Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 15	No. 2	pp. 673-678	2016

Original Research Paper

Seasonal Assessment of Wastewater Characteristics in Hilly Tourist Place and its Implication in Selection and Design of Wastewater Treatment Alternatives

Nitin Kumar Singh† and Siddhartha Pandey
Department of Civil Engineering, Indian Institute of Technology, Roorkee-247 667, Uttarakhand, India
†Corresponding author: Nitin Kumar Singh

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 18-07-2015
Accepted: 28-08-2015

Key Words:
Wastewater characterization
Hilly terrain
rbCOD
Municipal sewage
Ratio parameter

ABSTRACT

Present investigation reports temporal variation in wastewater quality generated in a hilly and isolated tourist place Rishikesh, India. The prevailing demographic and geographical conditions here disallow a conventional treatment process to be implemented. In this context, an extensive wastewater characterization was exercised for the fractionation and quantification of domestic wastewater constituents e.g. organics and other nutrients. Characterization results demonstrated that a medium strength of wastewater is being generated bearing moderate values of chemical oxygen demand (COD) with low, readily biodegradable COD content which infers that the wastewater generated is not readily biodegradable. Furthermore, various important ratio parameters were established and assessed to ideate an appropriate wastewater treatment system for hilly areas. Results manifest that a biological treatment system with high SRT and with less vulnerability to the seasonal shock loads imposed by various physico-chemical parameters is preferable, especially for hilly tourist places.

INTRODUCTION

Wastewater treatment in isolated, hilly and sacred tourist places has always been a challenging task for environmental engineers (Schories 2008) due to the infeasibility of lay down on sewer lines, sacredness of place and vulnerability of surface as well as groundwater bodies. Besides this, a panoptic variation in temporary and permanent population is an important factor to recommend an appropriate treatment system for these places as it directly reflects a tremendous fluctuation in volume and characteristics of the wastewater (Brar et al. 2000, Mielke et al. 1999).

India serves more than 16% of the world's population with only 4% available freshwater resources on earth (Singh 2003). Places adjacent to freshwater bodies are considered as environmentally sensitive, as these are often a significant attraction for tourists. Rishikesh, situated in the Uttarakhand state of India, is the first town where the Ganges touches the plains after emerging from the Gangotri glacier in Himalayas. According to the Central Ganga Authority (1987), Rishikesh is the first place where two primary water quality parameters i.e. BOD and coliforms become significant (Helmer & Hespanhol 1997). Being a fanatically religious and yoga practicing place, pilgrims gather here for spiritual healing and successively a proportionate waste gets generated inevitability during their stay which is mainly responsible for increased load of pollution in the river Ganges (Kumar & Chopra 2012). Increasing pollution in the Ganges, imposes more stringent effluent disposal limitations to the downstream wastewater treatment facilities.

In this context, an unconventional, yet effective waste water management option is needed to be devised and implemented in these tourist areas. From a wastewater management point of view, the development of low cost and sustainable wastewater treatment option must be emphasized within the context of maintaining the delicate balance between conservation of water bodies having sacred values like the Ganges and sustainable rural/urban development. Generally, domestic wastewater treatment is primarily confined to organics, nutrients and priority pollutant removal. For an effective wastewater management, a comprehensive and precise knowledge of wastewater characteristics is required to design WWTPs and disposal systems as well as the development of water conservation and waste reduction strategies (Bennett & Daniel 1975, Al-Jayyousi 2003). The necessity for a proper wastewater management has brought forth the need of detailed wastewater characterization.

The utmost necessity before selection of an appropriate wastewater treatment alternative, is the acquisition of qualitative and quantitative information on wastewater characteristic (Spanjers et al. 1998, Henze 1992, Phillips et al. 2009). To design a wastewater treatment scheme, various constraints such as ambient temperature, land availability, access to the place and socioeconomic role of water bodies, are needed to be appraised. Without a thorough characterization,

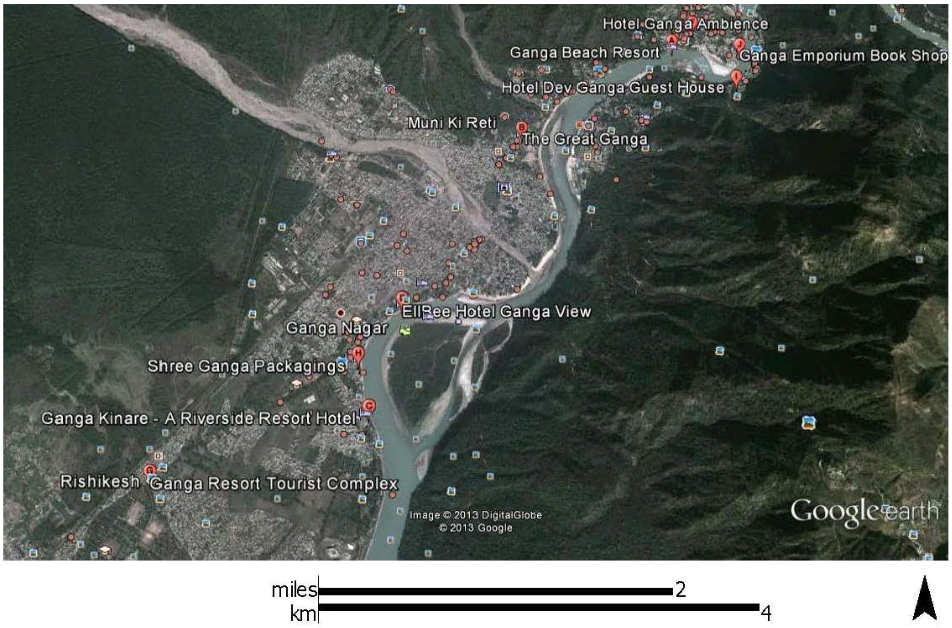

Fig. 1: Map of study area (Source: Google Earth).

wastewater treatment facilities may either be under or overdesigned resulting in inefficient treatment, consequently producing severe impacts on the surrounding environment. The wastewater quality is generally season specific and local weathering, and should be determined *in situ* for design purpose. Characterization of municipal wastewaters has been the central theme or the indispensable starting point, of many wastewater mitigation studies.

A detailed characterization can be useful to foreshadow the following (Metcalf & Eddy 2010):

- Waste sludge production (depends on the concentration of inert particulate COD)
- Aeration requirement (factor influenced by the presence of biodegradable COD)
- Denitrification rate i.e., total nitrogen removal and phosphorus removal governed by estimated readily biodegradable COD

It can thereby be concluded that it is necessary to characterize the wastewater in terms of physico-chemical and biological parameters, when planning a treatment scheme at hilly areas. It is also important to mention here that the selection and role of wastewater treatment alternatives become more important for places which lie in low temperature zones.

Present study encompasses a comprehensive and detailed characterization of municipal sewage in order to conceive an appropriate wastewater treatment alternative, addressing isolated and hilly areas. This study summarizes the seasonal variation in sewage quality using different pollution governing parameters and discusses probable impacts of the wastewater characteristics in the selection and design of treatment plans.

EXPERIMENTAL PROGRAMS

Description of the study area: Rishikesh is a hilly tourist place, which is well known for its yoga practices across the globe. The population of this area intermittently varies seasonally throughout the year. Approximately 50000 tourists are always expected to be present in Rishikesh. About ~10 fold difference can be experienced in the population here at seasonal prime, which directly reflects to the volume of wastewater generated. The city of Rishikesh is situated on the bank of river Ganges surrounded by the Himalayas and receives heavy rainfall sporadically. The summer season lies between the months of March to June, where the maximum temperature is notably around 35°C. The monsoon season lies generally between July and September and the rainfall is noticed highest typically in the month of August. During the winter season the average temperature is marked about 8°C with a maximum of 20°C. The water in the river Ganges is generally cold except during the monsoon.

MATERIALS AND METHODS

Spot samples were collected seasonally from sewage pumping station (SPS) in Rishikesh, from where the sewage is transferred to two existing wastewater treatment facilities.

Table 1: Characterization parameters with method followed in present study.

Parameter	References
Alkalinity, Hardness, TSS, VSS, iTSS, nbVSS, BOD_5, BOD_{5s}, BOD_{5f}, COD, COD_s, COD_f, CBOD, NBOD, TC, FC, HPC, E. Coli, Salmonella and Shigella	(APHA 1995)
rbCOD, sbCOD, Soluble nbCOD, Particulate nbCOD	(Wentzel et al. 1999, Ekama et al. 1986, Hu et al. 2002, Xu & Hasselblad 1996)
ffCOD, fsCOD	(Mamais et al. 1993)
nbVSS, bTKN, nbTKN, VFA	(Metcalf & Eddy 2010)

Table 2: Seasonal variation in wastewater characteristics (average ± std. deviation).

Parameters	Unit	Summer*	Winter*	Monsoon*
pH	-	7.3±0.6	7.3±0.1	8±0.9
Temperature	°C	22.6±3.5	19.5±2	22.6±1
Turbidity	NTU	482.0±404.7	186±65.8	59±25.9
Alkalinity	mg/L	363±43.2	274.3±48.6	316.7±35.5
Electrical conductivity	µS/cm	521.7±202.7	539.3±129	482.7±122.6
Hardness	mg/L	182±33.7	119.7±10	193.3±17.2
TSS	”	331.7±105.6	309.7±122.3	207.3±23.8
VSS	”	248.3±78.2	209±90.6	152.7±15
iTSS	”	83.3±28	100.7±32.5	54.7±9.8
nbVSS	”	34±8.9	22±6.6	16.3±5
BOD_5	”	183±58	167±39.7	132.7±23.4
BOD_{5f}	”	54±9	80.3±10.7	55.3±18.6
BOD_{5s}	”	8±1	21.3±5.8	11±1.7
Ultimate BOD	”	263.7±84.6	243±57.7	193±34
CBOD	”	153±50.5	145.3±33.3	109.3±20.2
NBOD	”	30±7.5	21.7±6.5	23.3±3.2
COD	”	485.7±95.6	461±218.8	375.7±40.5
COD_f	”	163.3±34.9	234±39.9	195±19.7
COD_s	”	95.3±7.1	72±15.9	73±9.5
bCOD rbCOD (soluble)	mg/L	24.7±6.7	22±5	21.3±6.8
sb COD (Particulate)	”	230.3±68.7	219±39.2	176±30.8
nbCOD nb COD (Soluble)	mg/L	136.3±47.2	134.7±107.1	106.3±22.
nb COD (Particulate)	”	94.3±6.4	85.3±75.1	72±20
ffCOD	mg/L	192.7±78.1	166.3±97.1	126±15.5
fsCOD	”	25.7±7.1	22.7±9.3	21±13.2
NH_4-N	”	22.2±6.5	46±29.1	30±5.6
NO_3-N	”	4.5±1.2	4.5±2	2.7±0.8
TKN	”	28.7±6.5	54±28	38±5.6
Total N	”	34.3±5.5	57.8±30.4	40.7±4.2
sTKN	”	7±3.6	10.3±4	9.3±2.5
fTKN	”	9.7±3.8	18±7.5	14.7±3.8
bTKN	”	23.7±5.5	45.7±22.5	31±5.2
nbTKN	”	5±1	8.3±5.5	7±2
OP	”	2.6±0.6	1.9±0.2	2.6±0.7
TP	”	4.6±0.9	3.1±0.4	4.3±1
VFA	”	121.7±22.6	57.3±7	29.3±4.9
Sulphate	”	78±5	48.7±3.5	25.3±4
Chloride	”	57±5.6	59.3±12.9	22±3
Microbial analysis TC	CFU/mL	$1.07×10^8±1.3×10^8$	$8.2×10^5±1.2×10^5$	$2.4×10^8±4×10^8$
FC	”	$3.4×10^5±5×10^5$	$1.5×10^4±2.3×10^4$	$4.3×10^4±2.1×10^3$
E. Coli	”	1700±1081.7	1400±360.6	2200±1053.6
Salmonella	”	22.7±5.5	22.3±7.1	21.7±11.9
Shigella	”	1233.3±550.8	2000±360.6	2133.3±288.7
HPC	”	1933.3±709.5	1933.3±251.7	1266.7±472.6

*Average values along with standard deviation are presented

Table 3: Ratio parameters at a glance in different seasons.

Time of year	Summer			Winter			Monsoon		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
COD : N	14.6	4.6	9-19	8.2	1	7-10	9.4	1.9	7-12
COD_f : N	4.8	1.3	3-6	4.6	1.8	3-7	4.8	0.9	4-6
COD_s : N	2.8	0.5	0.5-4	1.4	0.4	0.4-2	1.8	0.3	0.5-3
BOD_5 : N	5.5	2	3-8	3.2	1	2-5	3.3	0.9	2-5
BOD_{5f} : N	1.6	0.4	1-2	1.6	0.8	1-3	1.3	0.5	1-2
BOD_{5s} : N	0.2	0.05	0.1-0.3	0.4	0.2	0.2-0.7	0.3	0.05	0.2-0.4
VSS : SS	0.74	0.01	0.72-0.76	0.66	0.04	0.6-0.7	0.73	0.02	0.71-0.76
iTSS : SS	0.25	0.01	0.23-0.26	0.33	0.04	0.29-0.38	0.06	0.02	0.24-0.28
nbVSS : SS	0.1	0.02	0.08-0.12	0.08	0.04	0.03-013	0.08	0.03	0.04-0.11
BOD_5 : COD	0.37	0.05	0.33-0.43	0.39	0.09	0.28-0.46	0.35	0.05	0.29-0.38
BOD_{5f} : COD	0.11	0.009	0.1-0.12	0.19	0.07	0.11-0.26	0.14	0.05	0.08-0.19
BOD_{5s} : COD	0.01	0.001	0.01-0.02	0.05	0.02	0.02-0.06	0.02	0.006	0.02-0.03

Wastewater has been typically dissevered into its organic and inorganic constituents, e.g. carbonaceous substrate, nutrients (nitrogen & phosphorus compounds), solid fraction (fixed and volatile), interfering ions and microbial population etc. Table 1 summarizes the list of qualitative parameters which were quantified to characterize the municipal wastewater lineament in Rishikesh. These parameters were selected for their significance in designing a wastewater treatment scheme and for pollution abatement.

RESULTS AND DISCUSSION

Table 2 summarizes the comprehensive results incurred from characterization and provides a perspective of how the sewage quality varies seasonally throughout the year. These results can be construed as a rough indication of the treatability of wastewaters. The BOD_5:COD ratio is one of the most substantial parameters for such an interpretation. Both the parameters are used as indices of the organic content of wastewaters. BOD_5:COD ratio is a useful parameter for the modeling of wastewater treatment processes as it sets electron equivalence of the substrate, biomass and oxygen requirement, and also reflects biodegradable organics and residual constituents. Alone the BOD_5 is reckoned as a poor index of easily biodegradable substrate, whereas BOD_5:COD ratio may be conceived as an acceptable index for biological treatability, or more accurately a rough proportion of readily and slowly biodegradable organic matter. Results reported in Table 2 manifests that, in all the seasons, temperature lies in the mesophilic range (10-45°C), which is appreciably suitable for wastewater treating microorganisms.

In terms of solid loadings and organic content, a low strength sewage gets generated, especially during monsoon season with a decreasing trend in non-biodegradable content of volatile fraction. In addition, small quantities of recalcitrant compounds were found to be existed in the sewage of Rishikesh, which renders the industrial activity in this area as very limited.

Carbonaceous matter, characterized in terms of COD and BOD represents that a medium strength sewage gets generated in Rishikesh with a decreasing trend from summer to monsoon. Carbonaceous values of BOD show that the BOD exerted by nitrogenous content is very low as compared to organic compounds. High values of soluble COD imply an easier bioavailability of organic compounds in sewage which favours the biological treatment as a beneficial choice for wastewater treatment. Fractionation of COD was done to estimate readily and slowly biodegradable COD constituents. Results obtained from characterization of rbCOD and particulate COD suggest that sewage has a significant concentration of slowly biodegradable content which subsequently demands/favours the biological process with long sludge retention time (SRT) or sludge age. High SRT values are generally and preferably achieved by attached growth or hybrid processes. Total nitrogen content was found to be on higher side in winter. The probable reason may be less dilution in comparison to summer and monsoon seasons. TKN content of sewage comprises mainly of biodegradable constituents, which can be easily removed by a biological nutrient removal system with nitrogen assimilating bacteria. Total phosphorus content was found very less in comparison to total nitrogen content.

Microbial characterization was also done to quantify the presence of various human health threatening bacteria. Results incurred from this assessment show a high level of contamination with coliforms. Upon discharging infected sewage in the Ganges river stream, which is the sole source of drinking water supply in Rishikesh, the pathogenicity present in sewage may impose a severe threat on human health. Therefore, a disinfection of the sewage is must to be accomplished before its disposal.

Table 3 summarizes the various ratio parameters which are authoritative to be conceived before suggesting a waste water treatment alternative. Ideally COD to N ratio should prevaricate in the range of 2-20. Sewage rendered in Rishikesh has a medium value of COD to N ratio, entailing organic constituents dominate as compared to total nitrogen, which corresponds to an increase in oxygen demand and subsequently limits the denitrification and total nitrogen removal in treatment systems (Ding et al. 2012, Zafarzadeh et al. 2011).

The observed values of BOD_5 to N ratio were smaller as compared to ideal ratio 100:5 (Metcalf & Eddy 2010) indicating that the sewage has sufficient nutrients (N and P compounds) for biological growth of microorganisms. Although nitrogen constituents do not affect organics removal, but strongly influence the floc size and shape. Increased nitrogen level generally favours the filamentous growth of microorganisms which limits the selection of a suspended growth process. Temperature conditions at these places, also do not allow an anaerobic treatment system due to slow startup and growth. This is why an attached or hybrid growth process can be regarded as an appropriate and suitable option for such sewage kind (Slade et al. 2011, Pawlowski et al. 2013). The volatile fraction of the suspended solids is implicit in the VSS:SS ratio of wastewaters. As given in Table 3, this ratio was found to vary in the range of 0.66-0.74, indicating that ~30% of the suspended solids are of non-biodegradable nature. In this case, wastewater requires biological reactors with longer SRT (Paul & Liu 2012). The biodegradability of sewage for microbial transformation can be examined on the basis of BOD_5/COD ratio. In present study, although BOD_5 to COD ratio was on lower side throughout the year but ultimate BOD was significantly present in wastewater which requires a high biomass inventory with increased SRT in treatment systems (Pawlowski et al. 2013, Orhona et al. 1997).

CONCLUSIONS

An experimental campaign was run to assess the trend in the fluctuation of wastewater characteristics generated in hilly tourist areas. The organic content of sewage as depicted by COD concentration, exhibited fluctuation of 20-58% throughout the year, in reference with the beginning of summer period. Total nitrogen results are almost same in all the seasons, since nitrogen is closely related to human metabolism and likely to remain constant, whereas other parameters like COD, BOD, TP varies according to the activities with peak times or seasons throughout the year. It can be inferred from various assessed ratio parameters that selection of an appropriate treatment system not only depends on discrete parameters but also ratio parameters play a vital role. Authors suggest that a reliable wastewater characterization is a prerequisite for an accurate assessment of the pollution load, generated from a hilly place like Rishikesh, as well as the design of appropriate treatment technologies. For places lying in hilly terrain and having typical demographic and meteorological conditions alike Rishikesh, an attached or hybrid process can be a better alternative than other sole suspended/attached growth treatment systems.

ACKNOWLEDGEMENT

The authors are thankful to Uttarakhand PeyJal Nigam and Indian Institute of Technology, Roorkee, India for financial and technical support to accomplish this study.

REFERENCES

Al-Jayyousi, O.R. 2003. Grey water reuse: towards sustainable water management. Desalination, 156: 181-192.

APHA 1995. Standard Methods for the Examination of Water and Wastewater (19th ed.), American Public Health Association, American Water Works Association and Water Pollution Control Federation.

Bennett, E.R. and Daniel, L.K. 1975. Individual home wastewater characterization and treatment. Complement Report Series No. 66, Environmental Resource Center, Colorado State University.

Brar, M.S., Malhi, S.S., Singh, A.P., Arora, C.L. and Gill, K.S. 2000. Sewer water irrigation effects on some potentially toxic trace elements in soil and potato plants in Northwestern India. Can. J. Soil Sci., 80: 465-471.

Ding, Y., Song, X., Wang, Y. and Yan, D. 2012. Effects of dissolved oxygen and influent COD/N ratios on nitrogen removal in horizontal subsurface flow constructed wetland. Ecol. Eng., 46: 107-111.

Ekama, G.A., Dold, P.L. and Marais, G.V.R. 1986. Procedures for determining influent COD fraction and the maximum specific growth rate of heterotrophs in activated sludge systems. Water Sci. Technol., 18: 91-114.

Helmer, R. and Hespanhol, I. 1997. Water Pollution Control: A Guide to the Use of Water Quality Management Principles, CRC Press.

Henze, M. 1992. Characterization of wastewater for modelling of activated sludge processes. Water Sci. Technol., 25: 1-15.

Hu, Z., Chandran, K., Smets, B.F. and Grasso, D. 2002. Evaluation of a rapid physical-chemical method for the determination of extant soluble COD. Water Res., 36: 617-624.

Kumar, V. and Chopra, A.K. 2012. Monitoring of physico-chemical and microbiological characteristics of municipal wastewater at treatment plant, Haridwar city (Uttarakhand) India. J. Environ. Sci. Technol., 5: 109-118.

Mamais, D., Jenkins, D. and Pitt, P. 1993. A rapid physical-chemical method for the determination of readily biodegradable soluble cod in municipal wastewater. Water Res., 27: 195-197.

Metcalf, L., Eddy, H.P. and Tchobanoglous, G. 2010. Waste Water Engineering: Treatment, Disposal, and Reuse. McGraw-Hill.

Mielke, H.W., Gonzales, C.R., Smith, M.K. and Mielke, P.W. 1999. The urban environment and children health: soils as an integrator of lead, zinc and cadmium in New Orleans, Louisiana, USA. Environ. Res., 81: 117-129.

Orhon, D., Ates, E., Sözen, S. and Çokgör, E.U. 1997. Characterization and COD fractionation of domestic wastewaters. Environ. Pollut., 95: 191-204.

Paul, E. and Liu, Y. 2012. Biological Sludge Minimization and Biomaterials/Bioenergy Recovery Technologies. John Wiley & Sons.

Pawlowski, A. Dudzinska, M.R. and Pawlowski, L. 2013. Environmental Engineering IV. CRC Press.

Phillips, H.M., Sahlstedt, K.E., Frank, K., Bratby, J., Brennan, W., Rogowski, S., Pier, D., Anderson, W., Mulas, M., Copp, J.B. and Shirodkar, N. 2009. Wastewater treatment modelling in practice: A collaborative discussion of the state of the art. Water Sci. Technol., 59: 695-704.

Schories, G. 2008. IWAPIL-innovative wastewater treatment applications for isolated locations. Desalination, 224: 183-185.

Singh, A.K. 2003. Water resource and their availability. Proceeding of the National Symposium on Emerging Trends in Agricultural physics, Indian Society of Agrophysics, pp. 18-29.

Slade, A.H., Thorn, G.J.S. and Dennis, M.A. 2011. The relationship between BOD:N ratio and wastewater treatability in a nitrogen-fixing wastewater treatment system. Water Sci. Technol., 63: 627-632.

Spanjers, H., Vanrolleghem, P.A., Olsson, G. and Dold, P.L. 1998. Respirometry in control of the activated sludge process: Principles. IWA Scientific Technical Report No. 7, London, UK, pp. 48.

Wentzel, M.C., Mbewe, A., Lakay, M.T. and Ekama, G.A. 1999. Batch test for characterization of the carbonaceous materials in municipal wastewaters. Water S.A., 25: 327-335.

Xu, S. and Hasselblad, S. 1996. Simple readily biological method to estimate the biodegradable organic matter in wastewater. Water Res., 30: 1023-1025.

Zafarzadeh, A., Bina, B., Nikaeen, M., Attar, H.M. and Khiadani, M.H. 2011. Effect of dissolved oxygen and chemical oxygen demand to nitrogen ratios on the partial nitrification/denitrification process in moving bed biofilm reactors. Iran. J. Biotechnol., 9: 197-205.

ABBREVIATIONS

bCOD	Biodegradable COD
BOD_5	5 day biological oxygen demand
BOD_{5f}	Filtered BOD
BOD_{5s}	Soluble BOD
bTKN	biodegradable TKN
CBOD	Carbonaceous BOD
COD	COD
COD_f	Filtered COD
COD_s	Soluble COD
FC	Fecal coliforms
ffCOD	Flocculated filtered COD
fKN	Filtered Kjeldahl nitrogen
fsCOD	Flocculated soluble COD
HPC	Heterotrophic plate count
iTSS	Inert total suspended solids
nbCOD	Non-biodegradable COD
NBOD	Nitrogenous BOD
nbTKN	Non-biodegradable TKN
nbVSS	Non-biodegradable volatile suspended solids
OP	Ortho phosphorus
rbCOD	Readily biodegradable COD
sbCOD	Slowly biodegradable COD
sKN	Soluble Kjeldahl nitrogen
sTKN	Soluble TKN
TC	Total coliforms
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
TSS	Total suspended solids
VFA	Volatile fatty acids
VSS	Volatile suspended solids