system can act as a primary treatment unit and significantly reduce the suspended solids, BOD/COD and nutrient load to the pond. Area of the wetland system can be about 1200 m² for pond-1 and 500 m² for pond-2. The wetland system can be developed from within the pond area preferably around the inlet drains. The wetland system can have local plants like, phragmites, typha and ipomia palmate. It can also use vettivor grass and water hyacinth. Fodder plants may not be allowed in the wetland system. The wetland system can gradually transform from a land system to a pond system. The wetland system should be designed in such a way that the total system receives the incoming water and hydraulic short circuiting is as far as possible avoided.

The existing pond may be allowed to function as a facultative pond treating the incoming village sewage and storm water. For this the ponds may demand no modifications or interventions. However, the pond should not be allowed to get infested with aquatic weeds like water hyacinth and duck weed. It may be allowed to remain an algal pond. The pond may also stocked with fish (fishculturing).

Filtration system may be provided within the pond on the side diagonally opposite to the inlet drains for drawing water from the village pond for various uses within the premises. The water thus drawn out may not be potable. The filtration system may include a multigrade-multistage filter and a slow sand filter. The filtration system can be a modular system fabricated off-site.

Water coming out from the filter can satisfy the following quality: BOD: <10 mg/L; TSS: <20 mg/L, and MPN: <10000/100 mL.

Table 4.1: Characteristics of sewage wastewater samples of Drain-1

Drain-1 Parameter	1-October 2012			16-November 2012		7-January 2013		3-February 2013			16-April 2013			2-June 2013			Mean(S.D)
	5am	11am	5pm	10am	4pm	8am	2pm	7am	1 pm	7pm	6am	12 noon	6pm	9am	3pm	8pm	
COD(mg/L)	228	537	257	1059	2016	181	370	256	234	142	606	384	199	512	422	188	474 (471)
BOD(mg/L)	17.5	20.0	16.6	155	920	90.0	125	89.0	90.0	30.0	220	185	90.0	120	80.0	30.0	142 (216)
MPN(Ln/ 100mL)	14.6	16.0	13.9	15.1	14.1	14.5	15.3	7.24	11.1	7.4	9.99	8.45	7.43	9.61	9.2	12.2	11.2(3.17)
TSS (mg/L)	400	1166.6	1196	802	214	360	250	40	250	250	687	381	666	680	740	590	469 (314)
TDS(mg/L)	812	872	798	1203	960	680	1380	880	1060	970	1320	1100	758	1070	1030	1110	1000(198)
Cl (mg/L)	160	110	79.9	77.4	77.4	128	54.9	41.9	41.9	36.9	494	734	504	114	94.9	99.9	178 (206)
SO ₄ ²⁻ (mg/L)	10.6	14.8	8.30	4.91	2.40	10.6	17.2	57.6	32.9	33.9	62.5	74.0	14.8	28.6	23.2	16.4	25.7(21.5)
Alkal.(mg/lasCaCO ₃)	764	703	793	793	513	775	715	650	696	610	1000	1200	1110	1010	790	950	817 (187)
TKN(mg/L)	15.9	13.6	12.1	19.9	21.5	21.5	13.2	27.4	29.9	25.5	18.1	15.5	16.5	38.1	18.8	26.4	20.8(7.06)
NO ₃ ⁻ (mg/L)	8.11	13.0	6.95	6.73	4.20	0.18	1.10	7.45	2.99	4.98	1.10	1.90	1.00	1.10	0.08	1.145	3.87(3.69)
NO ₂ ⁻ (mg/L)	2.40	1.65	1.10	2.20	0.09	1.25	0.01	2.20	2.50	0.82	0.06	0.028	0.13	0.11	0.13	0.087	0.92(0.97)
Org.N ₂ (mg/L)	3.60	3.85	4.79	7.40	5.90	6.51	1.20	6.42	8.80	6.10	6.00	7.50	7.60	16.0	6.80	8.41	6.68(3.15)
Amm.N ₂ (mg/L)	8.40	9.80	11.2	15.4	11.9	15.4	11.9	20.9	21.1	19.5	12.0	8.0	8.9	22.1	12.5	18.0	14.1(4.81)
TotalN ₂ (mg/L)	26.5	28.3	20.2	23.0	14.3	23.0	14.3	37	35.3	31.2	19.3	17.5	17.7	39.3	19.0	27.6	24.5(7.95)
Total-P(mg/L)	2.4	3.7	5.3	9.3	5.1	2.5	2.8	3.8	1.6	0.81	0.73	1.3	2.1	2.8	3.4	5.1	3.29(2.16)
Turbidity (NTU)	398	502	447	312	272	83.4	74.1	64.2	62.3	61.9	56.8	44.2	39.1	45.7	55	27.1	159 (166)

Table 4.2: Characteristics of sewage wastewater samples of Drain-2

Drain-2 Parameter	1-October 2012			16-November 2012		7-January 2013		3-February 2013			16-April 2013			2-June 2013			Mean(S.D)
	5am	11am	5pm	10am	4pm	8am	2pm	7am	1 pm	7pm	6am	12 noon	6pm	9am	3pm	8pm	
COD(mg/L)	294	1030	456	574	147	288	118	370	290	212	512	303	185	458	342	255	364 (219)
BOD(mg/L)	14.6	60.0	13.3	220	70.5	115	20.0	80.0	60.0	60.0	85.0	35.0	50.5	90.4	60.0	15.5	65.6 (50.8)
MPN(Ln/ 100mL)	14.6	13.4	14.3	4.7	7.0	15.0	14.8	7.86	7.43	8.36	9.99	8.85	12.5	12.4	14.5	14.8	10.6 (3.46)
TSS (mg/L)	323	3292	332	1024	746	820	1210	380	445	520	226	311	359	650	510	700	740 (734)
TDS(mg/L)	754	466	808	1640	1806	410	510	1203	1240	920	1080	970	812	989	1060	1020	980 (380)
Cl (mg/L)	74.9	87.4	87.4	84.9	79.9	63.4	68.9	43.1	41.1	38.0	599	399	354	114	110	114	147 (159)
SO ₄ ²⁻ (mg/L)	8.24	24.7	8.90	41.1	16.4	12.1	14.0	60.0	36.0	47.9	11.5	29.6	22.2	12.8	18.3	19.54	23.9 (15.1)
Alkal.(mg/lasCaCO ₃)	758	820	760	585	470	812	620	475	585	559	1030	830	870	900	980	850	744 (174)
TKN(mg/L)	18.9	26.4	10.0	17.8	27.6	28.6	18.7	21.9	13.2	26.4	38.9	32.0	18.8	42.2	35.0	29.8	25.3 (9.03)
NO ₃ ⁻ (mg/L)	5.18	6.34	5.00	6.75	3.06	1.10	1.8 0	4.00	6.60	3.00	2.48	0.26	0.65	0.04	0.10	1.05	3.04 (2.47)
NO ₂ ⁻ (mg/L)	1.00	2.00	1.08	2.50	0.61	0.14	0.19	2.52	2.31	0.65	0.03	0.06	0.03	0.17	1.15	0.15	0.91 (0.93)
Org.N ₂ (mg/L)	3.50	10.2	5.75	9.20	6.80	8.10	7.85	6.50	1.25	4.20	11.4	13.2	7.60	12.9	13.0	9.00	8.15 (3.49)
Amm.N ₂ (mg/L)	6.40	16.1	13.2	8.50	11.0	17.2	12.9	15.4	11.9	22.2	27.5	18.8	11.2	29.3	22.0	20.8	16.5 (6.54)
TotalN ₂ (mg/L)	25.1	34.8	16.1	27.0	14.6	29.8	20.7	28.5	19.8	30.0	41.4	32.2	19.4	42.4	36.2	31.1	28.0 (8.40)
Total-P(mg/L)	2.80	2.90	2.80	10.0	5.60	3.85	4.22	10.0	5.09	6.81	2.62	1.57	0.48	1.99	2.61	2.35	4.10 (2.78)
Turbidity (NTU)	423	535	440	289	73	90	88.1	74.3	71.2	68.3	57	60	48	39	32	29	151 (168)

Table 4.3: Characteristics of sewage wastewater samples of Drain-3

Drain-3	1-October 2012			16-November 2012		7-January 2013		3-February 2013			16-April 2013			2-June 2013			Mean(S.D)
	5am	11am	5pm	10am	4pm	8am	2pm	7am	1 pm	7pm	6am	12 noon	6pm	9am	3pm	8pm	
COD(mg/L)	301	161	125	235	66	290	421	213	71	64	388	230	199	280	188	168	212 (106)
BOD(mg/L)	20.5	18.3	15.0	130	26.6	80.0	130	60.0	20.0	18.9	120	55.0	45.5	75.0	60.0	40.0	57.1 (40.2)
MPN(Ln/ 100mL)	14.9	15.7	14.1	9.99	9.31	11.1	10.7	11.6	11.4	9.3	11.9	9.79	9.58	9.95	12.1	12.2	11.3 (1.97)
TSS (mg/L)	90	60	60	718	1694	460	400	260	240	370	300	160	240	600	570	610	427 (395)
TDS(mg/L)	1516	720	1310	720	400	880	1020	1030	780	1030	730	650	610	754	846	959	872 (272)
Cl (mg/L)	84.9	73.2	63.7	72.4	82.4	76.9	46.9	31.9	12.8	31.9	44.5	37.5	46.9	74.9	99.9	105	61.0 (26.3)
SO₄²⁻(mg/L)	24.6	10.6	41.1	14.8	10.6	30.4	78.1	39.1	32.9	57.6	16.6	12.5	8.10	16.0	11.6	10.4	25.9 (19.8)
Alkal.(mg/lasCaCO₃)	720	640	583	560	480	446	343	570	610	575	480	420	383	820	730	800	572 (143)
TKN(mg/L)	13.9	12.2	14.2	10.1	25.9	29.8	28.5	30.8	27.7	21.9	17.7	15.5	20.1	28.6	32.0	24.9	22.1 (7.34)
NO₃⁻(mg/L)	11.3	4.10	4.15	2.3	1.78	0.15	1.13	3.21	11.3	13.8	1.10	1.30	3.80	0.03	0.06	0.09	3.72 (4.43)
NO₂⁻(mg/L)	2.00	0.88	0.61	0.28	0.20	0.24	0.55	3.51	3.39	1.05	0.19	0.08	0.12	0.10	0.15	0.18	0.84 (1.13)
Org.N₂ (mg/L)	2.80	1.00	5.40	3.29	11.1	10.8	14.8	3.30	6.92	2.10	4.00	4.81	7.98	13.2	14.0	10.4	7.24 (4.56)
Amm.N₂ (mg/l)	11.4	11.1	7.9	6.9	14.8	16.9	13.6	27.4	20.8	19.8	13.7	10.7	12.2	15.4	18.0	14.5	14.6 (5.13)
TotalN₂ (mg/L)	27.3	17.2	19.0	12.8	27.8	30.1	30.2	37.5	42.3	36.7	19.1	16.9	24.1	28.7	32.1	25.1	26.6 (8.26)
Total-P(mg/L)	2.70	14.2	6.60	11.1	6.20	4.90	4.20	1.00	1.60	5.0	3.40	1.61	2.00	1.60	1.93	0.91	4.30 (3.76)
Turbidity (NTU)	387	447	342	323	257	64.8	33.9	16.9	20.3	23.8	20.1	27.3	31.1	19.0	17.7	23.9	128 (159)

Table-4.4: Characteristics of storm water samples of Drain -1

Drain-1	29 th September 2012 (Rainfall intensity- 21mm)			3 rd February 2013 (Rainfall intensity- 16mm)			7 th June 2013 (Rainfall intensity- 34mm)		
	Initial sample	Duration 30 min.	Initial to next sample ratio	Initial sample	Duration 30 min.	Initial to next sample ratio	Initial sample	Duration 30 min.	Initial to next sample ratio
COD (mg/L)	103	51	2.01	228	147	1.55	538	440	1.22
BOD (mg/L)	40.0	17.5	2.28	60.0	23.2	2.58	120	75.6	1.58
MPN(Ln/100mL)	14.34	13.91	1.030	10.46	9.952	1.051	14.88	14.94	0.995
TSS (mg/L)	1650	553	2.98	290	150	1.93	340	222	1.53
TDS (mg/L)	542	472	1.14	830	540	1.53	442	312	1.41
Cl (mg/L)	44.9	59.9	0.74	35.8	37.9	0.94	60.0	66.7	0.89
SO₄²⁻(mg/L)	9.00	8.21	1.09	18.4	24.0	0.76	41.9	33.6	1.24
Alkalinity(mg/Las CaCO₃)	550	410	1.34	690	614	1.12	580	485	1.19
TKN (mg/L)	21.4	19.9	1.07	25.4	18.9	1.34	21.0	26.2	0.80
NO₃⁻(mg/L)	2.88	5.10	0.56	6.12	7.50	0.81	2.18	3.20	0.68
NO₂⁻(mg/L)	0.31	1.75	0.17	4.23	3.64	1.16	0.016	1.06	0.01
Org. N₂ (mg/L)	5.90	7.50	0.78	7.45	4.32	1.72	7.58	6.13	1.23
Amm.N₂(mg/L)	15.5	12.4	1.25	18.0	14.6	1.23	13.5	20.1	0.67
TotalN₂ (mg/L)	24.5	26.8	0.91	35.7	30.0	1.19	23.2	30.5	0.76
Total-P (mg/L)	3.006	5.28	0.56	3.00	4.21	0.71	1.00	2.90	0.34
Turbidity(NTU)	461	352	1.38	19.7	16.4	1.20	31.9	33.8	0.94

Table-4.5: Characteristics of storm water samples of Drain -2

Drain-2	29 th September 2012 (Rainfall intensity- 21mm)			3 rd February 2013 (Rainfall intensity- 16mm)			7 th June 2013 (Rainfall intensity- 34mm)		
	Initial sample	Duration 30 min.	Initial to next sample ratio	Initial sample	Duration 30 min.	Initial to next sample ratio	Initial sample	Duration 30 min.	Initial to next sample ratio
COD (mg/L)	350	285	1.22	457	260	1.75	515	422	1.22
BOD (mg/L)	45.5	30	1.51	115	70	1.64	120	40	3
MPN(Ln/100mL)	14.9	14.8	1.00	12.3	14.4	0.85	14.2	12.2	1.16
TSS (mg/L)	1312	720	1.82	480	340	1.41	680	620	1.09
TDS (mg/L)	610	310	1.96	920	580	1.58	812	990	0.82
Cl (mg/L)	60.9	63.4	0.96	39.5	36.7	1.07	89.5	69.7	1.28
SO₄²⁻(mg/L)	18.20	17.48	1.04	22.3	19.3	1.15	8.45	9.70	0.87
Alkalinity(mg/Las CaCO₃)	820	748	1.09	512	488	1.04	610	640	0.95
TKN (mg/L)	18.7	15.4	1.21	21.4	22.5	0.95	30.4	28.9	1.05
NO₃⁻(mg/L)	4.00	2.67	1.49	2.59	1.40	1.85	1.009	0.08	12.6
NO₂⁻(mg/L)	1.003	0.007	1.43	2.00	0.58	3.44	0.166	0.024	6.91
Org. N₂ (mg/L)	1.8	1.1	1.63	8.5	4.9	1.73	6.3	1.9	3.31
Amm.N₂(mg/L)	16.9	14.3	1.18	12.9	17.0	0.75	24.1	27.0	0.89
TotalN₂ (mg/L)	23.7	18.0	1.31	25.9	24.4	1.06	31.5	29.0	1.08
Total-P (mg/L)	1.009	1.50	0.67	4.90	3.70	1.32	2.00	1.45	1.37
Turbidity(NTU)	174	280	0.62	80.9	74	1.09	22	32	0.68

Table-4.6: Characteristics of storm water samples of Drain -3

Drain-3	29 th September 2012 (Rainfall intensity- 21mm)			3 rd February 2013 (Rainfall intensity- 16mm)			7 th June 2013 (Rainfall intensity- 34mm)		
	Initial sample	Duration 30 min.	Initial to next sample ratio	Initial sample	Duration 30 min.	Initial to next sample ratio	Initial sample	Duration 30 min.	Initial to next sample ratio
COD (mg/L)	331	58	5.70	301	188	1.60	203	166	1.22
BOD (mg/L)	38.3	22.9	1.67	50.0	45.5	1.09	30.8	20.0	1.54
MPN(Ln/100mL)	16.0	15.76	1.01	10.2	10.04	1.01	13.01	12.84	1.013
TSS (mg/L)	2166	1332	1.62	330	260	1.26	540	480	1.12
TDS (mg/L)	282	174	1.62	1490	960	1.55	810	760	1.06
Cl (mg/L)	53.7	52.4	1.02	31.6	32.9	0.96	44.9	43.2	1.03
SO₄²⁻(mg/L)	7.41	6.58	1.12	41.1	39.0	1.05	31.4	26.4	1.18
Alkalinity(mg/Las CaCO₃)	305	150	2.03	525	410	1.28	712	568	1.25
TKN (mg/L)	27.6	17.8	1.55	29.3	26.0	1.12	15.9	12.7	1.25
NO₃⁻(mg/L)	6.00	7.90	0.75	2.90	3.20	0.90	0.098	0.199	0.49
NO₂⁻(mg/L)	1.30	2.00	0.65	0.146	1.03	0.14	0.063	0.301	0.20
Org. N₂ (mg/L)	11.5	8.60	1.33	3.98	6.91	0.57	4.11	1.80	2.28
Amm.N₂(mg/L)	16.6	9.2	1.80	24.0	19.3	1.24	11.8	10.9	1.08
TotalN₂ (mg/L)	34.9	27.7	1.25	32.3	30.2	1.06	15.9	13.2	12.0
Total-P (mg/L)	2.20	4.00	0.55	1.00	2.91	0.34	0.033	0.091	0.36
Turbidity(NTU)	327	299	1.09	39.2	31.3	1.25	19.9	21.7	0.91

Table-4.7: Drain-1 inflow rates (m³/hr)

DAY	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
6:00	-	-	-	570	-	-	-
7:00	-	-	-	24.46	-	-	-
8:00	-	-	-	22.29	-	-	-
9:00	3.05	32.62	14.27	3.39	9.51	14.27	8.15
10:00	2.44	34.66	14.27	3.39	9.51	14.27	8.15
11:00	3.53	8.15	10.19	2.99	6.79	10.19	5.43
12:00	3.53	6.62	4.74	2.71	5.89	4.74	5.43
1:00	3.53	8.15	5.09	3.49	4.41	5.09	5.809
2:00	3.53	7.44	5.09	3.49	4.41	5.09	4.41
3:00	3.80	7.64	5.09	3.49	4.41	5.09	4.75
4:00	25.95	8.15	4.08	3.49	4.41	4.08	20.39
5:00	4.35	7.34	5.43	8.83	19.57	5.43	4.57
6:00	4.96	4.45	10.60	10.33	17.51	10.60	5.09
7:00	4.75	4.13	9.51	6.34	8.15	9.51	4.07
8:00	-	-	-	NA	-	-	-
9:00	-	-	-	NA	-	-	-

Table-4.8: Drain-2 inflow rates (m³/hr)

DAY	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
6:00	-	-	-	32.62	-	-	-
7:00	-	-	-	39.34	-	-	-
8:00	-	-	-	77.03	-	-	-
9:00	85.64	46.21	21.20	40.78	29.63	21.61	78.30
10:00	36.70	40.78	42.41	37.03	25.16	20.39	65.25
11:00	48.93	29.80	19.37	20.39	21.90	74.22	14.23
12:00	14.08	20.18	19.37	15.22	32.62	74.22	17.61
1:00	9.55	8.36	12.91	11.41	13.34	13.59	14.68
2:00	5.43	8.92	10.29	7.21	7.67	8.35	8.07
3:00	3.80	10.79	8.88	6.93	11.01	5.07	5.80
4:00	14.68	9.90	9.58	12.23	5.74	7.34	4.45
5:00	27.79	10.87	15.33	17.47	7.34	27.38	33.68
6:00	38.74	13.37	19.16	36.70	27.38	26.10	26.71
7:00	54.37	27.73	20.39	36.70	37.28		18.55
8:00	-	-	-	47.18	-	-	-
9:00	-	-	-	21.75	-	-	-

Table-4.9: Drain-3 inflow rates (m³/hr)

DAY	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
6:00	-	-	-	27.89	-	-	-
7:00	-	-	-	89.88	-	-	-
8:00	-	-	-	91.80	-	-	-
9:00	63.75	66.93	47.81	63.75	57.37	78.14	57.37
10:00	66.93	61.20	47.81	63.75	69.32	80.32	57.37
11:00	66.93	29.75	39.84	56.00	69.32	57.37	39.84
12:00	66.93	57.37	47.81	53.27	69.32	57.37	47.81
1:00	66.93	28.68	47.81	53.27	46.21	44.62	47.81
2:00	65.02	35.85	47.81	34.15	31.87	44.62	19.92
3:00	40.98	20.08	61.20	34.15	31.87	37.29	28.68
4:00	19.92	19.92	31.87	23.90	31.87	46.61	71.71
5:00	59.76	59.76	31.87	38.25	30.60	20.59	44.62
6:00	95.62	95.62	29.64	47.81	38.25	38.25	40.98
7:00	59.28	59.28	47.81	54.64	38.25	43.56	56.00
8:00	-	-	-	57.37	-	-	-
9:00	-	-	-	32.93	-	-	-

Table-4.10: Water samples of Pond 1 at different locations

Station locations	Various depths	COD mg/l	BOD mg/l	MPN /100ml	TSS mg/l	TDS mg/l	Cl mg/l	SO ₄ ²⁻ mg/l	Nitrate mg/l	Nitrite mg/l	TKN mg/l	amm. N ₂	org. N ₂ mg/l	total N ₂ mg/l	TP mg/l	Alkal. mg/l As CaCO ₃	Chlorp mg/l
2nd point	surface	222	35	1.3*10 ³	115	1000	284	57.6	0.062	0.019	16.5	15.5	8.8	16.6	0.489	1010	–
	mid (2 feet)	229.4	80	2.4*10 ³	85	960	204	49.3	0.026	0.022	22.2	14.2	8.0	22.3	0.515	890	–
	lower (3 feet)	333	60	2.6*10 ³	55	880	349	56.3	0.044	0.017	19.9	12.9	6.9	19.9	0.524	970	–
4th point	surface	51.8	70	6.8*10 ²	105	1090	404	40.6	0.074	0.026	11.0	7.5	3.5	11.1	0.253	880	–
	mid (2 feet)	66.4	10	7.8*10 ³	33	1010	229	57.6	0.002	0.023	15.9	10.1	5.7	15.9	0.341	1000	–
	lower (3 feet)	140.6	50	6.4*10 ³	43	1136	239	16.4	0.07	0.035	10.5	5.7	4.8	10.6	0.393	980	–
5th point	surface	784.4	55	4.5*10 ²	106	1050	184	64.6	0.048	0.021	20.0	13.3	6.7	20.1	0.387	970	–
	mid (2 feet)	695.6	60	2.2*10 ³	136	1060	209	23.4	0.063	0.015	22.0	17.1	4.9	22.1	0.403	980	–
	lower (3 feet)	706.2	165	2.1*10 ³	101	850	154	72.8	0.019	0.031	20.0	17.3	2.6	20.1	0.418	880	–
6th point	surface	865.8	30	1.7*10 ³	112	1180	130	8.2	0.054	0.644	10.8	7.6	3.2	11.5	0.414	930	–
	Mid (2 feet)	1361.6	95	2.6*10 ³	130	960	175	32.9	0.072	0.862	16.4	8.0	8.4	17.398	0.424	790	–
	lower (3 feet)	1413.4	205	1.7*10 ⁴	77	880	215	7.4	0.082	0.918	9.7	7.5	2.2	10.7	0.503	870	–
7th point	surface	236.8	95	1.4*10 ⁴	80	1180	170	83.9	0.058	0.75	50.9	34.6	16.3	51.7	0.549	890	–
	mid (2 feet)	599.4	80	1.7*10 ³	192	1060	200	90.5	0.065	0.453	25.4	15.3	10.0	25.9	0.585	840	–
	lower (3 feet)	666	75	1.7*10 ³	65	960	174	84.7	0.068	1.338	24.8	17.1	7.7	26.2	0.613	700	–

Table-4.11: Water samples of Pond 2 at different locations

Station locations	Various depths	COD mg/l	BOD mg/l	MPN /100ml	TSS mg/l	TDS mg/l	Cl mg/l	SO ₄ ²⁻ mg/l	Nitrate mg/l	Nitrite mg/l	TKN mg/l	Amm. N ₂	Org. N ₂ mg/l	Total N ₂ mg/l	TP mg/l	Alkal. mg/l As CaCO ₃)	Chlorp mg/l
1st point	Surface	350	100	1.7*10 ⁴	140	250	34	16.7	1.008	0.510	19.3	18.2	1.1	20.8	3.89	479	2.85
	mid (2 feet)	340	80	1.4*10 ⁴	132	238	37.5	16.6	1.055	0.280	12.3	10.45	1.9	13.6	3.4	456	-
	lower (4 feet)	259	60	1.5*10 ⁴	88	165	39	17.5	0.098	0.086	16.3	14.5	1.8	16.4	2.19	457	-
2nd point	Surface	202	43	2.8*10 ⁵	548	635	23.8	23.2	1.268	0.609	28.8	27.5	1.29	30.6	5.63	528	3.15
	mid (2 feet)	169	10	2.9*10 ⁵	525	649	25	18.8	1.198	0.508	23.5	20.1	3.4	25.2	4.66	521	-
	lower (4 feet)	155	18	1.8*10 ⁴	478	621	35	15.0	1.043	0.505	29.0	25.9	3.1	30.5	4.03	498	-
3rd point	Surface	132	54	3.1*10 ⁵	320	532	61.5	27.33	1.300	0.809	19.8	18.5	1.3	21.9	3.8	429	-
	mid (2 feet)	69	39	2.9*10 ⁵	318	510	59	19.18	0.879	0.051	20	18.1	1.9	20.9	3.2	473	-
	lower (4 feet)	60	20	2.9*10 ⁵	279	505	58	18.0	0.604	0.068	22	20.6	1.4	22.6	3.1	393	-
4th point	Surface	132	31	1.6*10 ⁶	422	613	51.4	17.8	4.020	0.390	25	23.6	1.5	29.4	4.9	510	1.90
	Mid (2 feet)	128	22	1.4*10 ⁶	388	605	49.8	16.9	3.998	0.310	18	15.4	2.6	22.3	4.8	445	-
	lower (4 feet)	135	30	1.2*10 ⁶	358	588	47	26	1.920	0.299	18.5	15.7	2.8	20.7	4.2	440	-
5th point	Surface	152	31	3.1*10 ⁵	319	728	58	33.5	2.390	0.065	14.5	9.9	4.6	16.9	5.3	622	2.95
	mid (2 feet)	148	30	3.8*10 ⁵	310	699	40.8	18.7	1.119	0.061	17.3	13.7	3.6	18.4	4.7	612	-
	lower (4 feet)	139	30	3.2*10 ⁵	269	646	51.9	10.1	1.000	0.059	16.4	12.3	4.1	17.4	3.8	608	-

Table-4.12: Watershed Characteristics

SUB-WATERSHED	AREA Acres (m ²)	CHANNEL LENGTH	SLOPE	Tc	CN
		Feet (m)			
Pond- 1	23.17 (93765)	720 (219.45)	0.002	24	77
Pond-2	37.37 (151230)	1181 (360)	0.013	18	76

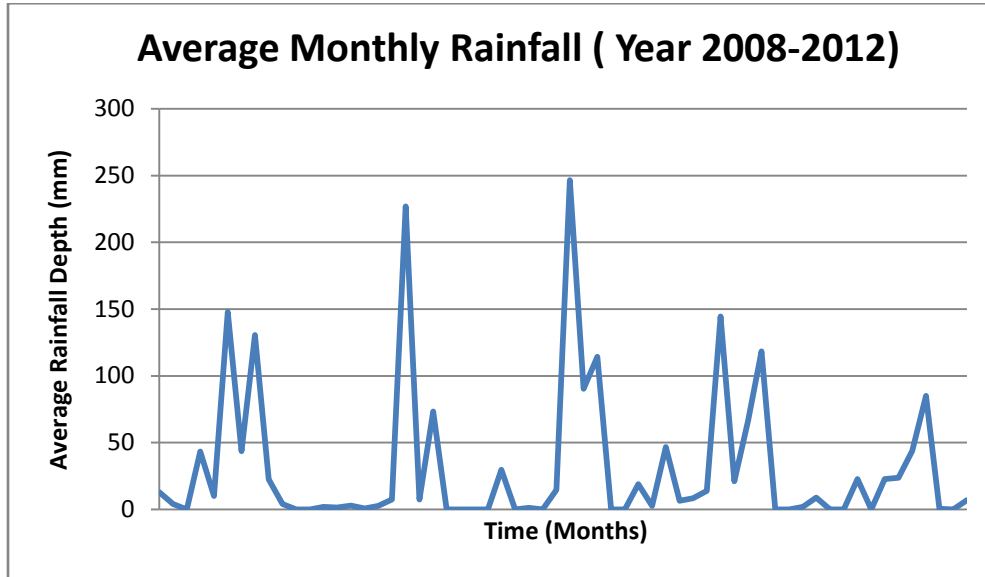


Fig. 1.5: Rainfall data for the village region

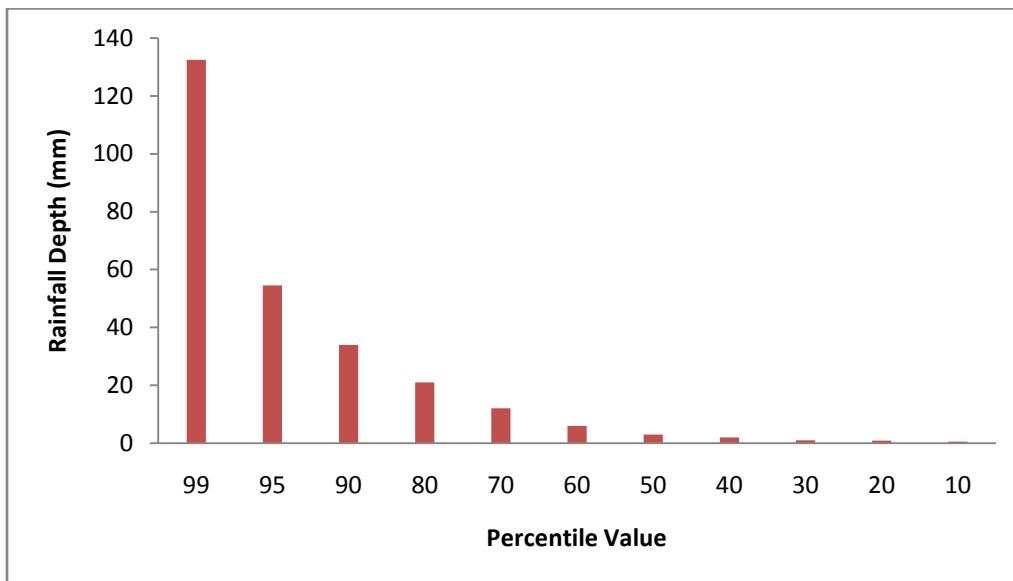


Fig 1.6: Percentile event size relationship

Table 4.13: Storm water flows

Village ponds	Storm water volume at 90% percentile $\leq 34\text{mm}$	Storm water directly added to the pond	Total stormwater	Daily sewage load (m^3/day)
Pond 1	496.4	120	616.4	364.8
Pond 2	350.9	160	510.9	156

Table 4.14: Storm water loads in village ponds

Pollution loads	Pond 1	Pond 2
COD (kg/90% rainfall event)	157	72.9
BOD (kg/90% rainfall event)	31.3	12.1
TSS (kg/90% rainfall event)	304	299
TP (kg/90% rainfall event)	1.4	0.6
Total N₂ (kg/90% rainfall event)	13.4	9.0
Coliform count	13.4*	13*

* natural log numbers per 100 mL

Table-4.15: Pollution loads through the sewage

Pollution loads	Pond 1		Pond 2	
	Conc. (mg/L)	Kg/day	Conc. (mg/L)	Kg/day
COD (kg/day)	419	794	212	261
BOD (kg/day)	103.8	208	57.1	70.4
TSS (kg/day)	604.5	1048	427	526
TP (kg/day)	3.70	6.5	4.3	5.3
Total N₂ (kg/day)	26.3	47.3	26.6	32.8
Coliform count (nat. logs/100 ml)	10.9 (5.4×10^5)	---	11.3 (8.1×10^5)	---

CHAPTER 5

CONCLUSION

The present study has concentrated on the quantification and characterization of the village sewage and storm water being received by the two ponds of the village. US-SCS-CN method was employed for the quantification of the storm water. Rainfall data for the village was not available. Rainfall data from a station around 50 km away from the village was used. The data available was just the number of rainy days and the monthly rainfall. Hence, for data on individual storm events, rainfall data for Patiala station was depended on.

For the quantification of sewage two methods were unsuccessfully tried. With the existence of two water supply systems, a village level water supply system and a multitude household level water supplies, water consumption could not be measured accurately and used for estimating sewage generation. Flow measurement in the drain through monitoring the float velocity could not be worked on because of the difficulties to monitor in darkness. Per capita sewage generation of 120 LCPD was finally used for the quantification of sewage.

The study has revealed the following:

- Water and pollution contributions by storm water is not very significant when compared with the contributions by the sewage.
- The village ponds are working reasonably well in the treatment and disposal of sewage and storm waters they receive. Weed infestation and eutrophication were infact the problems associated with the ponds.
- Flooding and overflowing of the village ponds are very rare events. Hence, artificial/intentional disposal of the pond water is not actually required.

Not allowing black water into the drains to the village ponds, passing the incoming wastewater through a wetland system prior to entry into the pond, maintaining the pond to prevent weed infestation, and using a filtration system for extracting water from the village pond have been suggested as measures for the village pond water resources management.

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