Web-based Performance Benchmarking Data Collection and Preliminary Analysis for Drinking Water and Wastewater Utility

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ABSTRACT

High-quality drinking water and wastewater systems are essential to public health, business, and quality of life in the United States. Even though the current performance of these systems is moderate, the concern is about the future performance. Planning can be done for improvement once the current performance of utilities is evaluated, and areas with a scope of improvement are identified. Benchmarking and performance evaluation are key components in the process of continuous improvement for utility's performance. Benchmarking helps utilities make policies and programmatic decisions that reduce operational expenses and increase productivity by understanding areas of underperformance, understanding customer needs, developing future plans, and setting goals. This study establishes a strong case for implementing benchmarking methodologies among utilities to evaluate and improve performance.

There are many initiatives on performance benchmarking of utilities but a few of them focuses on one or few area of performance. There are a few initiatives which use subjective indicators. Additionally, consultants visit the utilities for performance evaluation. This research focuses on creating a web-based benchmarking platform for performance evaluation using holistic and quantitative indicators. Practical and robust methodologies are used and the research presents the current performance comparisons among utilities for areas that impact overall utility's performance. Web based benchmarking consists of two major parts – data collection and result visualization. A major contribution from this study is the creation of an online performance benchmarking database. With time more data will be collected which will provide utilities an access to a better database for performance evaluation. The future work in this research will be analyzing the data and results for each participant for each set of indicators, and finding possible reasons for underperformance, followed by suggesting solutions for improvement using the best practices.

DEDICATION

This thesis is dedicated to my parents, Naresh Rathor and Kalpana Rathor for their support and encouragement throughout my life.

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
AwwaRF	American Water Works Association Research Foundation
BM&M	Benchmarking and Metrics
BOD	Biochemical oxygen demand
CII	Construction Industry Institute
DEA	Data Envelopment Analysis
DUG	Database User Group
DW	Drinking Water
EBC	European Benchmarking Co-operation
EPA	Environmental Protection Agency
IBNET	International Benchmarking Network for Water and Sanitation Utilities
ICTAS	Institute of Critical Technology and Applied Science
IIRC	Innovative Infrastructure Review Committee
IWA	International Water Association
NSF	National Science Foundation
NWI	National Water Initiative
PE	Population equivalent

PILOT	Payment in lieu of taxes
PIs	Performance indicators
PSC	Project Sub-Committee
SAMGAP	Strategic asset management gap analysis tool
SW	Storm Water
SWIM	Sustainable Water Infrastructure Management
U.K.	United Kingdom
U.S.	United States
WATER*i*D	Water Infrastructure Database
WERF	Water Environment Research Foundation
WW	Wastewater

CHAPTER 1. INTRODUCTION

Asset management is a set of strategies for sustaining public infrastructure. An asset is a component of a facility with an independent physical and functional identity. The existing drinking water and wastewater assets in the U.S. have deteriorated to a poor state because of deferred maintenance and rehabilitation, driven primarily by financial considerations (Cagle, 2003). Further, the ASCE (American Society of Civil Engineers) grades (Table 1) reinforce the fact that these assets need improvement.

Table 1. ASCE grades for drinking water and wastewater assets in the U.S.

Year	Drinking Water Infrastructure	Trend	Wastewater Infrastructure	Trend
1988	B-		C	
1998	D	↓	D+	↓
2001	D	↔	D	↓
2005	D-	↓	D-	↓
2009	D-	↔	D-	↔

Much of our drinking water infrastructure, more than one million mile of pipes beneath our streets, is approaching the age at which it needs to be replaced. Restoring these water systems as they reach the end of their useful lives, and expanding them to serve a growing population will cost at least $1 trillion over the next 25 years (AWWA, 2012). Regarding wastewater assets, the physical condition of many of the nation's 16,000 wastewater treatment systems is poor, due to a lack of investment in plants, equipment, and other capital improvements. In 2008, the U.S. Environmental Protection Agency (EPA) reported that the total investment needs of America's publicly owned treatment works as of January 1, 2004, were $202.5 billion.

Evaluation and improvement in the condition of these assets can be done using performance benchmarking. It provides regulators and utility managers with a way to make performance comparisons over time, across water utilities, and across countries (Berg, 2007). Benchmarking is important for documenting past performance, establishing baselines for gauging improvements, and making comparisons across service providers (Berg, 2007). Along with providing the comparison to understand past and current performance levels, a benchmarking exercise also provides identification of opportunities for improvement.

1.1 GOALS AND OBJECTIVES

The goals of this research are to evaluate the performance of utilities using benchmarking and use the results to improve the management of the utility. The objectives to achieve these goals are:

- Identify a comprehensive set of indicators for performance benchmarking

- Evaluate utility performance using quantitative indicators
- Implement robust methodology for data collection and analysis
- Develop a web-interface for continuous data collection and results visualization
- Create a database to compare past and current performance

1.2 WHAT IS BENCHMARKING?

Benchmarking involves identifying the best practices in a particular discipline, activity or process, and then being able to apply that experience and knowledge in a meaningful context to improving your own operations. Camp (1995) considered benchmarking as finding and implementing best practices that lead to superior performances of an organization. Barber (2004) defined benchmarking as a process of investigation and learning from the best in a class to get useful information for improving and changing an organization. Watson (1993) stated that benchmarking is a systematic and continuous measurement process to continuously measure and compare an organization's business process against its competitors and similar leading entities across the world, to gain information which will help the organization to take action to improve its performance.

The basic steps to successful benchmarking are:

- Know your operations — identify and document your business system and respective core business processes
- Know industry leaders and/or competitors
- Learn from best practices and incorporate these into your operations in a relevant way
- Continue to improve over time to gain superiority.

Benchmarking is a systematic measurement of organizational performance over time and against other equivalent organizations or industry norms. Benchmarking comes in two types:

Output: The measuring stick is what the organization delivers – amount of water or wastewater treated per year, etc. It often is efficiency oriented, measuring the cost per unit of output.

Best Practice: An ongoing systematic process to search for and introduce international best practice into an organization, in such a way that all parts of the organization understand and achieve their full potential. The search may be for products, services, business practices and processes of competitors or those organizations recognized as leaders, in the industry or in the specific processes chosen.

1.3 WHY BENCHMARK?

Benchmarking is essential to understand the areas that contribute to a good overall performance of a utility. It helps a utility to identify areas of strengths and weaknesses. Along with providing the comparison to understand past and current performance levels, a benchmarking exercise also provides identification of opportunities for improvement. It also provides the value in terms of both cost and service to be gained from the improvement, identification of any factors that could delay potential improvement opportunities, prioritization of improvement opportunities, and realistic timelines and costs involved in achieving any potential improvement.

1.4 BENEFITS OF BENCHMARKING

Benchmarking is a fundamental requirement of good management and can help managers and regulators to identify historical trends, determine today's baseline performance, and quantify relative performance across utilities (Berg, 2007).The major benefits of benchmarking are listed below:

1. Reduces the operational cost
2. Increases the productivity by identifying areas for improvement
3. Helps to understand customer needs
4. Develops a future plan and sets goals
5. Allows employees to visualize the improvement which can be a strong motivator for change
6. Creates a sense of urgency for improvement

1.5 LIMITATIONS OF BENCHMARKING

Benchmarking certainly has its virtues. Benchmarking is not informative when it is used to compare fundamentally different processes. The major limitations of benchmarking are listed below:

1. Benchmarking is time consuming and expensive.
2. Participation in a benchmarking study may require additional staff for the utilities.
3. Benchmarking is important but should ideally be done on a continuous basis to keep track of change in performance.
4. Utilities should be comparable in size, model, culture, and strategy.
5. Benchmarking reveals the standards attained by competitors but does not consider the circumstances under which the competitors attained such standards.
6. Benchmarking may lead to complacency and arrogance. Utilities may tend to relax after excelling beyond competitors' standards, which may lead to complacency and overconfidence.
7. Many organizations make the mistake of undertaking benchmarking as a stand-alone activity. Benchmarking is only a means to an end, and it is worthless if not accompanied by a plan to change.
8. Lack of cooperation by the utility personnel may occur due to the confidentiality of data.
9. Reliability of data may be an issue while performing benchmarking.

1.6 PROCESS AND METHODOLOGIES FOR BENCHMARKING

The process of performance benchmarking is cyclic and continuous. The benchmarking process is divided into seven basic steps as described in Figure 1.

Figure 1. Basic steps for performance benchmarking

It is unlikely for two different industries to use the same methodology to benchmark performance, and there is no single right methodology. Therefore, methodology should be tailored expressly for drinking water and wastewater utilities. There are many methodologies defined by researchers for drinking water and wastewater industry, and a short description follows.

1.6.1 One to One Benchmarking

This is the most basic type of benchmarking in which one utility learns from other utility by visiting them. This helps a utility to learn how other utilities function. Normally for this type of benchmarking, the utility chooses to visit one of the best performing utilities.

1.6.2 Review Benchmarking

This type of benchmarking is performed with the help of experts and consultants. The experts visit each utility to review the performance. In this type of benchmarking experts identify areas of improvement and suggest solutions for improvement.

1.6.3 Database Benchmarking for overall performance indicators

This type of benchmarking uses an existing database with a number of specific core indices, such as volume of water treated, length of main, number of tests for treated water, population served, number of customer enquiries, financial performance and many more. The already defined specific core indices are used to collect the data from the utilities and values are compared with the existing database. This also helps to grow the existing database.

1.6.4 Customer Survey Benchmarking

This type of benchmarking focuses on the customer satisfaction on service quality which is important in evaluating utility performance. The trends over time also help to evaluate the variation of customer satisfaction level.

1.6.5 Excellence Model

The excellence model is a set metrics designed to capture all key aspects of a successful utility. This requires development of an optimized model based on creating an idealized benchmark specific to each utility incorporating all the factors which affect the overall performance (Berg, 2007). As with any methodology, this approach also has its limitations and the models can be very complicated.

CHAPTER 2. LITERATURE REVIEW

Literature on drinking water, wastewater and other industries was reviewed related to the benchmarking process, methodology and indicators. A web search was done, which provided publicly available articles and major reports, such as those published by the EPA. In addition to a web search, database search engines available through the Virginia Tech library were used to access literature. The most prevalently used database search engines were the Science Direct and Compendex. The source of information is summarized in the Figure 2 and Table 2. The information was gathered from the following sources:

1. Major global reports on benchmarking of drinking water, wastewater and other industries.
2. Journal and conference papers on performance benchmarking process, methodologies and indicators.
3. Books on methodologies, indicators and practice for drinking water and wastewater performance benchmarking.
4. Information gathered from drinking water and wastewater utilities on their benchmarking practices using data mining sheets and interviews.

Table 2. Details of documents reviewed

Sr. No	Source	Number of documents reviewed
1	Major Reports	13
2	Journal and Conference Papers	66
3	Books	6
4	Benchmarking data sheets from utilities	19

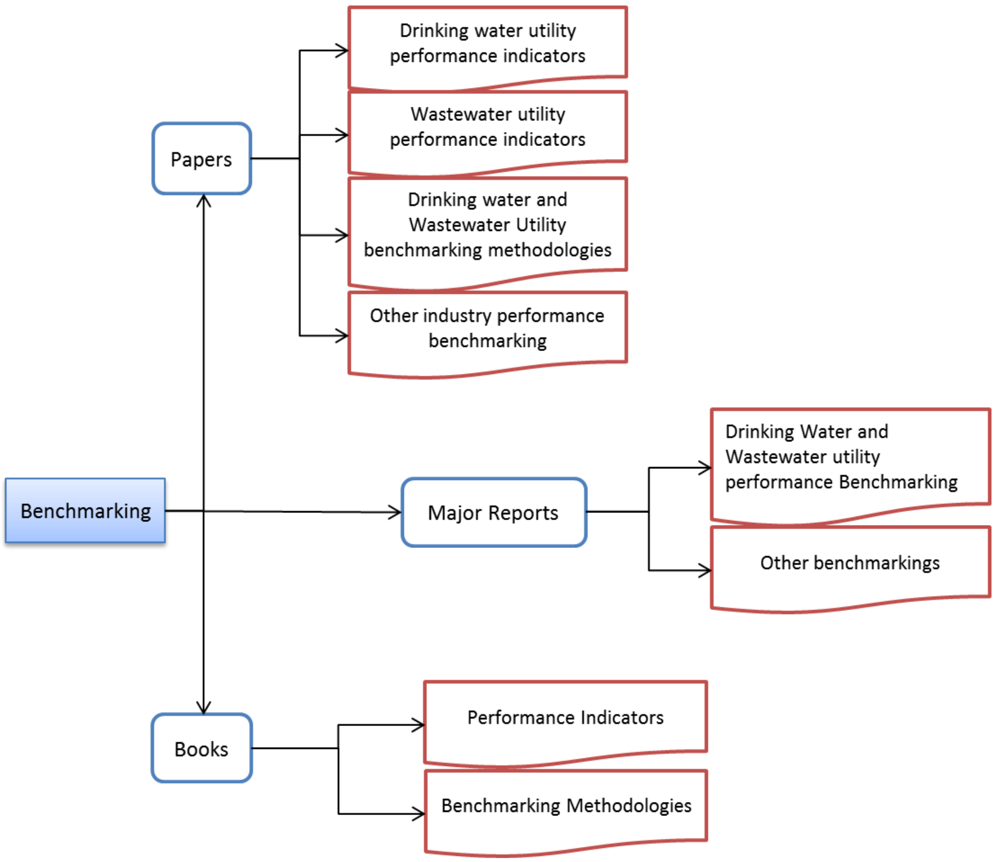

Figure 2. Source of information

2.1 LITERATURE REVIEWED – JOURNAL AND CONFERENCE PAPERS

Papers related to benchmarking process, methodology, and indicators used in drinking water, wastewater, and other industries were reviewed. The number and type of papers reviewed is summarized in Table 3.

Table 3. Journal and conference papers reviewed

Industry type	**Number of papers reviewed**	**Industry type**	**Number of papers reviewed**
General benchmarking	21	Automotive	1
Drinking water industry	13	Flood model	1
Wastewater industry	8	Pipeline	1
Construction	6	Project management	1
Data Envelopment Analysis	5	Railways	1
Airport	3	Telecom	1
Energy	3	Transportation	1
Total papers reviewed - 66			

2.1.1 Use of performance benchmarking in drinking water industry

Benchmarking is important for documenting past performance, establishing baselines for gauging productivity improvements and making comparisons across service providers (Berg et al, 2007). One example of using benchmarking is in the study on “Methods and trends of performance benchmarking in UK utility regulation” (Dassler et al, 2006) which establishes a case that the regulations are subject to available information and lack of information may lead to inefficient allocation. One widely accepted solution is benchmarking (also called ‘yardstick competition’), which is suggested in the article “A theory of yardstick competition” (Shleifer, 1985). This study considers Shleifer’s approach and compares the approach with the actual use in United Kingdom regulatory bodies in telecommunications, water and energy. Another regional benchmarking initiative is discussed in the article “Benchmarking Central American water utilities” (Corton et al, 2009) which provides a comprehensive efficiency analysis of water utilities in six countries in Central America. Similarly, another regional study on benchmarking has been discussed in the paper “The long-term reform of the water and wastewater industry: The case of Melbourne in Australia” (Abbott et al., 2011). This study analyzes the economic performance of the Melbourne water and wastewater industry from the early 1970s.

The literature shows vast differences in the performance between leading companies and average companies in performing particular activities. By benchmarking leading companies, many firms have experienced significant success in upgrading their organizational capabilities (Barber, 2004). Performance benchmarking helps to pinpoint the specific areas which can be improved.

Performance benchmarking can be used to solve various internal and external issues related to the utilities. For example, conflicts in the design and implementation of policies such as cognitive conflicts, interest conflicts, values conflicts, and authority conflicts can be resolved using benchmarking water utility performance (Berg, 2006). Benchmarking can promote conflict resolution between groups by allowing participants to focus on performance and can help bridge the gap between technical researchers and those practitioners currently conducting studies for government agencies and water utilities (Berg, 2007). Another area of performance which can be improved using benchmarking is quality of service. The article on “service quality and prospects for benchmarking” (Chen, 2005) summarizes that service quality is a very important factor of the water and sewerage industry. The author, using data from the Peruvian water sector (1996-2001), examines how the introduction of quality indicators affects performance comparisons across utilities. Another area which can benefit using benchmarking is utility rate regulations. The paper on “Statistical benchmarking in utility regulation: Role, standards and methods” (Lowry, 2009) states that statistical benchmarking is widely used these days in utility rate regulations.

2.1.2 Use of performance benchmarking in wastewater industry

Wastewater industry uses benchmarking for performance evaluation in a similar way as drinking water industry. For example, in the study on "Benchmarking procedure for full-scale activated sludge plants" (Abusam et al., 2004) a benchmarking methodology was proposed which was intended to evaluate performance of wastewater treatment plant. This paper proposes a data-based approach which can be used to benchmark a full-scale sludge plant for nitrogen and carbon removal.

One of the most efficient methodologies is the DEA approach. In the article on "Energy efficiency in Spanish wastewater treatment plants: A non-radial DEA approach," Sancho et al. (2011) used a non-radial Data Envelopment Analysis (DEA) methodology for the calculation of energy efficiency indices for a wastewater treatment plants (WWTPs) located in Spain. This study shows that reducing the carbon footprint of wastewater treatment plants is very important both for economic and environmental reasons. The DEA approach was also used by Sancho & Garrido (2009) to analyze the efficiency of wastewater treatment plants as a basic requisite to increase the potential of the water reuse. To achieve this, empirical research was carried out for 338 plants in Valencia region in Spain. It was verified that the large plants run more efficiently than smaller plants.

2.1.3 Use of performance benchmarking in other industries

The review shows that benchmarking is popular and effective in performance evaluation not only in drinking water and wastewater industry but also in other industries. Benchmarking use is prominent in industries like - airports, construction, energy, railway, Telecom, Transportation, automotive, pipeline and others. These industries are using various methodologies and processes of benchmarking. For example, the construction industry is using web-based system for data collection, performance and practice use reporting, and industry analysis (Lee et al., 2005). In the case of airport industry, it was observed that many airports are engaged in Best Practice Benchmarking (46 percent), but it also indicated that many were not (54 percent), and these airports seem to have developed other ways of satisfying their performance management requirements (Francis et al., 2002). Further, the study on development of benchmarking tools for monitoring progress towards sustainable transportation in New Zealand presents the development of a national benchmarking process for their transport sector. The project and its outcomes are considered to be of benefit to road land transport authorities across the world who wishes to develop a benchmark process of their own (Henning et al., 2011).

2.2 LITERATURE REVIEWED - REPORTS

This section provides a list of reports on performance benchmarking of drinking water utilities, wastewater utilities and other industries.

Benchmarking reports - Drinking water and wastewater industry:

1. Assessing utility practices with the strategic asset management gap analysis tool (SAMGAP), 2010, (WERF)
2. National Performance Framework: Urban performance reporting indicators and definitions handbook, Australian Government, 2011, National Water Initiative (NWI)
3. Benchmarking Performance Indicators for Water and Wastewater Utilities: 2006 Annual Survey Data and Analysis Report, Qualserve (AWWA)
4. Canadian National Water & Wastewater Benchmarking Initiative, 2011, (AECOM)
5. City of Palo Alto, City Council Staff Report, 2011
6. Effective Utility Management, A Primer for Water and Wastewater Utilities, 2008, (EPA)
7. Energy Index development for Benchmarking Water and Wastewater utilities, 2007, By Steven W Carlson and Adam Walburger (AwwaRF)
8. GHD's Approach to Driving Asset Management Improvement Programs using Total Enterprise Asset Management Quality Framework, Tool - GAP-EX1, 2007, Australia, (GHD)
9. Key Performance Indicators and Benchmarking for Water Utilities in MENA, Arab Region, 2010, (InWEnt)
10. TILDE (Tool for Integrated Leakage Detection) Project, 2005, By Frøydis Sjøvold, SINTEF; Peter Mobbs, WRc; SGI, (European Commission)
11. Water and Wastewater Benchmark, Learning from International Best Practices, 2010, (European Benchmarking Co-operation)

Benchmarking reports - other industries:

1. Benchmarking and Metrices Implementation Toolkit, Pocket Guide CII
2. Transportation Performance Index - summary report, 2010, by U.S. Chamber of Commerce’s Let’s Rebuild America initiative (LRA)

2.3 LITERATURE REVIEWED - BOOKS

Books on performance indicators, process of benchmarking and benchmarking methodologies were reviewed. The books by IWA (International Water Association) on performance indicators were used to define the indicators. The books on methodologies were used for the analysis of the collected data from utilities across United States. List of reviewed books is summarized below:

1. Performance Benchmarking for Water Utilities, 1996, By Bill Kingdom (AWWA)
2. Performance indicators for wastewater services, 2003, By Rafaela Matos, A. Cardoso, P. Duarte, R. Ashley, A. Molinari (IWA)
3. Performance indicators for water supply services, 2006, By Helena Alegre (IWA)
4. The Benchmarking Book: A How-to-Guide to Best Practice for Managers and Practitioners, 2009, by Tim Stapenhurst
5. Wastewater Treatment Plant Design, 2003, by P. Aarne Vesilind (IWA)

6. Water Utility Benchmarking: Measurement, Methodologies, and Performance Incentives, 2010, By Sanford Berg (IWA)

2.4 CURRENT PERFORMANCE BENCHMARKING PRACTICES IN DRINKING WATER AND WASTEWATER INDUSTRY

There are many initiatives in different countries in drinking water and wastewater utility performance benchmarking. Major initiatives are summarized in Table 4. The summary of major benchmarking initiatives is described below:

SAM GAP – Developed by Water Environment Research Foundation (WERF)

The Strategic Asset Management (SAM) gap analysis tool, developed by WERF is a tool for measuring the confidence level embedded in an organization's current asset management procedures and decision-making environment. SAM GAP is an online self-assessment process that allows an organization to compare their performance against data from over 170 asset management practitioners. It has a detailed and comprehensive questionnaire with 166 questions. The utility's information are compared to appropriate practices for similar industry organizations and reported graphically, accompanied by a detailed list of suggested areas for improvement. The customized report generated by SAM GAP benchmarks the utility's practices against its peers, and against the best run organizations in the world. Because it can be run at any time, the tool helps the utility measure improvement in their asset management processes.

(Information retrieved from http://simple.werf.org/UploadFiles/SAM2C06)

National Water and Wastewater Benchmarking Initiative, Canada - AECOM

This project was developed due to the need of Canadian municipal water and wastewater utilities to evaluate utility performance. It is a high level metric benchmarking process and has developed into a network and information base for Canada's municipal utilities. The Benchmarking Initiative was started in 1997 as a pilot project that included 4 participating cities and team members from AECOM and the National Research Council. It has now grown to serve as the standard for utility benchmarking in Canada.

(Information retrieved from http://www.nationalbenchmarking.ca/)

EBC: European Benchmarking Co-operation

The European Benchmarking Co-operation (EBC) is a benchmarking initiative for water and wastewater services. Its focus is to help utilities in improving performance. The International Water Association briefly defines benchmarking as: "a tool for performance improvement through systematic search and adaptation of leading practices". Benchmarking focuses at continuously improving performance, hence benchmarking is a cyclical process.

(Information retrieved from http://www.waterbenchmark.org/)

The International Benchmarking Network for Water and Sanitation Utilities (IBNET) – World Bank Group

It is the world's largest database for water and wastewater utilities performance data. IBNET supports and promotes good benchmarking practice among water and wastewater services by:

- Providing guidance on indicators, definitions;
- Facilitating the establishment of national or regional benchmarking schemes;
- Undertaking peer group performance comparisons;

(Information retrieved from http://www.ib-net.org/)

QualServe Benchmarking

QualServe is a joint initiative by the American Water Works Association and the Water Environment Federation to support water, wastewater, and combined water/wastewater utilities in improving performance and increase customer satisfaction. QualServe has four basic components:

- Self-Assessment.
- Peer Review
- Benchmarking Performance Indicators
- Benchmarking Data Sharing Workshop

(Information retrieved from http://www.awwa.org/files/QualServe/FactSheet/QualServefact%20sheet2011.pdf)

Table 4. Details of major benchmarking initiatives

Country	Project title	Utilities participated	Number of indicators	Detail
USA (WERF) 2010	SAM-GAP	Total - 130	Total - 193	Drinking water and wastewater utility asset management practice gap analysis and benchmarking tool
Canada 2011 (started 1997)	National DW and WW Benchmarking initiative - AECOM and the National Research Council	39-WW	50-DW	Serve as the national standard for water and wastewater utility benchmarking in Canada

Europe 2010	European Benchmarking Co-operation	Total-41	154-DW	A tool for performance improvement through systematic search and adaptation of leading practices
			128-WW	
		34-DW	50-WW	
		16-SW	15-SW	
IBNET – DFID (UK) and The world bank	The International Benchmarking Network for Water and Sanitation utilities	2000 from 85 countries (overall)	Total-150	Objective is to support access to comparative information that will help to promote best practice among water supply and sanitation providers worldwide
USA and Canada - AWWA and WEF (2010)	QualServe Benchmarking	52	Total - 34	Assessment of Leadership and Organizational Development, Business Operations, Customer Relations, Water Operations, and Wastewater Operations

In Table 4, DW is drinking water, WW is wastewater, and SW is storm water

2.5 CONCLUSION

A major conclusion is that, benchmarking is important for documenting past performance, establishing baselines for gauging productivity improvements, and making comparisons across service providers (Berg et al, 2007). It was observed that very few web-based benchmarking exists. Most of the benchmarking initiatives require consultants to visit the utility, which can be eliminated by using a web-based benchmarking platform. Along with this, web-based benchmarking will provide a platform not only for data gathering but will also provide a platform for results display. A few benchmarking initiatives are subjective and the subjectivity can be removed by quantifying the performance indicators. Many benchmarking initiatives in the drinking water and wastewater industry are not holistic and have a limited scope. A holistic evaluation of overall performance can be done using a comprehensive set of indicators which cover all the areas of utility performance.

CHAPTER 3. PERFORMANCE BENCHMARKING METHODOLOGY

3.1 METHODOLOGY

Database benchmarking methodology is adopted to create a web-based benchmarking platform. This benchmarking platform can be used by the utilities for performance evaluation and benchmarking. The benchmarking platform was developed using the available literature and suggestions from the utility personnel. The validation and review of the adopted methodology is especially important, as the products of the research are intended for use as a source of guidance for performance evaluation of utilities. Two review committees, one each for drinking water and wastewater were assembled to review the methodology, indicators and analysis results. These committees consist of three utility personnel and two consultants. The adopted methodology was reviewed by utility personnel and consultants followed by modification with a focus to capture the overall performance.

Database benchmarking methodology involves identifying and using indicators which can be used for benchmarking. The next step was to collect data for indicators and to develop a database for various core indicators which can be used to evaluate the overall performance. The collected data was used to compare performance of each indicator, for participating utilities. The utilities can make comparisons for each indicator with other utilities to observe the difference in performance using the web-interface. Once the areas of underperformance are identified, utilities can identify the reasons for underperformance and make future strategies to improve the performance. The first set of data was collected from 10 drinking water and 9 wastewater utilities using data-mining sheets. The newly developed web-based benchmarking platform is a part of WATER*i*D project. WATER*i*D is a knowledge database and contains information on both drinking water and wastewater infrastructure. Information about utility performance benchmarking, pipeline condition assessment, pipeline renewal engineering, subsurface utility engineering information for locating pipelines, management practices, models and tools, costs, and product qualification are parts of the project.

The web-interface on WATER*i*D serves a dual purpose:

Data collection

Utilities can access the benchmarking page to download the data mining sheet, and send the data mining sheets with data for the indicators to the benchmarking team at Virginia Tech. The collected data is saved at a secured location on the website, which is accessible only to respective utility personnel and the benchmarking team at Virginia Tech. The data provided by utilities is analyzed and results are generated.

Visualization of results

Once the data is analyzed, it is converted into useful information and utilities can access their results on website for each performance indicators. This web interface gives the user a flexible way of visualizing the results.

3.2 INDICATORS

The indicators used for this study were defined using the literature sources, and were modified using the suggestions from utility personnel. Performance indicators have a clear definition and are achievable, auditable, universal, simple, and quantifiable. A list of 150 indicators was created for drinking water and 140 indicators for wastewater. Based on the suggestions and comments from the utility personnel 89 indicators were selected for drinking water and 89 indicators were selected for wastewater. These indicators cover the major areas which impact the overall utility's performance. Indicators were further divided in seven categories.

The book on Performance indicators for water supply services (Alegre, 2000) has a detailed list of indicators and definitions for performance evaluation of drinking water utilities. The categories for drinking water are:

1. Water resource utilization
2. Employee information
3. Physical assets
4. Service quality
5. Operational performance
6. Customer enquiries
7. Financial performance

The book on "Performance Indicators for Wastewater Services" (Matos et al. 2003) provides a detailed list of indicators and definitions for the performance evaluation of wastewater utilities. The categories for wastewater are:

1. Wastewater and Biosolids
2. Employee information
3. Treatment process
4. Treatment performance
5. Operational performance
6. Customer enquiries
7. Financial Performance

The indicators have been divided into essential and preferable indicators as illustrated in Figure 3. Essential indicators are used for basic level benchmarking and preferable indicators, used with essential indicators for advanced level benchmarking. The number of essential and preferable indicators is further described in Table 5 and Table 6 and the indicator classification is presented in the Appendix B and Appendix C. The list of indicators with definitions, units and results is summarized in Chapter 4 and Chapter 5.

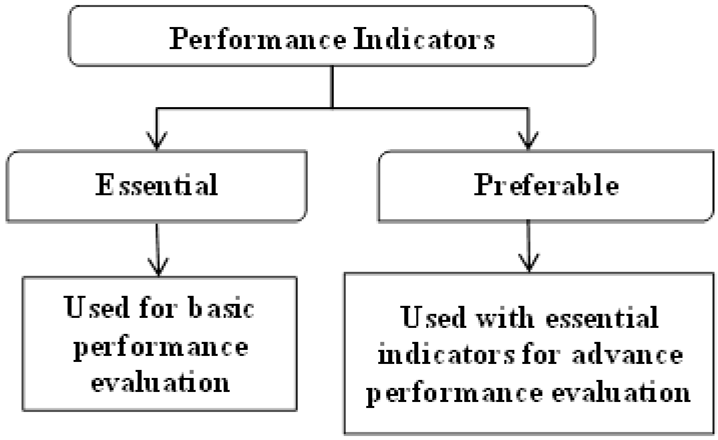

Figure 3. Performance indicators categories for benchmarking

Table 5. Number of indicators for different category used for drinking water utility data collection and benchmarking

Sr. No	Category	Number of Essential indicators	Number of Preferable indicators	Total number of indicators
1	Water resource utilization	3	0	3
2	Employee information	5	7	12
3	Physical asset	6	3	9
4	Service quality	6	8	14
5	Operational performance	20	2	22
6	Customer enquiries	1	6	7
7	Financial performance	17	5	22
Total number of indicators		**57**	**32**	**89**

Table 6. Number of indicators for different category used for wastewater utility data collection and benchmarking

Sr. No	Category	Number of Essential indicators	Number of Preferable indicators	Total number of indicators
1	Wastewater and Biosolids	5	0	5
2	Employee information	6	7	13

3	Treatment process	4	1	5
4	Treatment performance	7	18	25
5	Operational performance	13	1	14
6	Customer enquiries	1	6	7
7	Financial Performance	15	5	20
Total number of indicators		**50**	**39**	**89**

3.3 GEOGRAPHICAL DISTRIBUTION OF PARTICIPATING UTILITIES

The geographical analysis of the gathered data was done by dividing utilities according to their geographical location within EPA regions. A list of states in the defined EPA regions is described in Table 7. A formal invitation to participate was sent to the utilities from all EPA regions to have a good geographical coverage. A net meeting was set up with relevant employees of the utility. All research team members participated in the presentation, explaining the team's research and showing the utility how participating will not only benefit other utilities but will also benefit the participating utility. There is an option for the utilities to sign a Memorandum of Understanding stating that Virginia Tech will not release the utility's information without permission from the utility. The utilities were also informed that anything written about the experiences of the utility can be "sanitized" so that it does not reveal any information about the utility's identity. Once a utility agrees to participate, benchmarking data mining sheets are sent to the utilities for data collection. With the understanding that utility employees are very busy, all that was asked of them was provide only the readily available data for the indicators and documents that may be relevant to the drinking water and wastewater benchmarking research. Data mining process was started in April and data was collected from 10 drinking water utilities and 9 wastewater utilities. The number of participating utilities from each EPA region is summarized in Table 8.

Table 7. Description of EPA defined regions

Geographical Region Name	Region Description
EPA Region 1	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
EPA Region 2	New Jersey, New York, Puerto Rico and the U.S. Virgin Islands.
EPA Region 3	Delaware, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia.
EPA Region 4	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.
EPA Region 5	Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.
EPA Region 6	Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.
EPA Region 7	Iowa, Kansas, Missouri, and Nebraska.
EPA Region 8	Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.
EPA Region 9	Arizona, California, Hawaii, Nevada, and the territories of Guam and American Samoa.
EPA Region 10	Alaska, Idaho, Oregon, and Washington.

Table 8. List of participating drinking water and wastewater utilities by EPA regions

EPA Region	Drinking Water	Wastewater
EPA Region 3	5	4
EPA Region 4	2	3
EPA Region 6	1	1
EPA Region 9	-	1
EPA Region 10	2	-
Total	**10**	**9**

CHAPTER 4. PERFORMANCE BENCHMARKING RESULTS, ANALYSIS AND LIMITATIONS – DRINKING WATER UTILITIES

Data was gathered from 10 drinking water utilities. A total of 89 indicators were used for data collection and for analysis of overall performance. The collected data for this study is from 2011-2012. A committee was formed consisting of experts from the drinking water industry to review the results; from the feedback the analysis results were finalized.

For this study the utility specific results were shared only with the respective utilities. The results for seven key performance areas are summarized graphically. The results are also available on the WATER*i*D website and continuous data collection will be performed using the web-based benchmarking platform. This will enable the database to grow and will result in a better database for future benchmarking. Further, each graph has the maximum, minimum, average and median value for the indicator and the definition is described below:

Maximum (Max) value: maximum of all the values collected from utilities for the indicator.

Minimum (Min) value: minimum of all the values collected from utilities for the indicator.

Average value: average of all the values collected from utilities for the indicator.

Median value: median of all the values collected from utilities for the indicator.

4.1 WATER RESOURCE UTILIZATION

Results and analysis:

The type and characteristics of the water resources vary greatly from case to case, both in terms of quantity and quality. The indicators related to water resource utilization are limited to aspects like how efficiently the resources are being used.

The result for each indicator is summarized in Table 9. It was found that some utilities have a significant percentage of water loss (non-revenue water) and is calculated as the percentage of treated water which is lost due to leakage and overflow as shown in Figure 4. Most of the utilities do not reuse or recycle the supplied water and the results are summarized in Figure 5. Reuse or recycling of water can help in conserving the natural resources of water, if done properly. Water reuse makes more sense in drier parts of the United States. It was found that in some areas like Florida all wastewater is called recycled water, which is pumped into groundwater aquifers to be used in the future. Availability of raw water resources varies for different utilities and depends on the geographical location of the utility and the results are summarized in Figure 6.

Limitations:

1. Some utilities are located at regions where extracting raw water does not require any permit and extraction is dependent on the capacity of intake structures.
2. Some utilities are located at critical locations where they have a limitation on extraction of water.
3. It should be noted that there is a cost associated with reusing water and in water rich environments; the economic justification may not exist in such cases.

Table 9. List of indicators, definition and results for water resource utilization

Indicator	Definition	Unit	Max	Min	Average	Median
Inefficiency of use of water resource	Total Water lost due to leakage and overflow / Total treated water produced x 100	%	27.30	7.54	15.21	12.67
Reused or recycled supplied water	volume of water reused or recycled / total volume of water entering the utility for treatment x 100	%	6.11	0.00	1.22	0.00
Water resources availability	total volume of water entering the utility for treatment / Total volume of water available as per withdrawal permit from lakes, river and other sources x 100	%	51	10	34	43

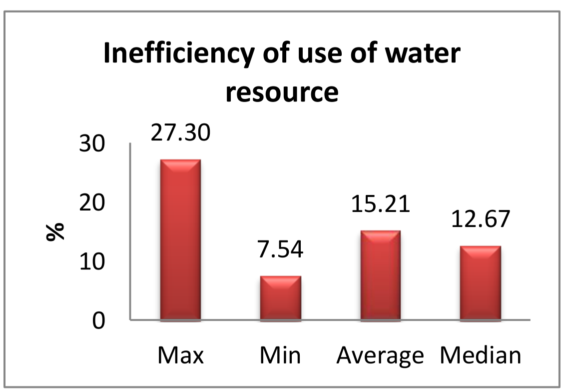

Figure 4. Inefficiency of use of water resource

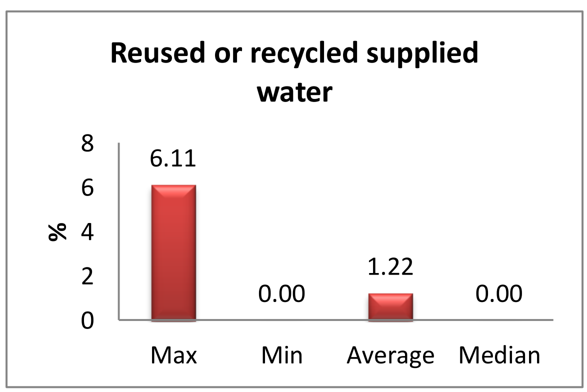

Figure 5. Reused or recycled supplied water

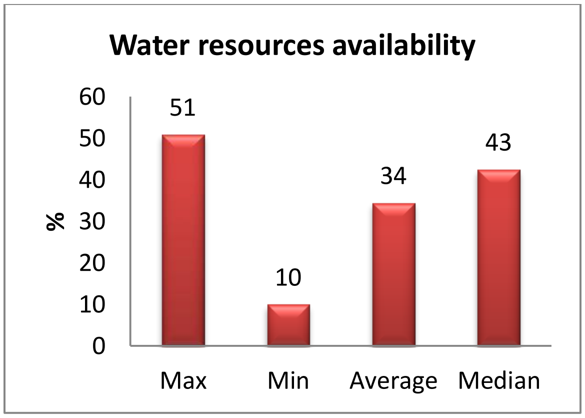

Figure 6. Water resource availability

4.2 EMPLOYEE INFORMATION

Results and analysis:

Employee related indicators offer insight into how the participating utilities have staffed their utility – both in leadership and operations staff; how they're structured in terms of the types of employees; how they invest in their employees (e.g. training); and, how they maintain a safe working environment. Lin (2005), Berg and Lin (2007), Alsharif et al. (2008), Lonborg (2005), Mugisha (2007), Lambert et al. (1993), Aida et al. (1998), and Tupper and Resende (2004) are among researchers who have considered number of employees (or labor or staff) as one of the inputs in their studies.

The result for each indicator is summarized in Table 10. The number of employee**s** per 1000 connection**s** and per million gallon**s** of water produced per day is summarized in Figure 7 and Figure 8. Percentage of employees in higher management (Figure 9), human resources (Figure 10), financial and commercial (Figure 11), customer service (Figure 12), planning, design and construction (Figure 13) and water quality monitoring (Figure 15) were found lower as compared to percentage of employees in operations and management (Figure 14) in all the utilities. This is because the main work in the utility involves operations and management of water treatment. It was also found that most of the utilities invest significant time and resources on personnel training as shown in Figure 16; most of this training is related to safety. The percentage of employees injured in working accidents in the last one year is summarized in Figure 17. The percentage of employees injured in the last one year is high for a few utilities. For such utilities the first step is to determine the reasons for poor safety, and the next step is to implement better health and safety programs. The rate of absences due to accidents show that the time lost due to accidents is on a lower side for all the utilities as summarized in Figure 18.

Limitations:

1. The number of employees per 1000 connections and per million gallons of water produced per day depends on the size, location and number of connections served by the utility
2. The number of employees in functions like human resources and finance vary significantly between municipalities and drinking water authorities. In a municipality, many of these functions are provided in the general fund; the utility then pays a PILOT (payment in lieu of taxes) and/or makes a transfer of funds to the general fund for indirect costs. In an authority they usually have those positions on staff.

Table 10. List of indicators, definition and results for employee information

Indicator	Definition	Unit	Max	Min	Average	Median
Total employee						
Employee per 1000 connection	total no. of employees / number of connections x 1000	number / 1000	4.50	1.15	2.50	2.37
Employee per million gallons of water produced per day	total no. of employees / Million gallons of water produced daily	number / Mgal	7.80	2.57	4.95	4.46
Employee as per function						
Higher management employees	Number of full time equivalent employees dedicated to directors, central administration, strategic planning, marketing and communications, legal affairs, environmental management, business development / total number of employee x 100	%	16.73	1.53	7.09	5.04
Human resources employees	Number of full time employees dedicated to personnel administration,	%	2.53	0.83	1.73	1.79

	education and training, occupational safety and social activities / total number of employee x 100					
Financial and commercial employees	Number of full time equivalent employees dedicated to economic and financial planning, economic administration, economic controlling and purchasing / total number of employee x 100	%	10.46	1.39	5.07	4.22
Customer Service employees	Number of full time equivalent employees dedicated to customer relations / total number of employee x 100	%	15.56	9.91	13.40	14.07
Planning, designing and construction employees	Number of employees working in planning, designing & construction / total number of employee x 100	%	19.18	1.11	11.72	13.30
Operations and maintenance employees	Number of employees working in operations & maintenance of the utility / total number of employee x 100	%	65	15	45	50
Water quality monitoring employees (lab personnel)	Number of lab testing employees / total number of employee x 100	%	5.99	1.63	4.08	4.36
Training						
Personnel training	total training hours for all the employees in last 1 year / total number of employees	hours / employee / year	40.00	6.35	18.17	16.89
Personnel health						

and safety						
working accidents - % of employees injured in last 1 year	number of employees injured on the job in the last 1 year / total number of employees x 100	%	9.72	2.30	6.10	6.22
Absences due to accidents	sum of all the absences due to all the employees due to reasons related to accident in last 1 year / total number of employees	number / employee / year	0.46	0.00	0.25	0.27

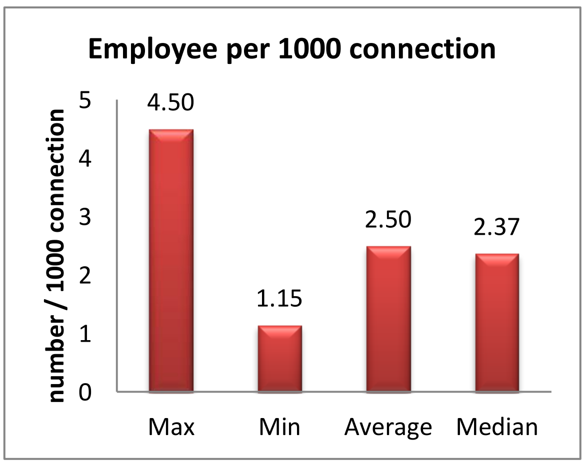

Figure 7. Employee per 1000 connections

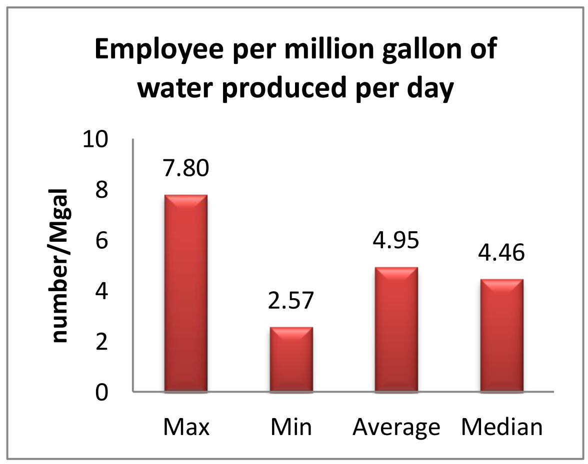

Figure 8. Employee per mgal of water produced per day

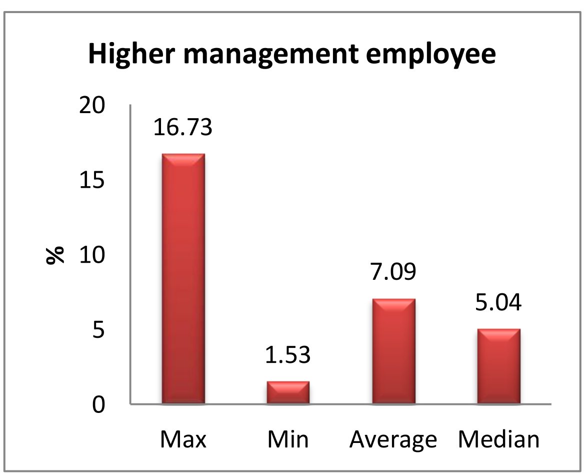

Figure 9. Higher management employee

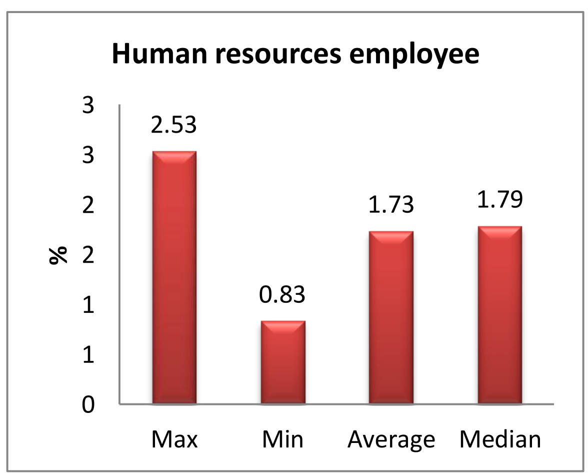

Figure 10. Human resource employee

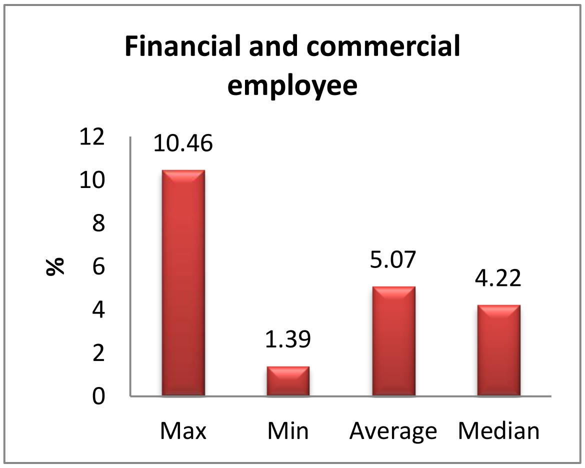

Figure 11. Financial and commercial employee

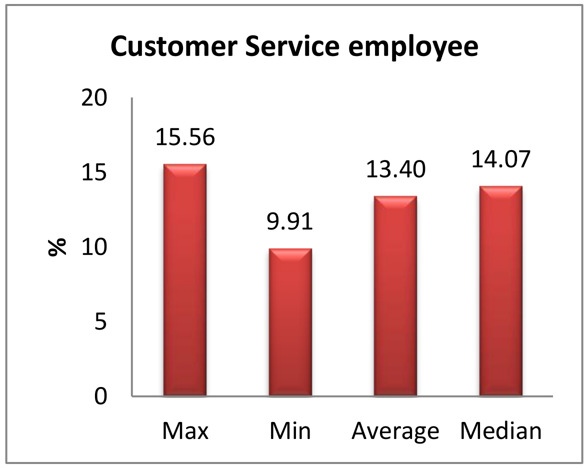

Figure 12. Customer service employee

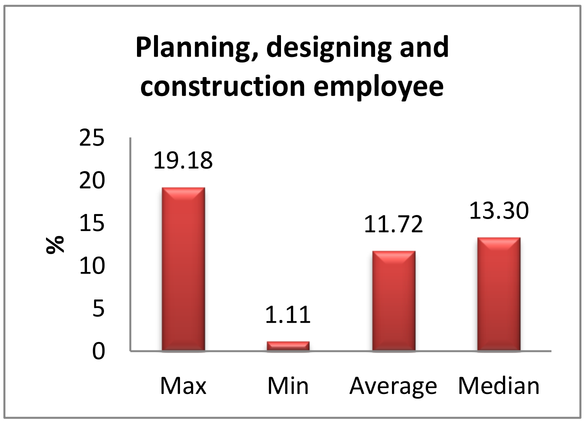

Figure 13. Planning, design and construction employee

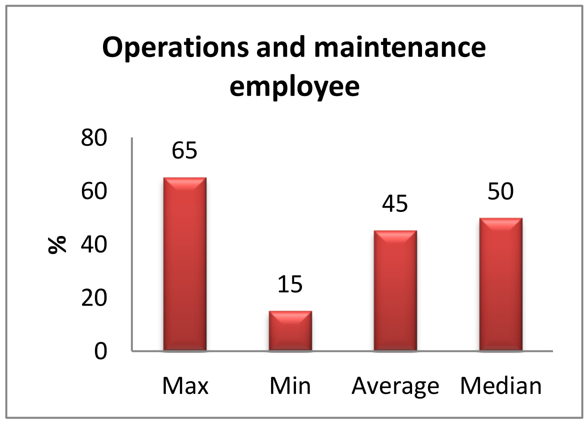

Figure 14. Operations and maintenance employee

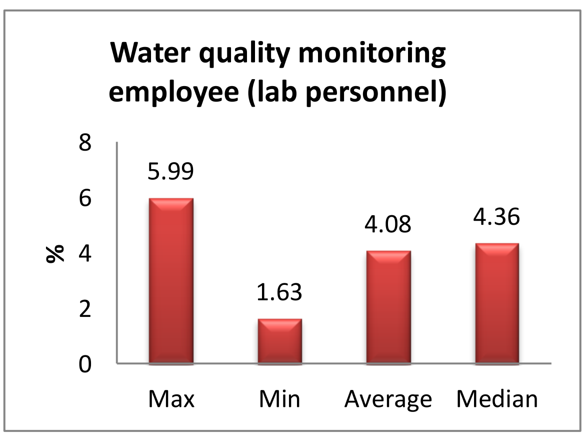

Figure 15. Water quality monitoring employee

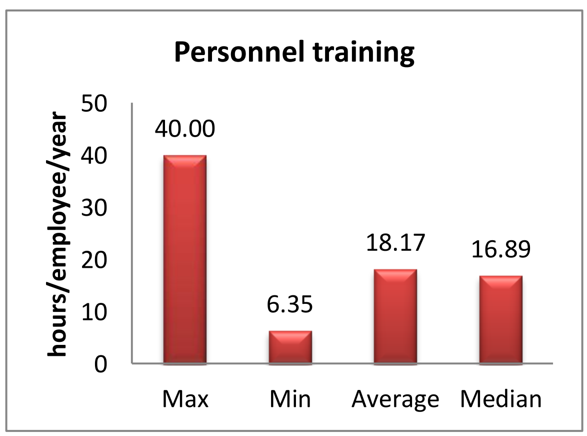

Figure 16. Personnel training

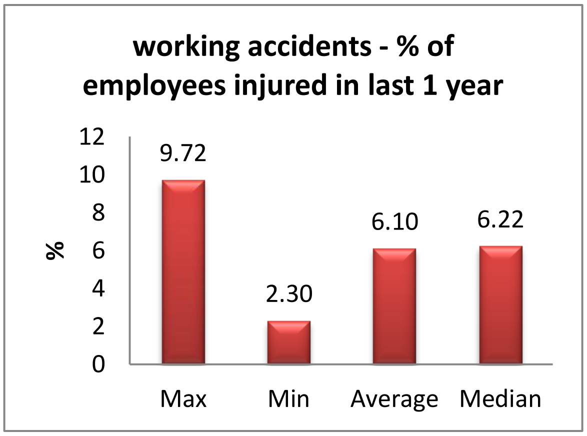

Figure 17. Working accidents - % of employees injured in last 1 year

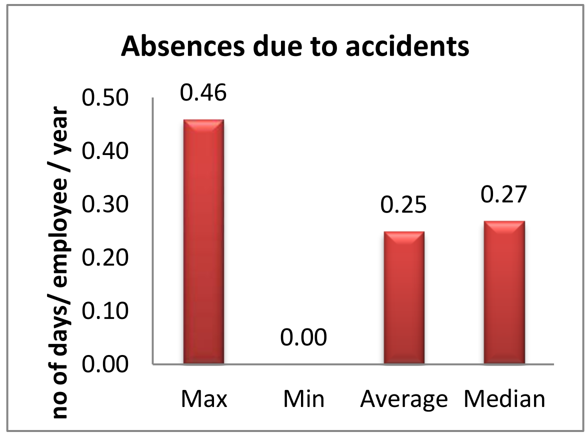

Figure 18. Absences due to accidents

4.3 PHYSICAL ASSETS

Results and analysis:

A physical asset is referred as any item of economic, commercial and/or exchange value that has a tangible existence. Physical assets usually refer to cash, equipment, inventory and properties owned by the business. Managing these assets is important for proper functioning of utilities. To manage any asset it is required to quantify the asset's performance and understand the need for maintenance and replacement. Benchmarking has become a tool that can be used to inform the public debate over infrastructure improvements (Chen, 2005).

The results (Table 11) from the data collected for this category summarize how efficiently these assets are being used. Treatment plant utilization show the percentage usage of the available capacity and the result is summarized in Figure 19. The utilization depends on the capacity of treatment and demand of water. All the utilities show the availability of additional treatment capacity which is not currently in use. Treated water produced verses treated water storage capacity (Figure 20) show how much water is produced as compared to the treated water storage capacity. Most of the utilities show a high value for this indicator, which implies that utilities produce more water than the storage capacity and pump it to customers as soon as the water is treated. The results in Figure 21, Figure 22 and Figure 23 shows the length of mains (total, transmission and distribution); the results for total main length show higher values for utilities located in big cities with large population and lower values for utilities in small towns with low population. The value also changes with the change in population density. Valve density shows the number of valves per mile of main as summarized in Figure 24. The results for this indicator show that density for valves has a significant difference in value for different utilities. The hydrant density (Figure 25) show the number of water hydrants per length of main and this indicator value is in a close range for all the utilities. Meter density show the percentage of customer with meters, and the results show a value close to 100% for all the utilities as summarized in Figure 26.

The indicators for daily used capacity of raw water storage reservoir, pumping capacity utilization, electrical energy consumption per population served, and electrical energy consumption per million gal of water treated have not been included because there was insufficient data for making conclusions.

Limitations:

1. The indicator for main length, valve density and hydrant density depends on the total area in which the utility provides service and on population density. Higher number for these indicators does not mean a better performance.

Table 11. List of indicators, definition and results for physical assets

Indicator	Definition	Unit	Max	Min	Average	Median
Treatment plant utilization	Average Volume of water treated daily / Maximum daily water treatment capacity x 100	%	77	32	52	50
Water produced vs. Treated water storage capacity	Average Volume of water treated daily / capacity of treated water storage reservoir x 100	%	389	26	195	156
Total Main length		miles	5166	460	2953	3124
Transmission main		miles	333	20	163	154
Distribution main		miles	3933	360	2547	2948
Valve density	total no of isolating valves / total miles of distribution main length	number / mile	26.78	0.21	14.88	12.48
Hydrant density	total no of hydrants / total miles of	number / mile	7.66	5.16	6.19	6.12

	distribution main length					
Meters	total number of meters / total number of connections x 100	%	101	93	99	100

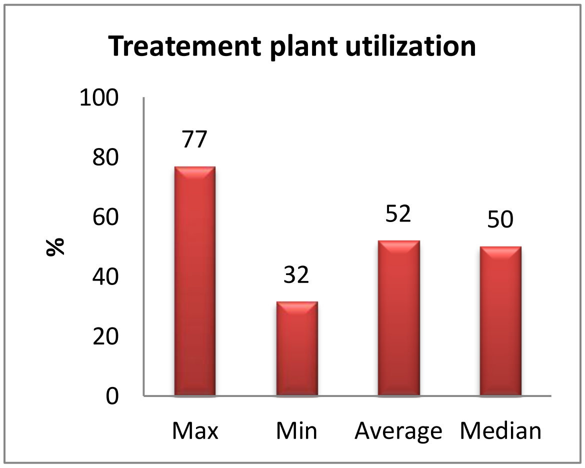

Figure 19. Treatment plant utilization

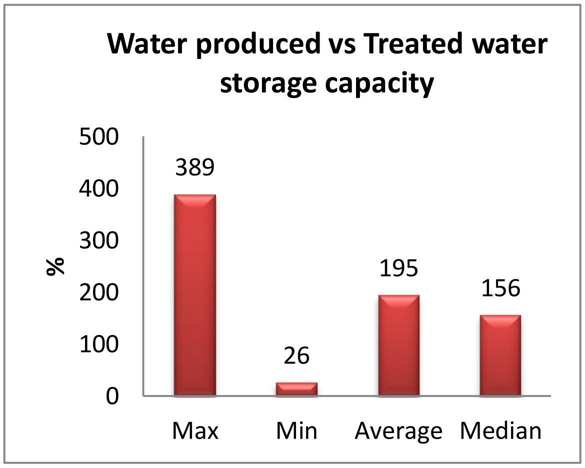

Figure 20. Water produced vs. treated water storage capacity

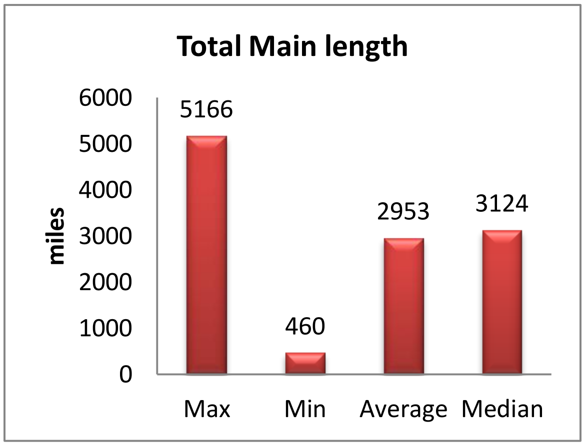

Figure 21. Total main length

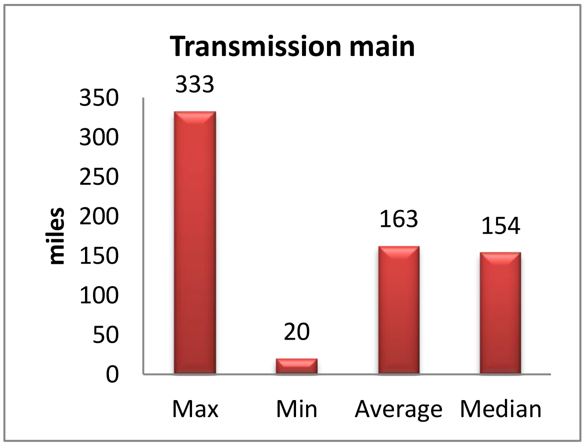

Figure 22. Transmission main length

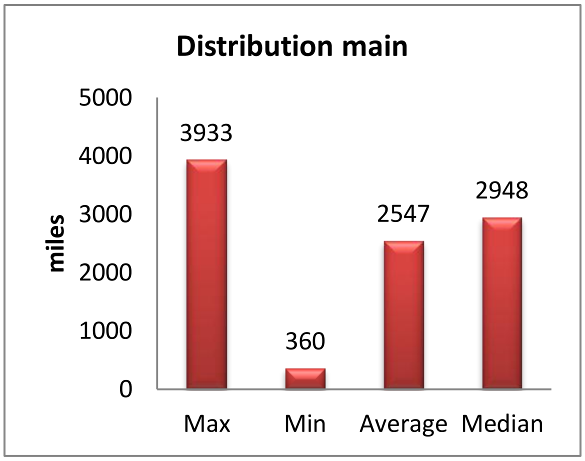

Figure 23. Distribution main length

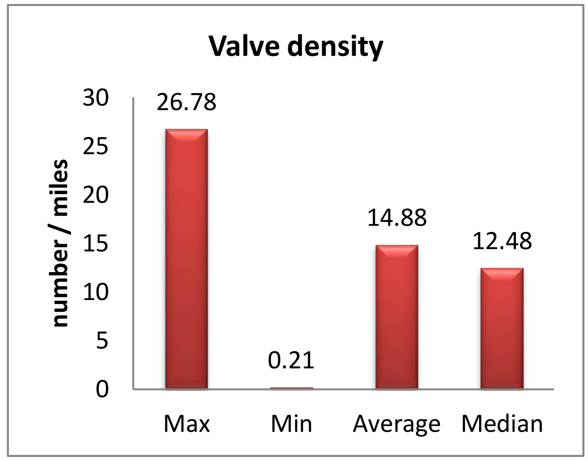

Figure 24. Valve density

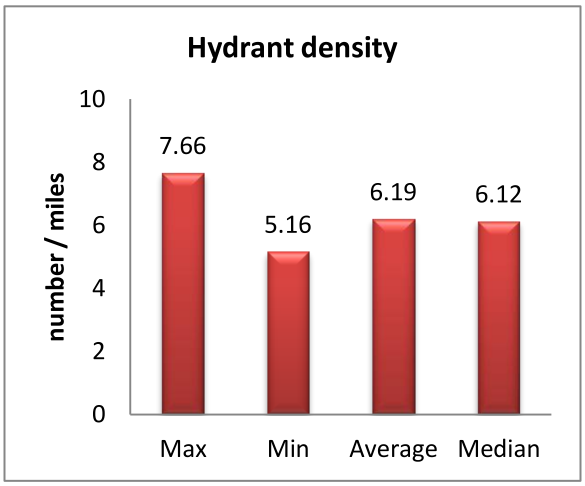

Figure 25. Hydrant density

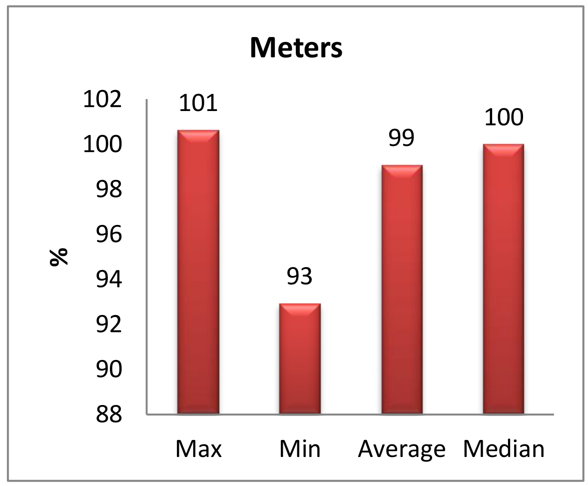

Figure 26. Meter density

4.4 SERVICE QUALITY

Results and analysis:

Quality of service is a vital ingredient in a utility's ability to maintain profitability and continued success. Service quality is a very important aspect of the water industry (Chen, 2005).

All the results are summarized in Table 12. Population coverage show the percentage of population served in the service area and for most of the utilities this number is high as summarized in Figure 27. Main breaks show the number of main breaks in every 100 miles of mains last year and it shows how the mains have been maintained in the past. It was found that a few utilities have a higher number for this indicator (29 main breaks per 100 miles in the last one year) as summarized in Figure 28. The utilities with higher values for this indicator should focus on maintaining, repairing and replacing mains. This will ensure smooth functioning of operations and will help to provide a high quality service. Water interruptions are a critical part of service, and higher number of interruption causes dissatisfaction to the customers. Percentage connections with interruption in service show that most of the connections that experienced interruption were for a time less than 4 hours as summarized in Figure 29, Figure 30, Figure 31 and Figure 32. This shows that most of the utilities solved the water interruption on a priority basis. Quality of supplied water is also important and critical in evaluation of the quality of service. Many tests have been defined in the standards which are required to be performed before supplying the treated water. The indicators related to tests are divided in two categories. First is the percentage of tests compliant with the standards for treated water for each type of tests and second is the total percentage of required number of tests performed. Result for total percentage of tests compliant with the standard is summarized in Figure 33 and total percentage of required tests done is summarized in Figure 34. Percentage of aesthetic tests compliant with the standard is summarized in Figure 35 and percentage of required aesthetic tests done is summarized in Figure 36. Percentage of microbiological tests compliant with the standard is summarized in Figure 37 and total percentage of required microbiological tests performed is summarized in Figure 38. Percentage of physical-chemical tests compliant with the standard is summarized in Figure 39 and the percentage of required number of physical-chemical tests done is summarized in Figure 40. Percentage of radioactive tests compliant with the standard is summarized in Figure 41 and the percentage of required number of radioactive tests done is summarized in Figure 42. It is found that almost all utilities perform more than the minimum number of required tests and all the utilities showed almost 100% compliance with permit conditions for the tests.

Limitations:

1. Many utilities that have higher population coverage may not have effective competition in a given area, and there may be no market incentive to cut costs. Hence the utility with higher population coverage does not necessarily mean a good performance.
2. Number of main breaks per 100 miles depends on the age, quality and current condition of the pipes. These factors should be considered while making future plans for main rehabilitation, repair or replacement.
3. There are few testes like radioactive tests which are approved for reduced monitoring - once every 9 years. These practices should be taken into account while evaluating the performance related to tests.

Table 12. List of indicators, definition and results for service quality

Indicator	Definition	Unit	Max	Min	Average	Median
Population coverage	Total Population served / Total population of the service area x 100	%	100	25	75	90
Water supply						

Reliability						
Main breaks	Total number of main breaks in last 1 year / Total main length x 100	number / 100 miles	29	9	18	15
Water interruptions - unplanned						
% connections with interruptions of less than 4 hours in last 1 year	Number of connections experiencing disruptions of less than 4 hours in last 1 year / Total number of connections x 100	%	9.74	0.03	2.36	0.52
% connections with interruptions between 4-12 hours in last 1 year	Number of connections experiencing disruptions of between 4-12 hours in last 1 year / Total number of connections x 100	%	0.41	0.00	0.19	0.20
% connections with interruptions of greater than 12 hours in last 1 year	Number of connections experiencing disruptions of greater than 12 hours in last 1 year / Total number of connections x 100	%	0.04	0.00	0.01	0.00
Total % of connections	Total number of connections	%	1.94	0.04	0.77	0.54

experiencing disruption in last 1 year	experiencing disruption in last 1 year / Total number of connections x 100					
Quality of Supplied water						
Total % of tests compliant with permit conditions for treated water	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	99.90	99.98	100.00
Total % of required tests done	total no. of tests done / total no. of water quality tests required by standards x 100	%	483	100	167	100
Total % of Aesthetic tests compliant with permit conditions for treated water	total no. of Aesthetic tests complying with permit conditions / total no. of Aesthetic tests done x 100	%	100.00	99.65	99.91	100.00
Total % of required Aesthetic tests done	total no. of Aesthetic tests done / total no. of Aesthetic tests required by standards x 100	%	1608	100	603	100
Total % of Microbiological tests compliant with permit conditions for treated water	total no. of Microbiological tests complying with permit conditions / total no. of Microbiological tests done x 100	%	100.00	99.96	99.99	100.00
Total % of required Microbiological tests done	total no. of Microbiological tests done / total no. of Microbiological tests	%	229	100	134	103

	required by standards x 100					
Total % of Physical-chemical tests compliant with permit conditions for treated water	total no. of Physical-chemical tests complying with permit conditions / total no. of Physical-chemical tests done x 100	%	100.00	99.91	99.98	100.00
Total % of required Physical-chemical tests done	total no. of Physical-chemical tests done / total no. of Physical-chemical tests required by standards x 100	%	1083	100	346	100
Total % of Radioactive tests compliant with permit conditions for treated water	total no. of Radioactive tests complying with permit conditions / total no. of Radioactive tests done x 100	%	100	100	100	100
Total % of required Radioactive tests done	total no. of Radioactive tests done / total no. of Radioactive tests required by standards x 100	%	100	100	100	100

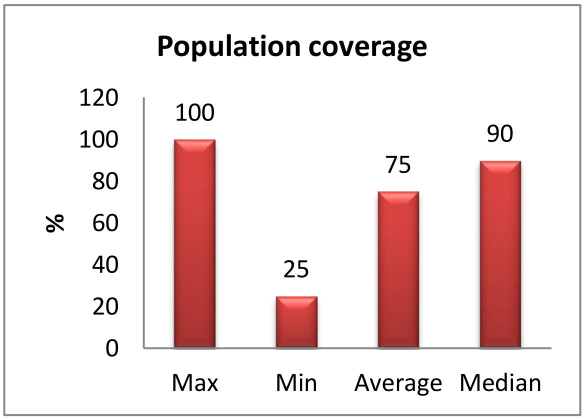

Figure 27. Population coverage

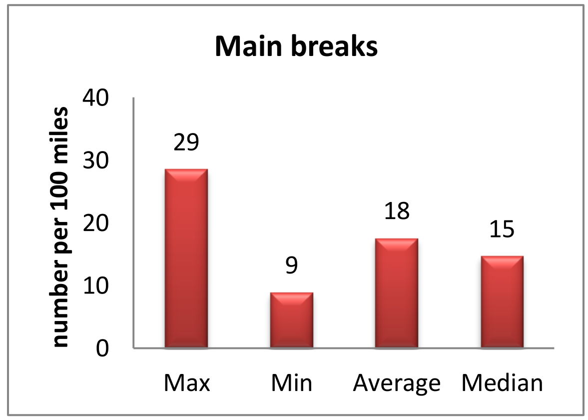

Figure 28. Main breaks

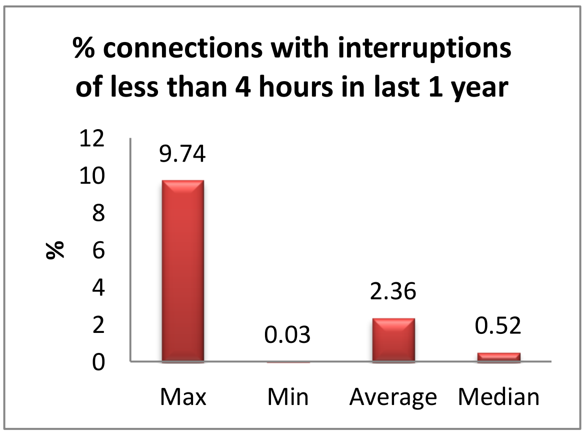

Figure 29. % connections with interruptions of less than 4 hours in last 1 year

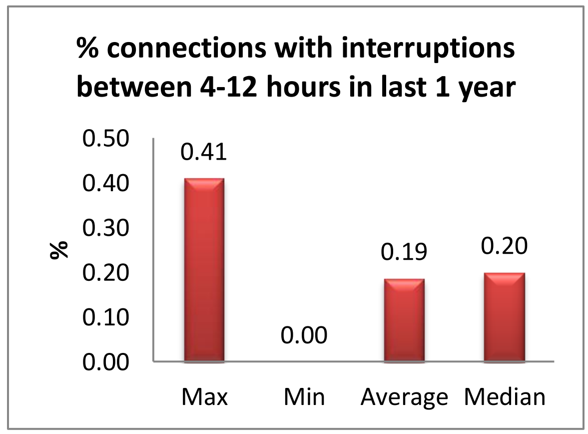

Figure 30. % connections with interruptions between 4-12 hours in last 1 year

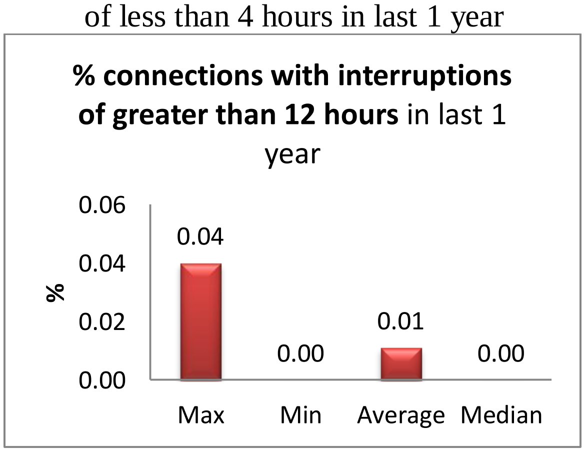

Figure 31. % connections with interruptions of greater than 12 hours in last 1 year

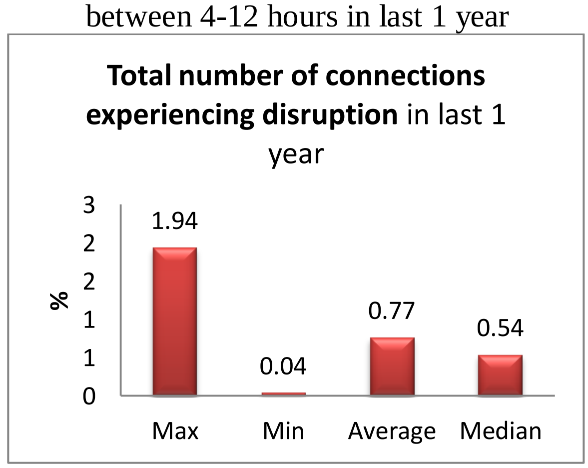

Figure 32. Total number of connections experiencing disruption in last 1 year

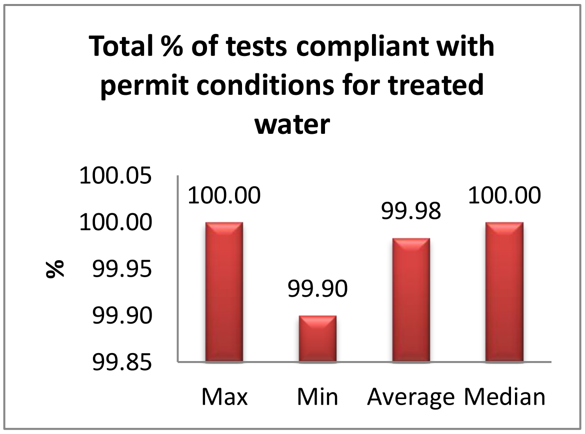

Figure 33. Total % of tests compliant with standard for treated water

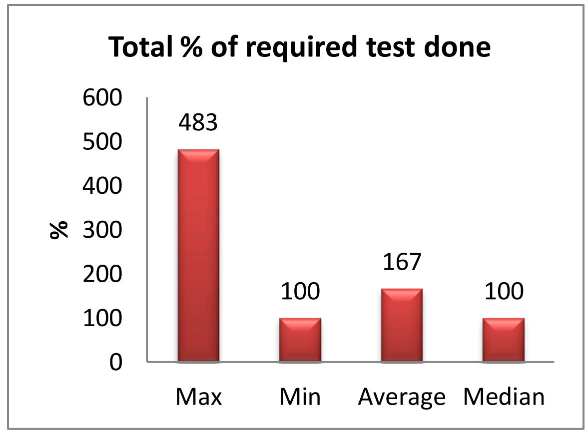

Figure 34. Total % of required tests done

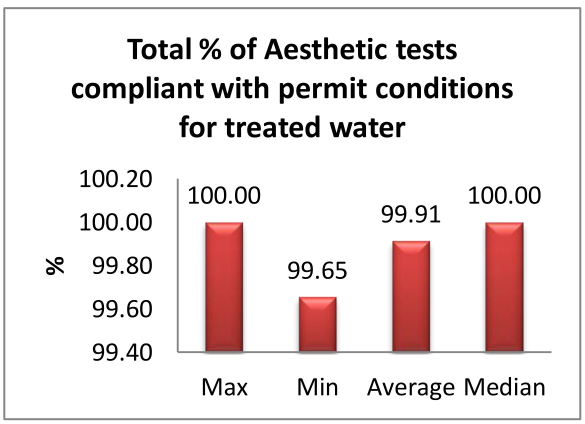

Figure 35. Total % of aesthetic tests compliant with standard for treated water

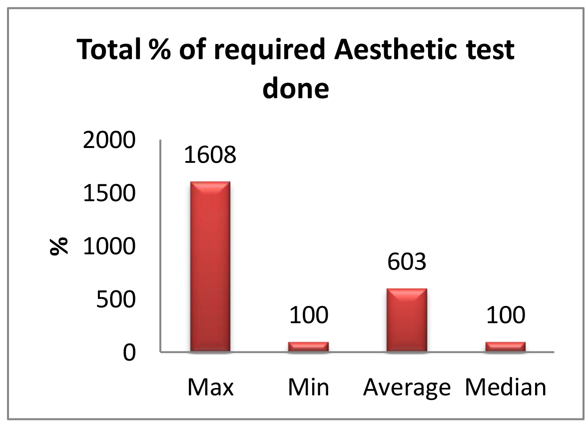

Figure 36. Total % of required aesthetic tests done

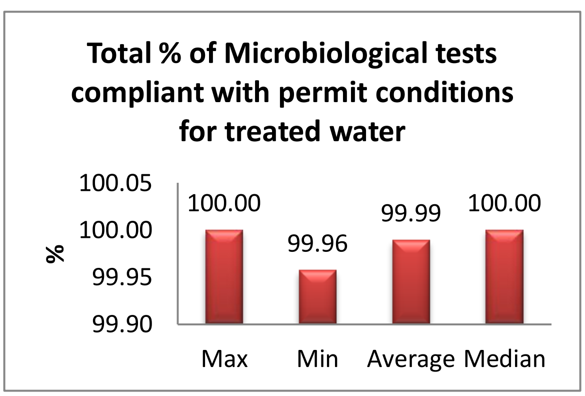

Figure 37. Total % of microbiological tests compliant with standard for treated water

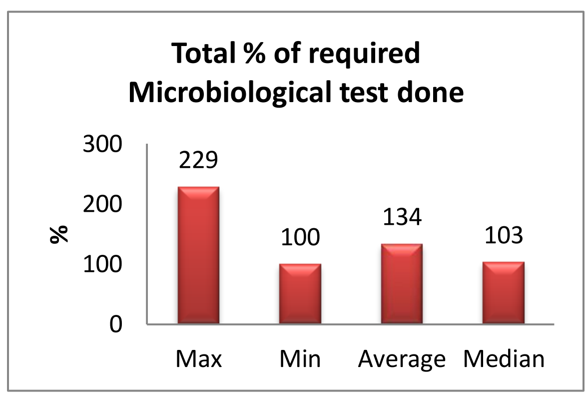

Figure 38. Total % of required microbiological tests done

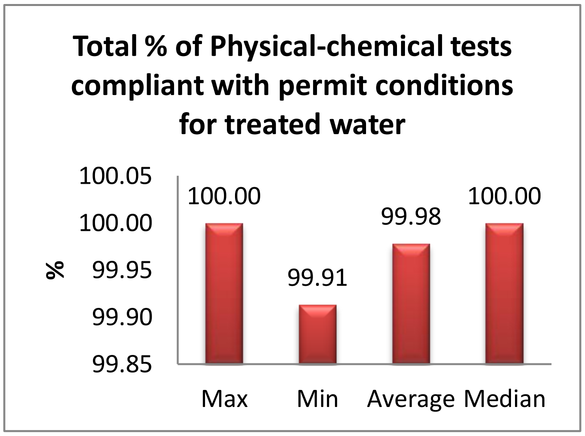

Figure 39. Total % of physical-chemical tests compliant with standard for treated water

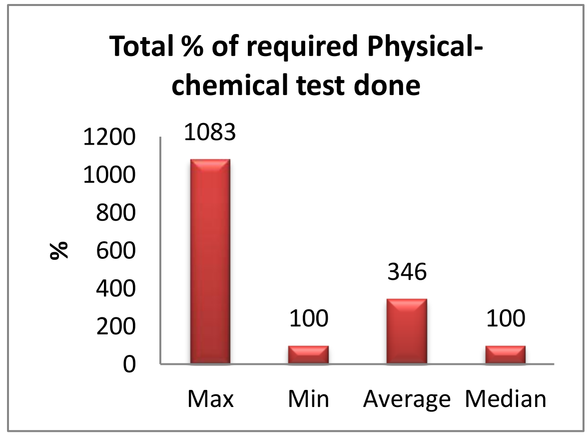

Figure 40. Total % of required physical-chemical tests done

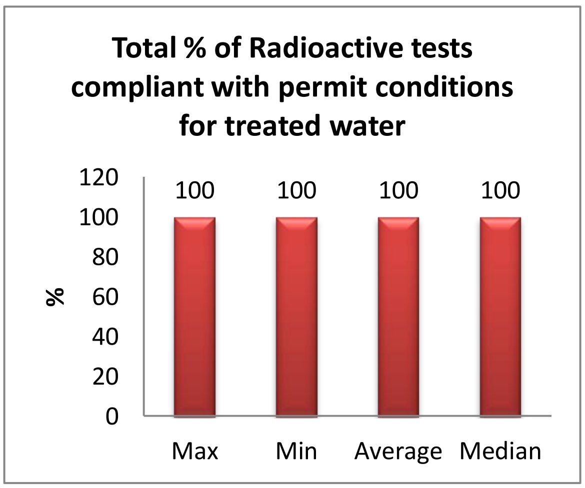

Figure 41. Total % of radioactive tests compliant with standard for treated water

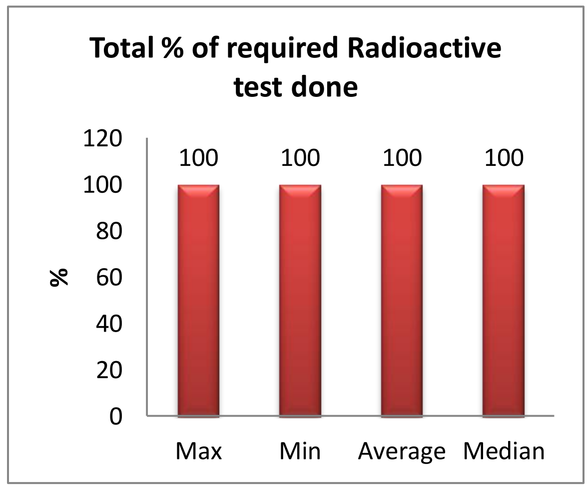

Figure 42. Total % of required radioactive tests done

4.5 OPERATIONAL PERFORMANCE

Results and analysis:

Those responsible for utility operations can only manage what they measure, so having information on productivity trends and relative performance enables utility managers to direct attention to shortfalls (Berg et al, 2007). The indicators for operational performance evaluate efficient use of resources, reliability, inspection of current assets, rehabilitation of existing assets, and losses due to low operational performance. Inefficient or ineffective operations also lead to higher costs.

All the results are summarized in Table 13. Pump inspection shows the percentage of existing pumps inspected as shown in Figure 43. It was found that a few utilities inspected all their pumps, while some utilities did not inspect any pumps in the last one year. Storage tank cleaning shows the percentage of tanks cleaned in the last one year and the results are summarized in Figure 44 and Figure 45. This indicator shows a lower number and most of the utilities do not clean all their storage tanks every year. Main inspection (Figure 46) shows the percentage length of main inspected and the values show that none of the participating utilities focuses on inspecting the mains, as the value for this indicator is close to zero for all the utilities. Results for valve inspection show that most of the utilities do not inspect the valves on a regular basis and change the valves whenever a problem occurs as summarized in Figure 47. Hydrant inspection shows the percentage inspected and the results for this indicator show that a few utilities inspect all the hydrants every year while others do not inspect the hydrants, rather replace the hydrants when they stop working as summarized in Figure 48.

Indicators for rehabilitation like leakage control shows the number of main breaks detected and repaired per 100 miles of main. Many utilities showed the value of this indicator in the range of 20 breaks in 100 miles and the utilities with higher values should focus on maintenance and rehabilitation of mains as summarized in Figure 49.

Transmission main and distribution main replaced and rehabilitated shows the percentage of mains replaced and rehabilitated in the last one year. Transmission mains show a higher value than distribution mains and as summarized in Figure 50 and Figure 51.

Valve replacements, service connection rehabilitation, pump refurbishment, and pump replacement show the summary of percentage of respective assets as summarized in Figure 52, Figure 53, Figure 54 and Figure 55.

Water loss includes water lost through leaks, breaks, backwash, flushing, under--registering meters, etc. Water loss per connection (Figure 56) and percentage of water lost which was treated in last one year shows values in the range of 7.5 to 27 percent as summarized in Figure 57. Water loss is a concern for every utility because loss of treated water is a loss in terms of both money and resources. Non-revenue water can sometimes be attributable to a poor meter replacement program, because a meter tends to under-register as it ages. Operational meters indicator shows the percentage of meters which are working and all the utilities shows a number close to 100 percent for this indicator as summarized in Figure 58. Unmetered water shows the percentage of water which is not metered and utilities show an average value around 10 percent for this indicator as summarized in Figure 59.

The indicators for system flow meter calibration, meter replacement rate, pressure meter calibration, water level meter calibration, online water quality monitoring equipment calibration are discarded because there was insufficient data to make conclusions.

One interesting fact about many waterlines around the country was found from the information gathered. The waterlines installed in 1900-1910 have a reliable service life of 100 to 110 years while those installed in 1930-1950 have a reliable service life of about 75 years. This is due to the better materials used during early nineteenth century. Along with this, during the 1950s a lot of galvanized lines were installed. As a result, all of the assets installed between 1900 and 1950 are reaching the end of their reliable service life at about the same time.

Limitations:

1. The inspection techniques for buried pressure pipe can be too costly for regular use. Alternatively some utility uses a criticality model that creates a matrix where pipe segments are ranked ranging from a low likelihood of failure and low consequence of failure up to a high likelihood and high consequence of failure. This takes into account pipe age, pipe material, previous failures, consequences of failure, etc. For example, a main transmission pipeline that provides service to the hospital has a much higher consequence of failure then a distribution line serving five houses on a cul-de-sac. The utilities showing lower values for physical inspection related indicator does not mean a lower performance.
2. Higher values for inspection and maintenance related indicators may mean a higher concern by a utility regarding the current asset condition, but this is not always the case. It is also a function of resources and age of the system.
3. For every asset, there is an optimal replacement or renewal time. Replacing it too soon wastes some of the remaining value of the asset and replacing it too late leads to higher cost of replacement and maintenance. This should be considered while analyzing the sustainability and rehabilitation related indicators.

Table 13. List of indicators, definition and results for operational performance

Indicator	Definition	Unit	Max	Min	Average	Median
Inspection and maintenance						
Pump inspection	Total number of pumps inspected or checked in last 1 year / Total number of pumps x 100	%	100	0	50	50
Storage tank cleaning - number	Total number of storage raw water and treated water tanks cleaned in last 1 year / Total number of raw water and treated water storage tanks x 100	%	8.57	0.00	2.86	0.00
Storage tank cleaning - volume	Total volume of raw water and treated water storage tanks cleaned in last 1 year / Total volume of all raw water and treated water storage tanks x 100	%	34	0	18	20

Main inspection	Total length of transmission and distribution main pipes inspected - physical inspection for proper working condition, internal inspection by video, flow measurements to calculate head loss etc. / Total length of mains x 100	%	0.29	0.00	0.10	0.01
Valve Inspection	Number of valves inspected - checked to insure it is operational / Total number of valves x 100	%	14	4	9	9
Hydrant inspection	Number of hydrants inspected - checked to insure it is operational / Total number of hydrants x 100	%	100	7	59	65
Sustainability/ rehabilitation						
Leakage control	number of leaks or main breaks detected and repaired - in last 1 year / total length of main x 100	number / 100 miles	31	9	21	20
Transmission Main replaced / rehabilitated - in last 1 year	length of transmission mains replaced or rehabilitated- in last 1 year (miles) / Total length of transmission mains (miles) x 100	%	16.52	0.00	5.84	1.00
Distribution Main replaced /	length of distribution mains replaced or	%	1.00	0.02	0.37	0.10

rehabilitated - in last 1 year	rehabilitated- in last 1 year (miles) / Total length of distribution mains (miles) x 100					
Valves replacement - in last 1 year	no. of valves replaced / total no. of valves x 100	%	1.00	0.04	0.39	0.15
Service connection rehabilitation - in last 1 year	no. of service connections replaced or renovated / total number of connections x 100	%	5.59	0.01	1.59	0.21
Pump refurbishment - in last 1 year	number of pumps refurbished / total number of pumps x 100	%	7.55	0.04	2.64	0.32
Pump replacement - in last 1 year	number of pumps replaced / total number of pumps x 100	%	4.93	0.00	2.46	2.46
Water losses						
Water loss per connection	total water lost in gallons or total non-revenue water - in last 1 year / Total number of connections	gallons / connection	42096	13937	23984	18052
% water lost	total water lost or total non-revenue water - in last 1 year / Total treated water produced - in last 1 year	%	27.3	7.54	16.2633	15.845
Water meter						
Operational meters	no. of working customer meters/total customer meters x 100	%	100	98	99	99
Unmetered water - volume which is	Volume of supplied water which is not metered - daily average	%	23.16	0.00	11.45	11.32

charged but not metered	/ Total volume of treated water supplied - daily average x 100					

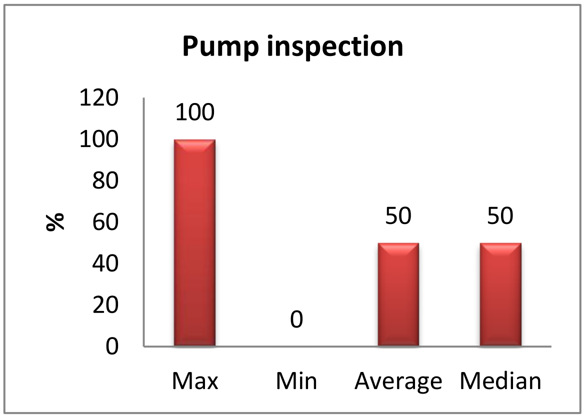

Figure 43. Pump inspection

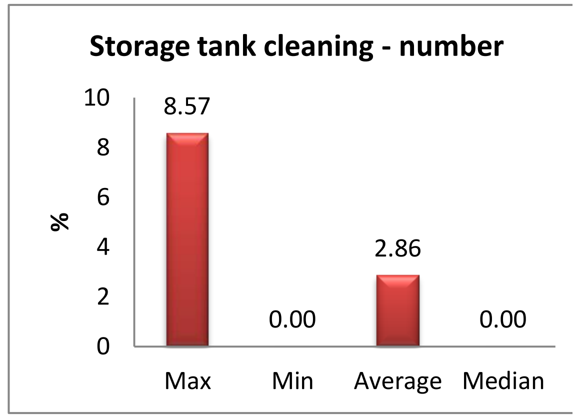

Figure 44. Storage tank cleaning - number

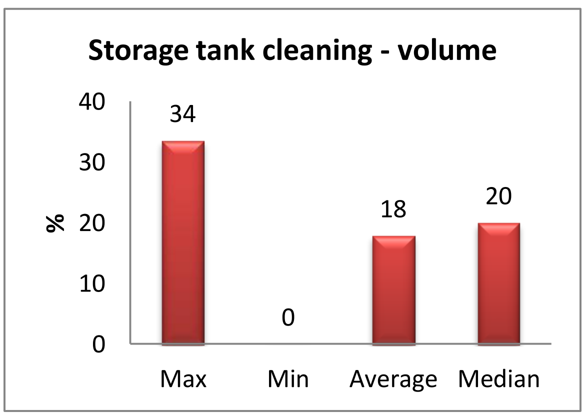

Figure 45. Storage tank cleaning - volume

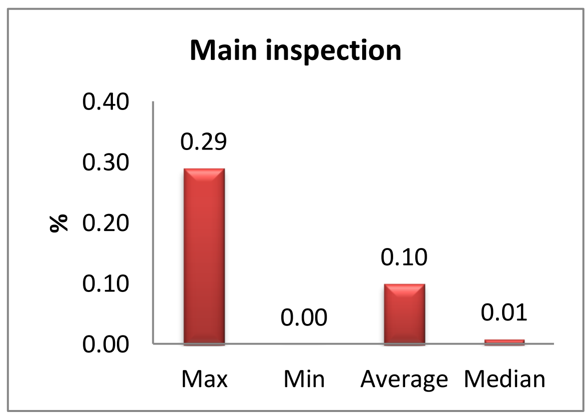

Figure 46. Main inspection

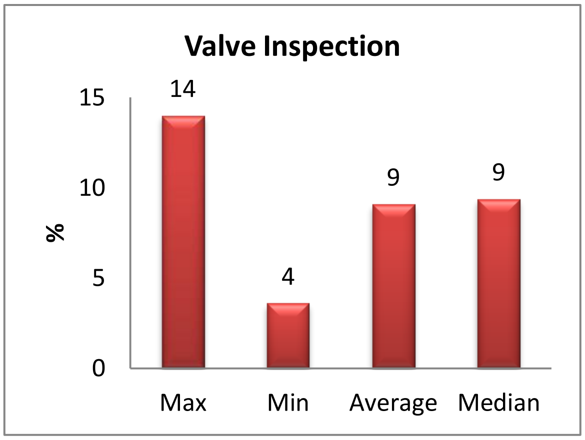

Figure 47. Valve inspection

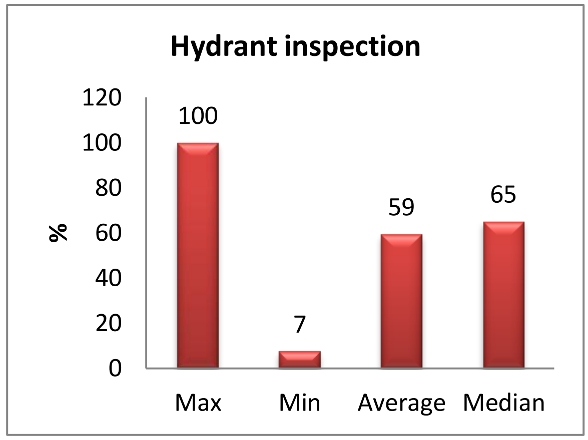

Figure 48. Hydrant inspection

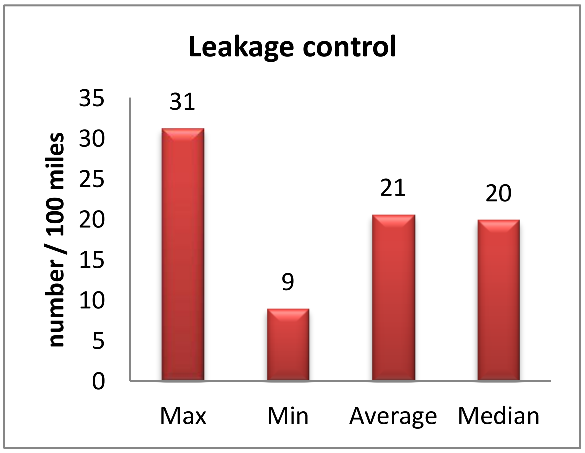

Figure 49. Leakage control

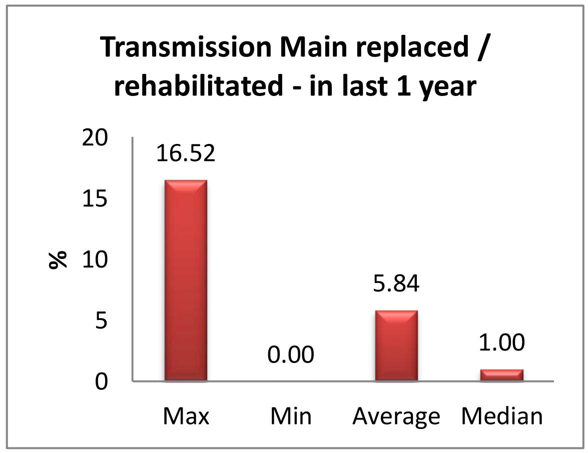

Figure 50. Transmission main replaced / rehabilitated - in last 1 year

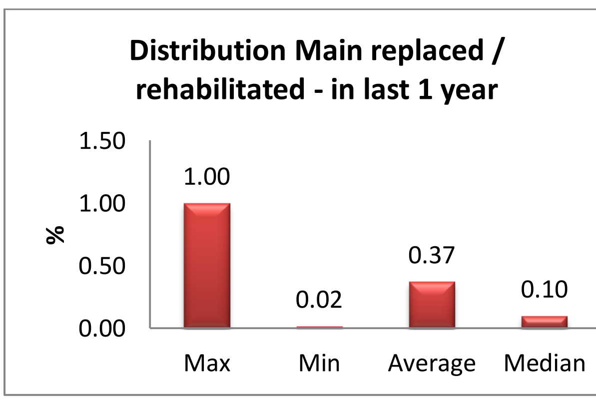

Figure 51. Distribution main replaced / rehabilitated - in last 1 year

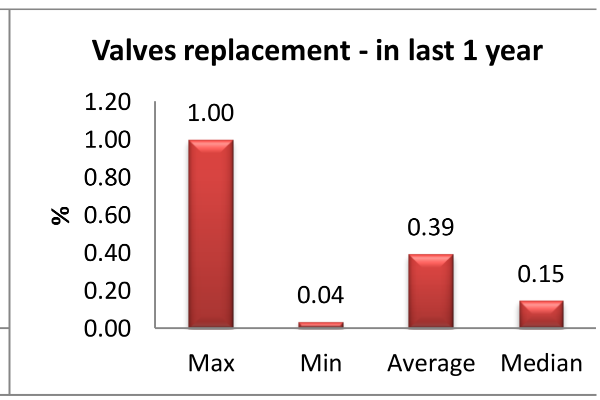

Figure 52. Valves replacement - in last 1 year

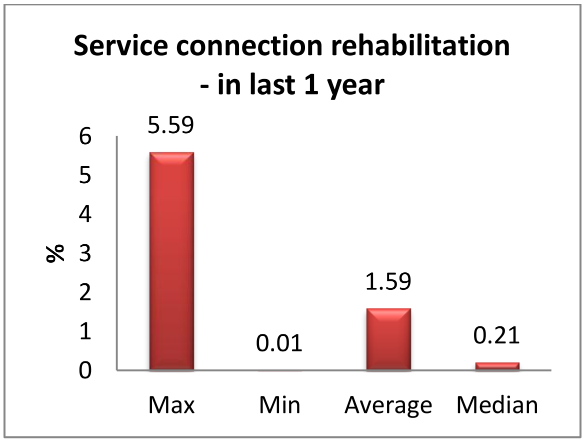

Figure 53. Service connection rehabilitation - in last 1 year

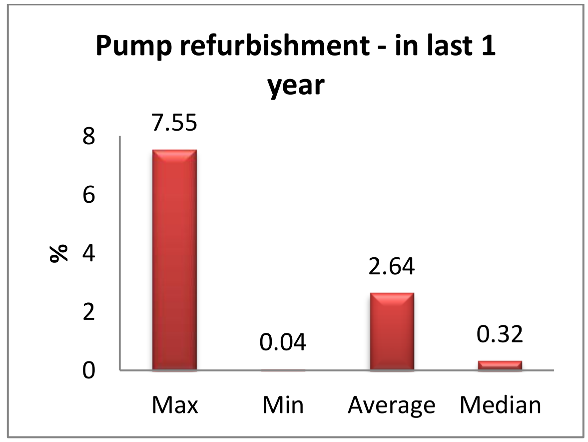

Figure 54. Pump refurbishment - in last 1 year

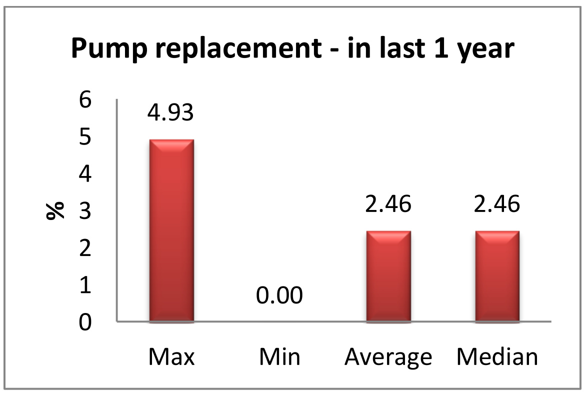

Figure 55. Pump replacement - in last 1 year

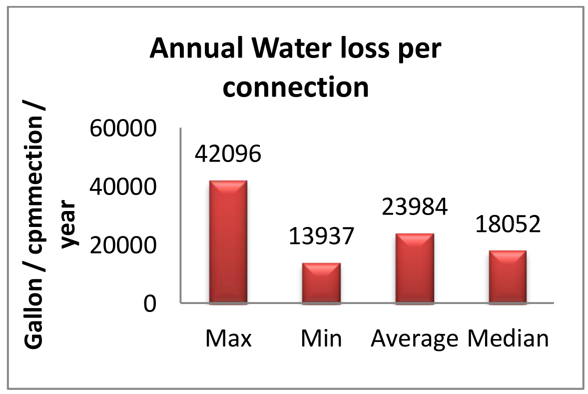

Figure 56. Annual water loss per connection

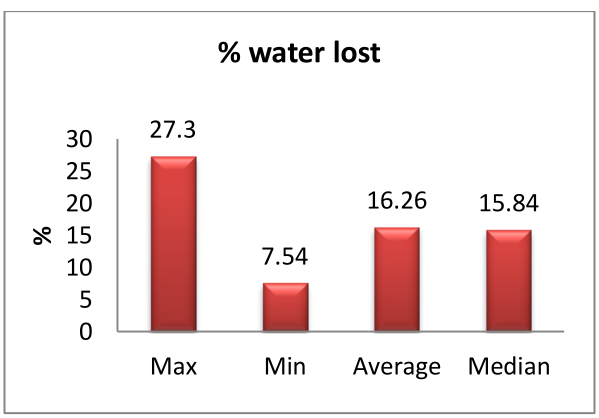

Figure 57. % water loss

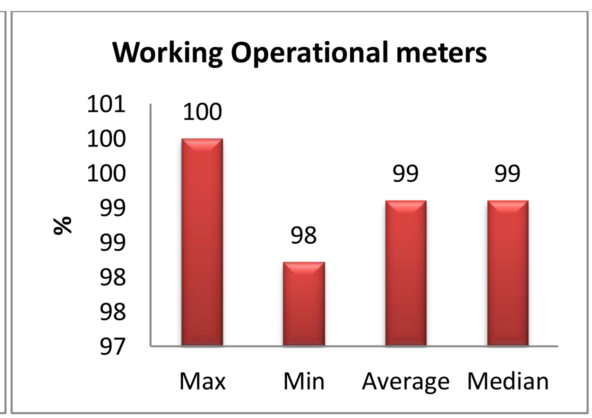

Figure 58. Working operational meters

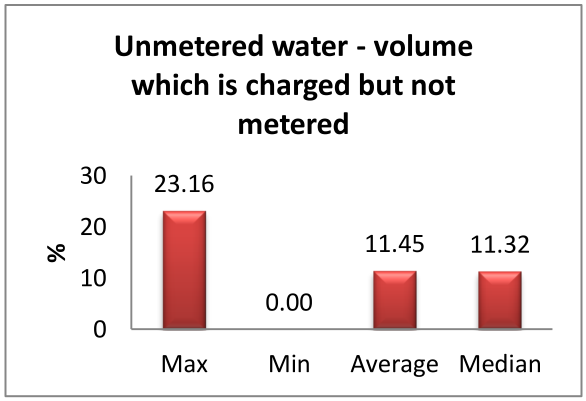

Figure 59. Unmetered water - volume which is charged but not metered

4.6 CUSTOMER ENQUIRIES

Results and analysis:
Customer satisfaction, a term frequently used is a measure of how the services supplied by a utility meet customer expectations. Customer satisfaction is defined as the number of customers, or percentage of total customers, whose reported experience with a firm, its products, or its services (ratings) exceeds specified satisfaction goals (Farris, 2010). In a survey of nearly 200 senior marketing managers, 71 percent responded that they found a customer satisfaction metric very useful in managing and monitoring their businesses (Farris, 2010). In a competitive marketplace where businesses compete for customers, customer satisfaction is seen as a key differentiator and increasingly has become a key element of business strategy (Gitman, 2005).

The result for each indicator is summarized in Table 14. Service enquiries per 100 connections show total enquiries in last one year per 100 connections and the value is in the range of 0.47 to 4.1 as summarized in Figure 60. The enquiries were further divided by type of inquiries. Percentage of pressure related reports (Figure 61), percentage of continuity related reports (Figure 64), percentage of water quality – taste related reports (Figure 65), percentage of water quality – odor related reports (Figure 62), and percentage of interruption related reports (Figure 63) show the percentage of reports in respective categories. It was found that pressure of water supply, continuity of water, and interruptions are the categories for which customers reported the most. The indicator for billing related reports was excluded because of insufficient data.

Limitations:

1. Customer enquiries are always not complaints. Enquiries can be due to many reasons like for asking general questions, informing about issues, following up for a new connection and many more. All these should be considered while evaluating the values for the indicators in this category.

Table 14. List of indicators, definition and results for customer enquiries

Indicator	Definition	Unit	Max	Min	Average	Median
Service enquiries per 100 connection	total number of enquiries - in last 1 year / total number of connections	number / 100 connection	4.10	0.47	1.93	1.68
Pressure related reports	no. of pressure related reports - in last 1 year / total no. of reports x 100	%	42.26	0.23	12.47	4.00
Continuity related reports	no. of Continuity related reports - in last 1 year / total no. of reports x 100	%	57.58	0.57	19.62	0.70
Water quality - taste related reports	no. of taste related reports - in last 1 year / total no. of reports x 100	%	3.23	0.03	1.16	1.01
Water quality - odor related reports	no. of odor related reports - in last 1 year / total no. of reports x 100	%	1.77	0.30	1.27	1.74
Interruption related reports	no. of Interruption related reports - in last 1 year / total no. of reports x 100	%	57.58	1.20	17.50	5.61

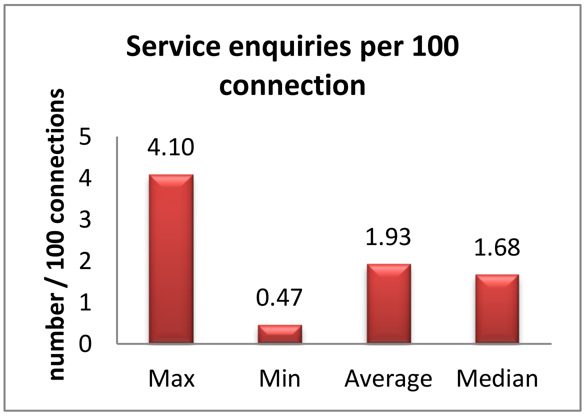

Figure 60. Service enquiries per 100 connection

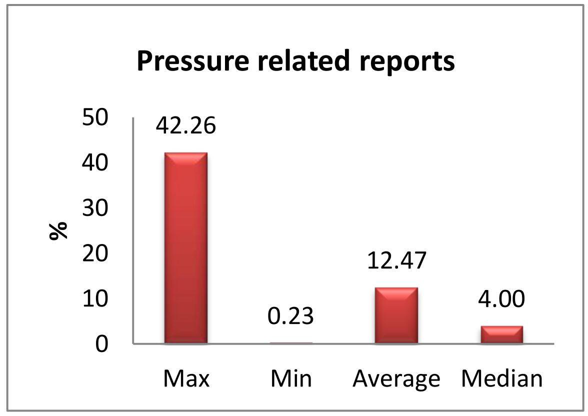

Figure 61. Pressure related reports

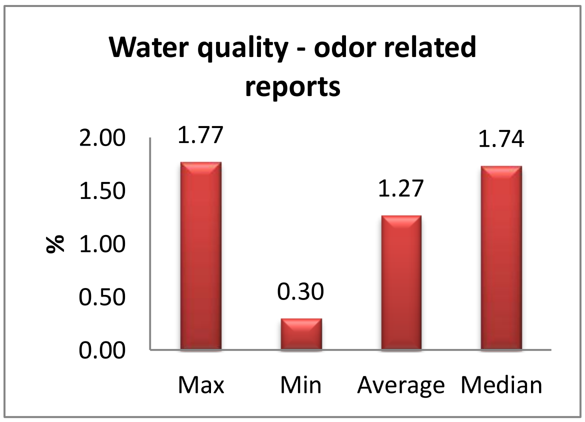

Figure 62. Water quality - odor related reports

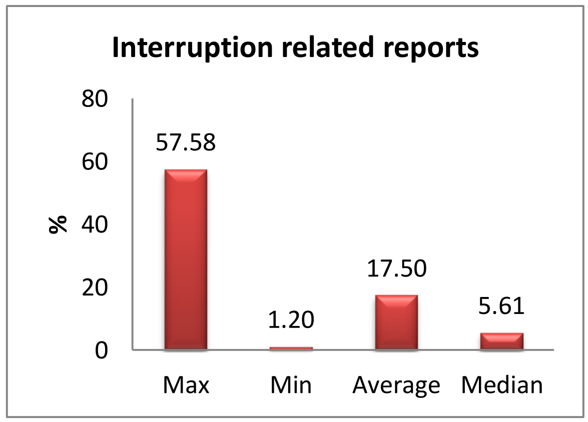

Figure 63. Interruption related reports

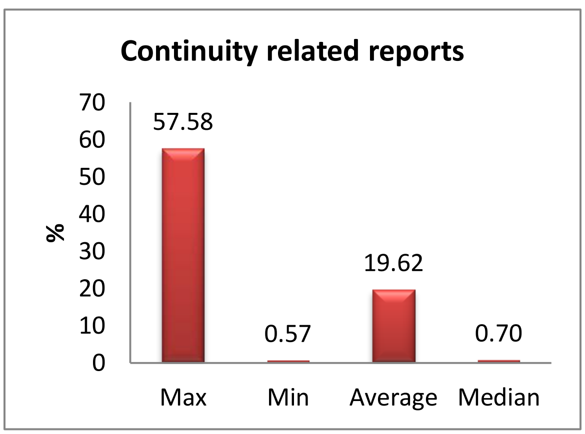

Figure 64. Continuity related reports

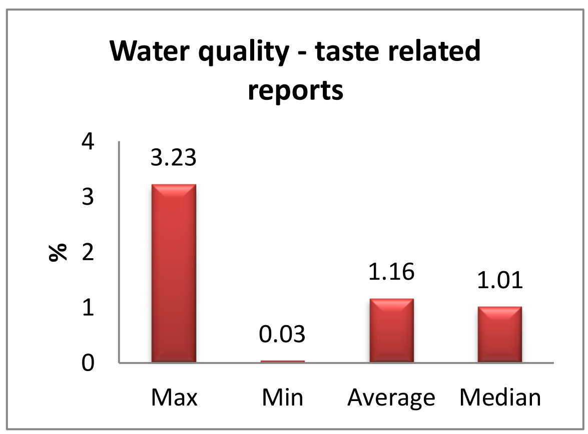

Figure 65. Water quality - taste related reports

4.7 FINANCIAL PERFORMANCE

Results and analysis:

Measuring the results of a utility's policies and operations in monetary terms is a definition of financial performance. Financial results are reflected in the utility's return on investment, return on assets, value added, total cost, revenue generated, cost coverage, profit, etc. Financial performance is a measure of how well a utility can use assets from its primary mode of business and generate revenues. This term is also used as a general measure of a utility's overall financial health over a given period of time. Consideration of financial sustainability includes examining the role of revenues, and expenses affect overall performance. Key financial ratios serve as indicators of long term performance, as revenues can be used to facilitate future capacity investments for both network expansion and external funding can be contingent on current cash flows more than covering operating expenses (Berg et al, 2007).

The result for each indicator is summarized in Table 15. The indicators for the revenue section summarize revenue per million gallons of treated water produced as shown in Figure 66. Revenue is further divided into percentage of sales revenue (Figure 67) and percentage of other revenue (Figure 68) which includes earnings from supply of raw water and others. It was observed that major percent of revenue is collected from sales for all the utilities. The indicators for the cost summarizes total cost per million gallons treated water produced (Figure 69), capital cost per million gallons of water produced (Figure 70), and operating cost per million gallons of water produced (Figure 71). The summary of percentage of operation cost is summarized by the type operation and is summarized in Figure 72 for transmission, storage and distribution, Figure 73 for treatment and testing, Figure 74 for energy cost, Figure 75 meter management and connection cost and Figure 76 for any other operational cost. It was observed that the percentage of operational cost for transmission, storage, distribution and water treatment and testing shows higher values as expected because these are the main functions of utilities.

Expenses related indicators summarize total expenses per million gallons of water produced as summarized in Figure 77, percentage of expenses on new assets is summarized in Figure 78 and percentage of total expenses on replacement and renovation is summarized in Figure 79. For all the utilities it was observed that majority of expenses was for new assets. Average water charge from direct consumption is summarized in Figure 80. Rate which utility charges the consumer (Figure 81) was collected from utilities and the values change depending on the cost of treatment and operation. Total cost coverage (Figure 82), operational cost coverage (Figure 83), current ratio (Figure 84), asset turnover ratio (Figure 85), and water loss cost - non revenue water cost (Figure 86) are indicators for the efficiency. Earnings per million gallons of treated water produced shows the earnings of utility per million gallons of water produced and the results are summarized in Figure 87. It was observed that a few utilities have a zero value for the indicator related to earnings; this is because these utilities are publically owned and cannot make net income.

It was observed that some utilities are experiencing a trend in reduction of demand and this is expected to continue in the forecast, while population is expected to increase. Various factors contributing to the reduction in demand included conservation programs, water and sewer rates, and improved system operations. One utility reported that in the last five years the average household consumption decrease from 6.53 hcf (4880 gallons) per month to 5.62 hcf (4200 gallons) per month. While from a conservation standpoint this is perceived as a good thing, but it is creating significant challenges to the utilities. For the utility, revenues in both water and sewer fund went down by approximately $1 million since last year and the city council was reluctant to raise water and sewer rates. But in this economic climate, any increases they approve can only cover rising operational costs. As a result, the utility had to significantly cut back the capital improvement programs (CIP). For example in the sewer fund the utility reduced the annual CIP from $20-$25 million down to $2 - $3 million at a time where infrastructure investment is critical for long term sustainability.

Limitations:

1. A higher value of revenue related indicators does not mean better financial performance because these values change with the cost involved. It is also dependent on the size and location of the utilities. Although, higher revenues are preferred but does not tell the entire story.
2. A lower value of cost related indicators does not necessarily mean better financial performance because cost is dependent on many factors like total population served, size of utility, location of utility and others. Cost is also dependent on revenue generated, so variation of cost should be considered with the variation of revenue.

Table 15. List of indicators, definition and results for financial performance

Indicator	Definition	Unit	**Max**	**Min**	**Average**	**Median**
Revenue						
Revenue per Mgal treated water produced - in last 1 year	Total revenue in last 1 year / Total treated water produced in last 1 year	$ / Mgal	6083	1045	3109	3189
Sales revenue in last 1 year	revenue generated by sales / Total revenue x 100	%	98.46	76.00	89.93	94.08

Other revenue in last 1 year	revenue generated which are not from sales / Total revenue x 100	%	67.67	1.54	17.27	10.12
Cost						
Total cost per Mgal treated water produced - in last 1 year	Capital cost plus Operating cost - in last 1 year / Total treated water produced in last 1 year	$ / Mgal	3638	975	2473	2394
Capital cost per Mgal treated water produced - in last 1 year	Total Capital cost in last 1 year / Total treated water produced in last 1 year	$ / Mgal	1847	126	995	1065
Operating cost per Mgal treated water produced - in last 1 year	Total Operating cost in last 1 year / Total treated water produced in last 1 year	$ / Mgal	5113	688	1930	1581
% Operational Cost by type						
% of Transmission, storage and distribution cost - in last 1 year	total cost related to Transmission, storage and distribution process / Total Operational cost	%	30	18	24	23
% of Water Treatment and water testing cost - in last 1 year	total cost related to Water Treatment and water testing / Total Operational cost	%	37	31	35	37
% of Energy /	total cost related to	%	14	9	11	11

Electricity used cost - in last 1 year	Energy / Electricity used / Total Operational cost					
% of Meter management and connection related cost - in last 1 year	total cost related to Meter management and connection related / Total Operational cost	%	10	1.16	7	10
Any other operational cost - in last 1 year	any other cost / Total Operational cost	%	32	10	23	26
Expenses on assets						
Total expenses - in last 1 year	Total expenses on plant and equipment – new / replacement / renovation - In the last 1 year / Total treated water produced in last 1 year	$ / Mgal	1847	591	1203	1242
% on New assets - in last 1 year	Expenses on new assets / Total expenses x 100	%	100	29	72	86
% on Replacement and renovation - in last 1 year	Expenses on replacement and renovation of existing assets / Total expenses x100	%	35	14	25	25
Water rate (calculated using sales revenue and water produced)						
Average Water charges from direct consumption	Total Sales revenue - in last 1 year / Total treated water produced in last 1 year	$ / Mgal	3929	1966	2724	2519

Water rate which utility charges the consumer	as per the standard utility rate	$ / Mgal	4745	2160	3361	2690
Efficiency						
Total cost coverage	total revenue in last 1 year / total cost in last 1 year	-	1.92	0.57	1.12	1.05
Operational cost coverage	total revenue in last 1 year / total operational cost in last 1 year	-	4.58	0.93	1.90	1.69
Current Ratio (Liquidity measure)	total current assets value / total current liabilities value	-	5.51	0.92	2.18	1.91
Asset turnover ratio	Sales revenue in last 1 year / total current assets value	-	2.88	0.06	0.55	0.19
Water Loss cost - non revenue water cost	Estimated cost of non-revenue water - in last 1 year / Total Operating cost in last 1 year x 100	%	9.47	1.40	4.09	1.40
Earnings						
Earnings per million gallons of treated water produced	Total earnings - in last 1 year /Total treated water produced in last 1 year	$ / Mgal	1403	335	790	716

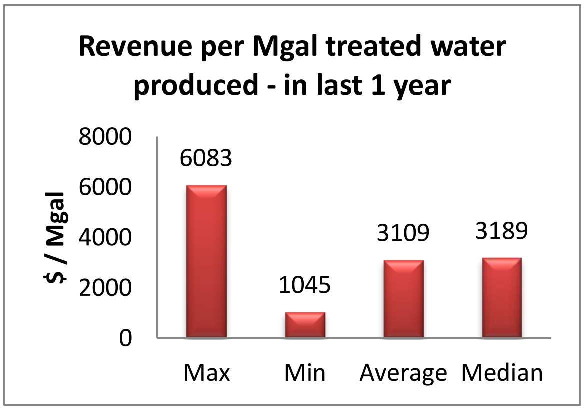

Figure 66. Revenue per Mgal treated water produced - in last 1 year

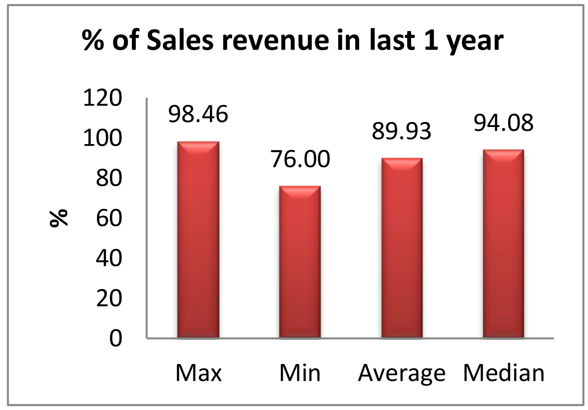

Figure 67. Sales revenue in last 1 year

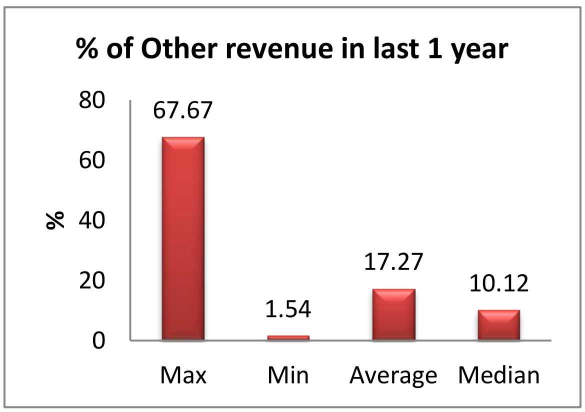

Figure 68. Other revenue in last 1 year

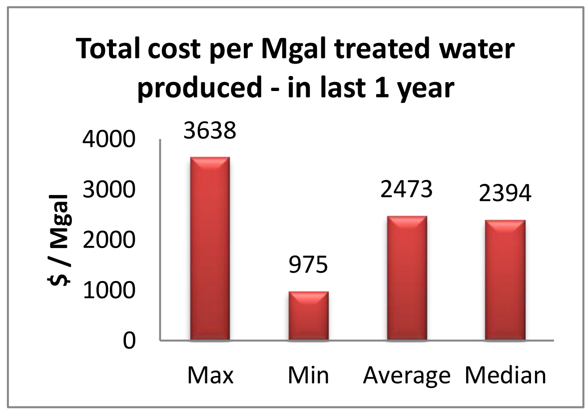

Figure 69. Total cost per Mgal treated water produced - in last 1 year

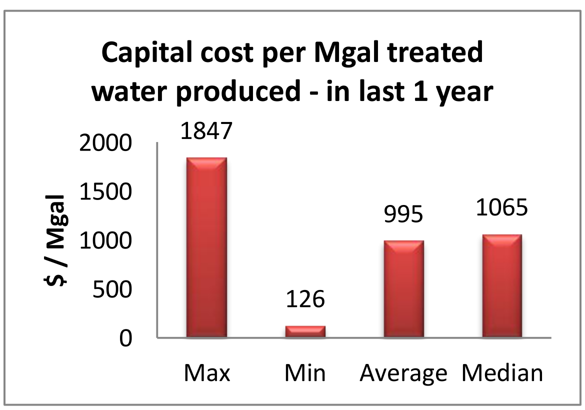

Figure 70. Capital cost per Mgal treated water produced - in last 1 year

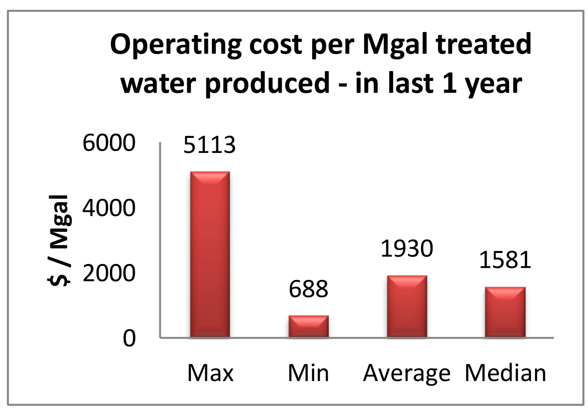

Figure 71. Operating cost per Mgal treated water produced - in last 1 year

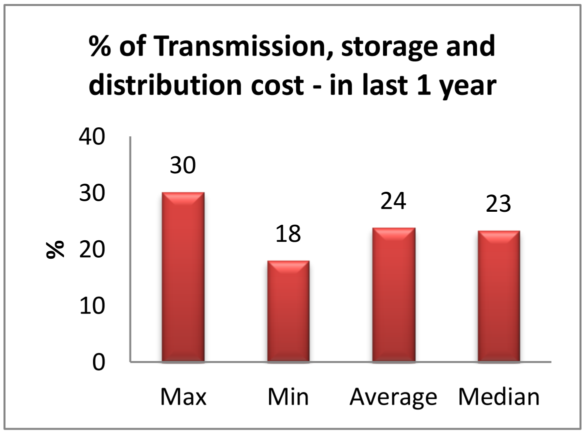

Figure 72. % of transmission, storage and distribution cost - in last 1 year

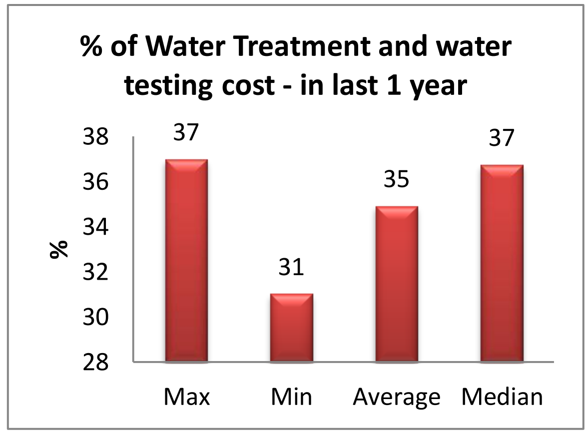

Figure 73. % of water treatment and water testing cost - in last 1 year

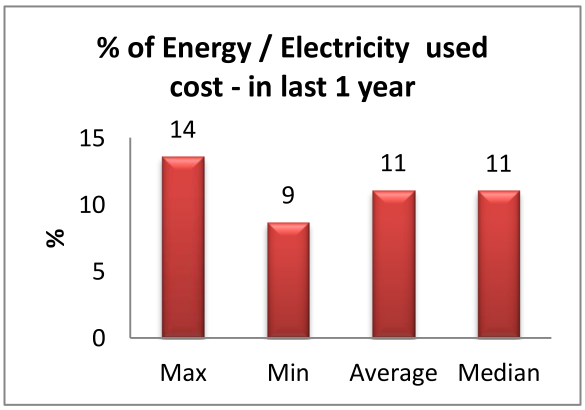

Figure 74. % of energy / electricity used cost - in last 1 year

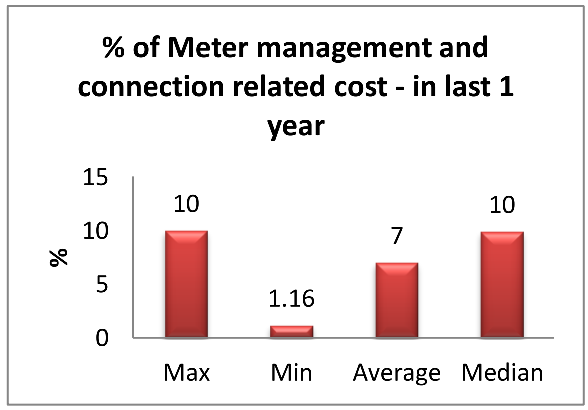

Figure 75. % of meter management and connection related cost - in last 1 year

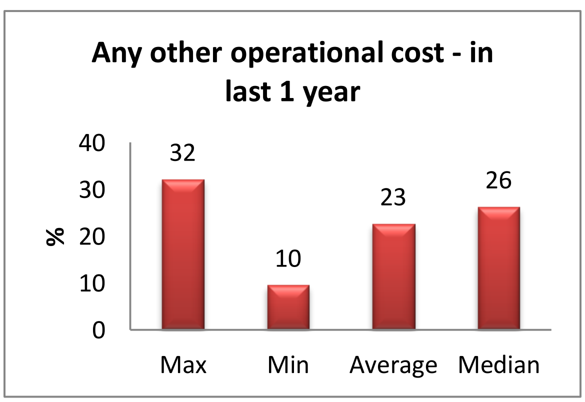

Figure 76. Any other operational cost - in last 1 year

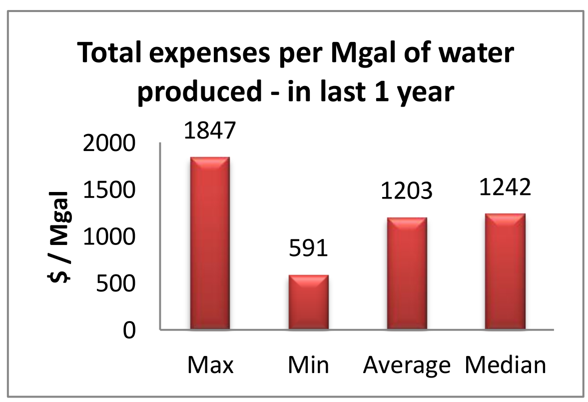

Figure 77. Total investment per Mgal of water produced - in last 1 year

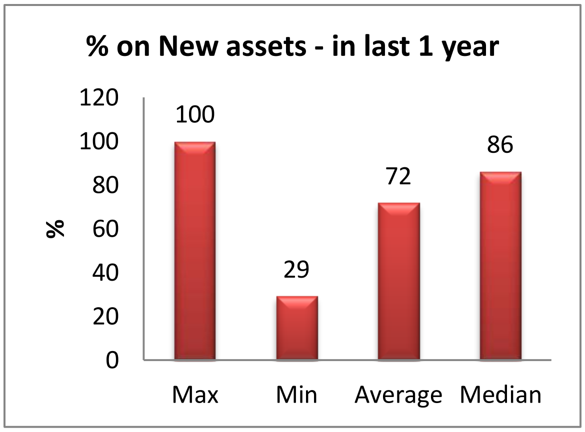

Figure 78. % on new assets - in last 1 year

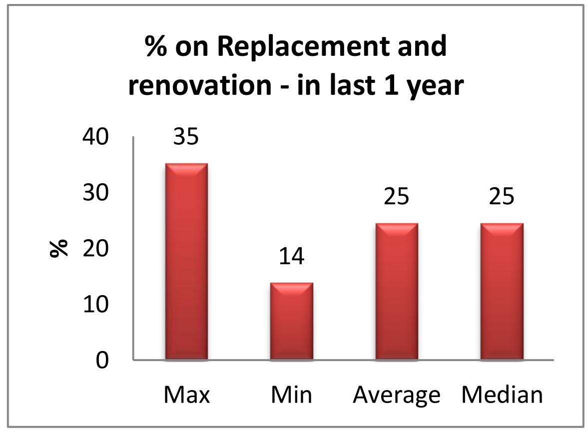

Figure 79. % on replacement and renovation - in last 1 year

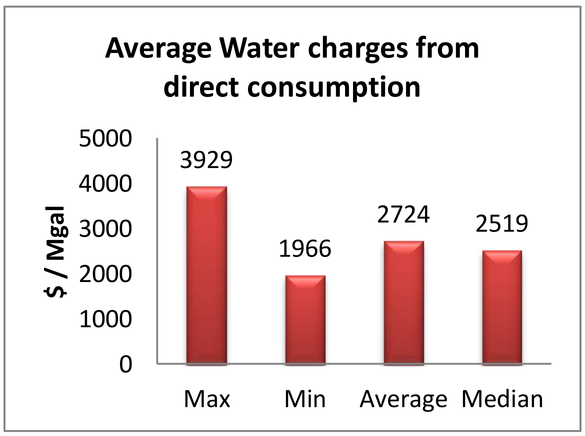

Figure 80. Average water charges from direct consumption

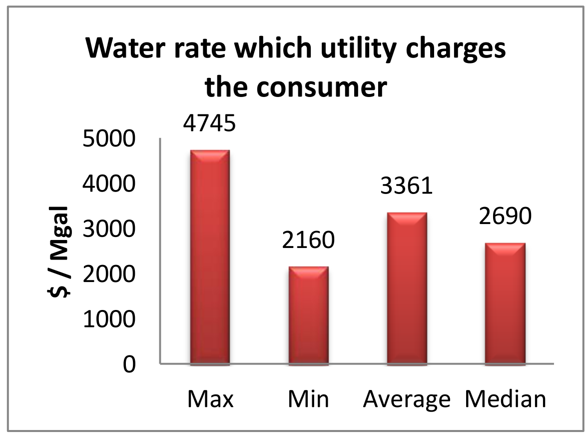

Figure 81. Water rate which utility charges the consumer

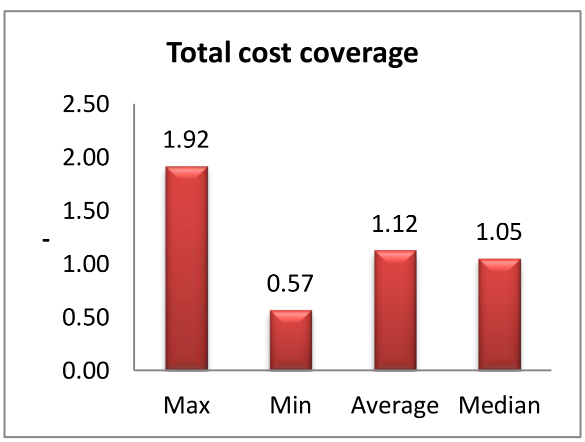

Figure 82. Total cost coverage

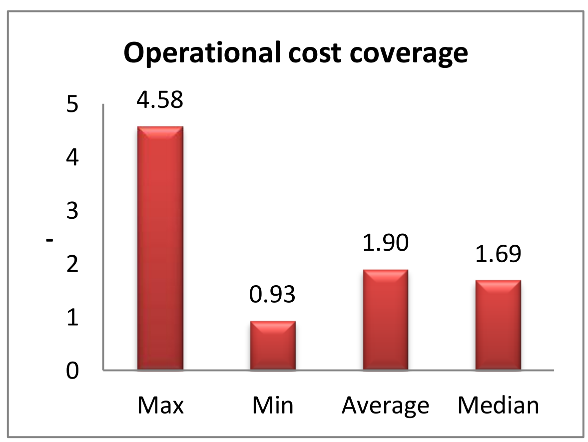

Figure 83. Operational cost coverage

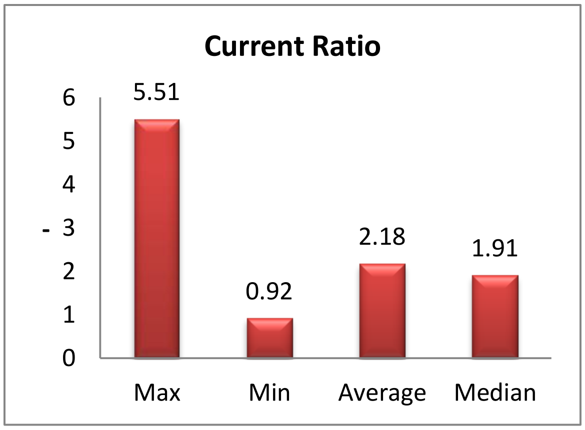

Figure 84. Current ratio (liquidity measure)

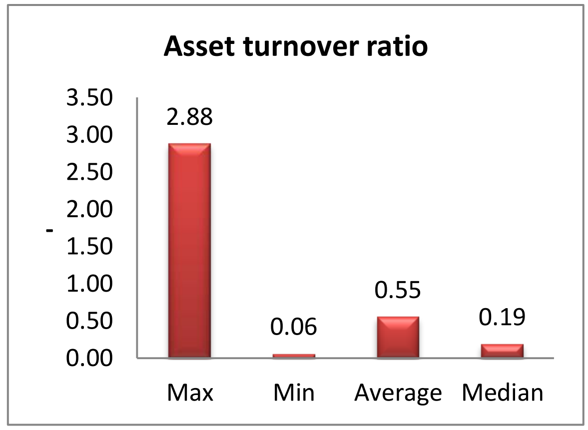

Figure 85. Asset turnover ratio

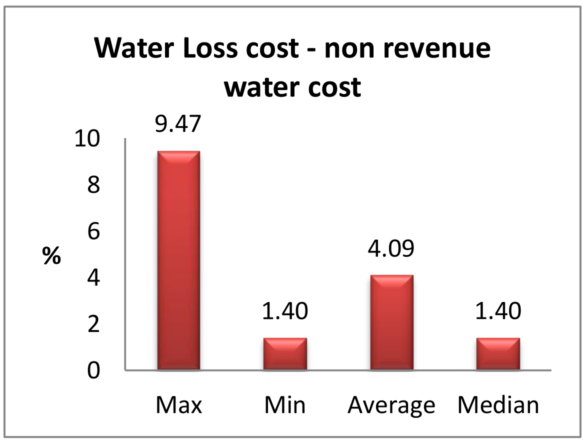

Figure 86. Water loss cost - non revenue water cost

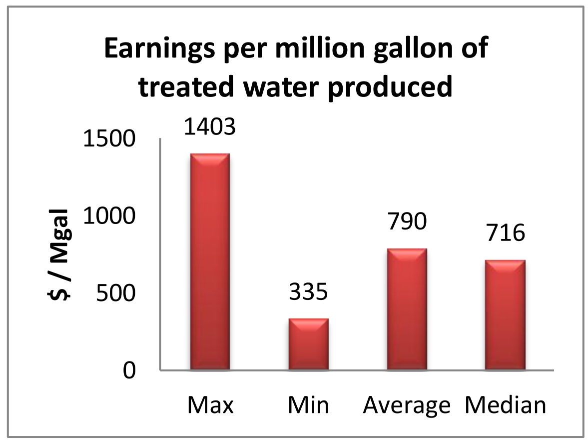

Figure 87. Earnings per million gallons of treated water produced

CHAPTER 5. PERFORMANCE BENCHMARKING RESULTS, ANALYSIS AND LIMITATIONS – WASTEWATER UTILITIES

The indicators were defined based on research papers, books and reports on benchmarking along with suggestions of utility personnel. The defined indicators represent seven key areas and a total 89 indicators were used for data collection. The collected data for this study is from 2011-2012. A committee consisting of representatives of wastewater utilities and consultants was formed to review the results. The committee members are experts from the wastewater industry, and provided their feedback about the results.

The graphs show the maximum, minimum, average and median value for the data collected for each indicator from all the 9 wastewater utilities. The results are also available on WATER*i*D website and continuous data collection will be performed using the web-based benchmarking data collection and result visualization platform. This will enable the database to grow and will result in better database for future benchmarking. Further, each graph has the maximum, minimum, average and median value for the indicator and the definition is described below:

Maximum value: maximum of all the values collected from utilities for the indicator.

Minimum value: minimum of all the values collected from utilities for the indicator.

Average value: average of all the values collected from utilities for the indicator.

Median value: median of all the values collected from utilities for the indicator.

5.1 WASTEWATER AND BIOSOLIDS

Results and analysis:

The indicators in this category evaluate the performance related to environmental impacts, including compliance with discharge consents, reuse of wastewater, and disposal of Biosolids produced.

The result for each indicator is summarized in Table 16. It was found that most of the utilities have a high value for compliance with discharge consent which is the percentage of population equivalent (PE) served by wastewater plant complying with discharge consents as summarized in Figure 88. PE for industrial waste is a quantitative expression of the population load of commercial or industrial wastewater in terms of the number of equivalent people that would create a waste of the same strength. One PE corresponds to the population load of sewage generated by one inhabitant. Usually it corresponds to BOD5 loads. BOD5 is defined as the biochemical oxygen demand of wastewater during decomposition occurring over a 5-day period. Percentage for reuse of treated wastewater shows a low percentage for most of the utilities as summarized in Figure 89. Percentage for use of biosolids which are produced (Figure 90) by a wastewater treatment plant shows an irregular trend among utilities and the value changes with the size of service area and population served. Biosolids use (Figure 91) and biosolids disposal (Figure 92) show irregular behavior for different utilities. A few utilities show higher values for biosolids use and low values for biosolids disposal and a few utilities show the opposite trends. The utilities with higher biosolids disposal can supply it for agriculture, products, materials, etc.

Limitations:

1. One key issue found related to wastewater reuse was that reuse regulations may impact a plant potential for reuse. For example, a utility explored the possibility of reuse and found that there are at least two different levels of treatment required depending upon the reuse application. In such case, the end user would have had personnel exposed to the reclaimed water, and this would have required significantly more treatment of the effluent and can make the project cost-prohibitive. A benefit of reuse is in areas where there are nutrient limit, reuse of the wastewater reduces the amount of nitrogen and phosphorus being discharged. This may help plants meet permit limits and generate nitrogen and phosphorus for nutrient trading, which can be an additional source of revenue.

Table 16. List of indicators, definition and results for wastewater and Biosolids

Indicator	Definition	Unit	Max	Min	Average	Median
Wastewater						
Compliance with discharge consents - last 1 year	current number of Population Equivalent (PE) served by WW treatment plant complying with discharge consents / Total Population Equivalent (PE) served x 100	%	100.00	43.48	81.80	100.00
Reuse	volume of wastewater reused after treatment in last 1 year / Total volume of wastewater treated in last 1 year x 100	%	8.10	0.00	1.59	0.00
Biosolids						
Biosolid production	dry weight of biosolids produced in last 1 year / Total Population Equivalent (PE) served	lbs / PE / year	153.39	42.05	66.85	51.71

Biosolid use	dry weight of produced biosolids used for agriculture, products, materials etc. - in last 1 year / dry weight of Biosolids produced in last 1 year x 100	%	100.00	0.00	33.28	10.26
Biosolid disposal	dry weight of Biosolids disposed - in last 1 year / dry weight of Biosolids produced in last 1 year x 100	%	100.00	0.00	52.77	51.74

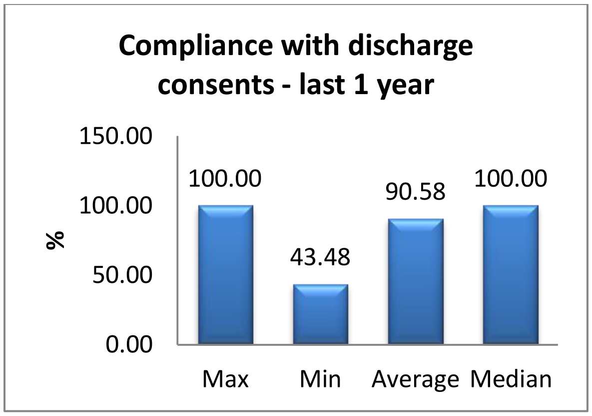

Figure 88. Compliance with discharge consents - last 1 year

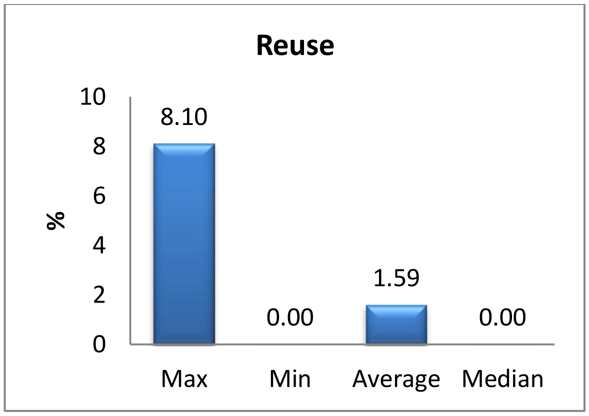

Figure 89. Reuse

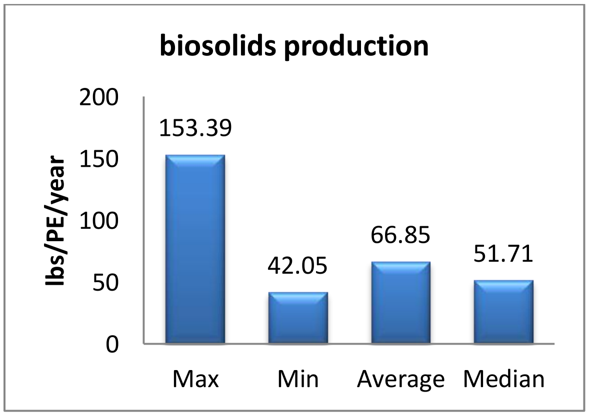

Figure 90. Biosolids production

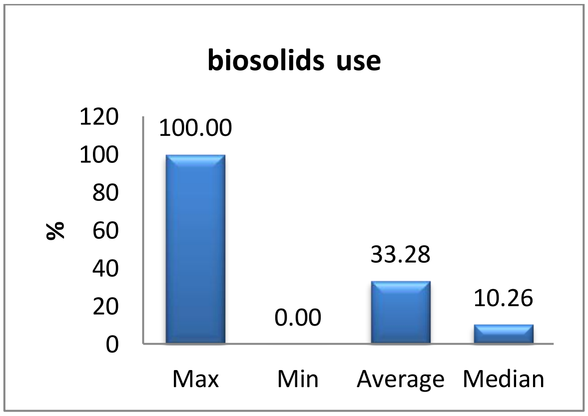

Figure 91. Biosolids use

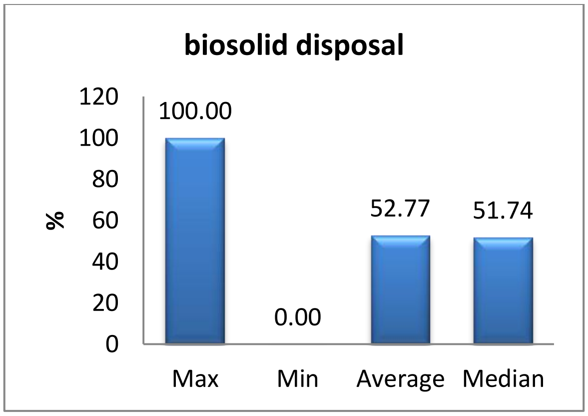

Figure 92. Biosolids disposal

5.2 EMPLOYEE INFORMATION

Results and analysis:

Employee related indicators are used to evaluate the efficiency and effectiveness of the wastewater utility's employees. Lin (2005), Berg and Lin (2007), Alsharif et al. (2008), Lonborg (2005), Mugisha (2007), Lambert et al. (1993), Aida et al. (1998), and Tupper and Resende (2004) are among researches who have considered number of employees (or labor or staff) as one of the inputs in their studies.

The results for each indicator are summarized in Table 17. Total employees per 1000 population equivalents served (Figure 93) shows higher values for smaller and medium sized utilities, and lower values for big sized utilities; the same is true for employee per million gallons of wastewater treated (Figure 94). Percentage of employees in higher management (Figure 95), human resources (Figure 96), financial and commercial (Figure 97), customer service (Figure 98), planning, designing and construction (Figure 99) and wastewater quality monitoring (lab personnel) (Figure 101) are low. Percentage of operations and maintenance employees (Figure 100) show higher value for all the utilities since this is the main function of a wastewater utility.

Personnel training show irregular trends for utilities as summarized in Figure 102. Working accidents is calculated as percentage of employees injured in the last 1 year. Absentees due to accidents shows higher values for a few utilities which is an area of concern as summarized in Figure 103 and Figure 104. Utilities with higher values in this category should first determine the reasons for poor safety and then implement programs to improve safety. Vaccination shows irregular results as shown in Figure 105 and a few utilities show very low values for this indicator.

Limitations:

1. Functions like HR and Finance staff vary significantly between municipalities vs. wastewater authorities. In a municipality, many of these functions are provided in the general fund, and the utility then pays a PILOT (payment in lieu of taxes) and/or makes a transfer of funds to the general fund for indirect costs. In an authority they usually have those positions on staff.

Table 17. List of indicators, definition and results for employee information

Indicator	Definition	Unit	Max	Min	Average	Median
Total employee						
Employee per 1000 population equivalent served	total no. of employees / total population equivalent served x 1000	number / 1000	3.26	0.14	1.03	0.91
Employee per million gallons of wastewater treated	total no. of employees / Million gallons of wastewater treated daily	number / Mgal	9.57	1.39	5.05	4.68
Employee as per function						
Higher management employees	number of full time equivalent employees dedicated to directors, central administration, strategic planning, marketing and communications, legal affairs, environmental management, business development / total number of employee x 100	%	23.81	0.65	7.83	3.43
Human resources employees	number of full time employees dedicated to personnel administration, education and training, occupational safety and social activities / total number of employee x 100	%	4.76	0.83	2.26	1.72

Financial and commercial employees	number of full time equivalent employees dedicated to economic and financial planning, economic administration, economic controlling and purchasing / total number of employee x 100	%	4.00	1.39	2.39	2.09
Customer Service employees	number of full time equivalent employees dedicated to customer relations / total number of employee x 100	%	13.52	2.00	9.39	12.64
Planning, designing and construction employees	number of employees working in planning, designing & construction / total number of employee x 100	%	16.67	3.77	9.71	7.50
Operations and maintenance employees	number of employees working in operations & maintenance of the utility / total number of employee x 100	%	66.84	25.83	50.64	59.24
Wastewater quality monitoring employees (lab personnel)	number of lab testing employees / total number of employee x 100	%	11.18	1.59	4.76	3.14
Training						
Personnel training	total training hours for all the employees in last 1 year / total number of employees	hours / employee / year	147.80	5.00	40.54	20.04
Personnel health and						

safety						
Working accidents - % of employees injured in last 1 year (%)	number of employees injured on the job in the last 1 year / total number of employees x 100	%	9.72	3.00	6.15	6.24
Absences due to accidents	sum of all the absences due to all the employees due to reasons related to accident in last 1 year / total number of employees	days / employee / year	1.36	0.15	0.63	0.50
Vaccination	total number of maintenance, operations and lab testing employees with vaccination for sewage and waste related diseases / total number of employees in maintenance, operations and lab testing x 100	%	100.00	0.00	51.90	44.79

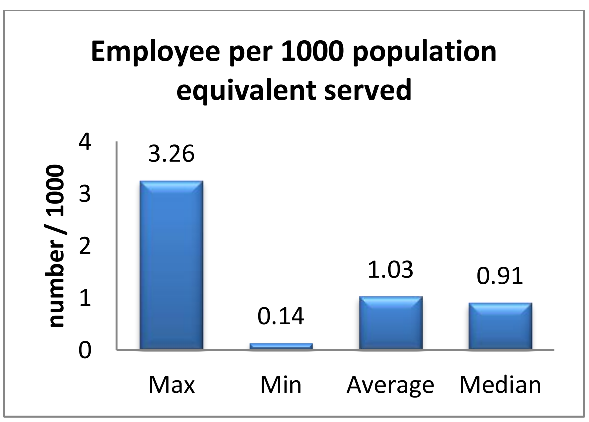

Figure 93. Employee per 1000 population equivalent served

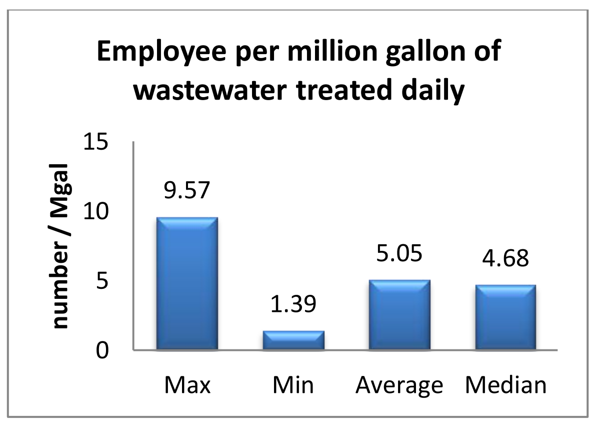

Figure 94. Employee per million gallons of wastewater treated daily

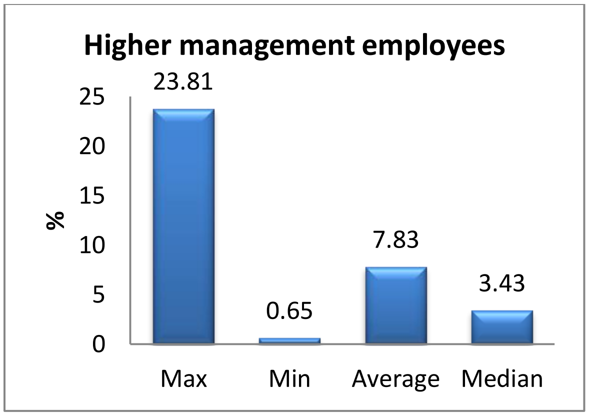

Figure 95. Higher management employees

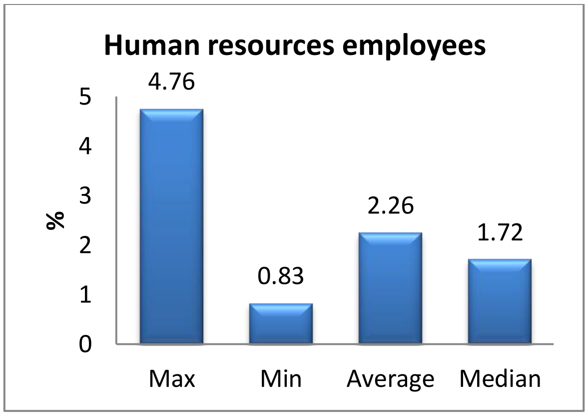

Figure 96. Human resources employees

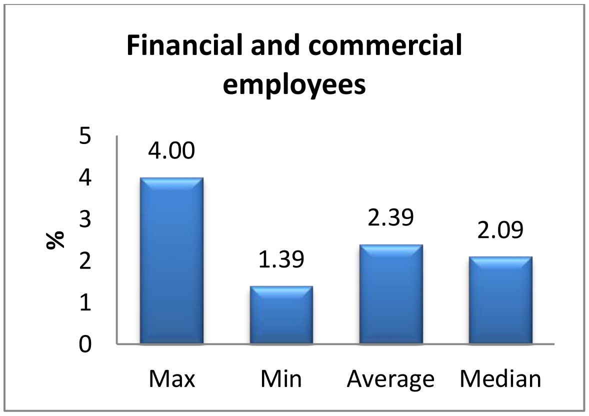

Figure 97. Financial and commercial employees

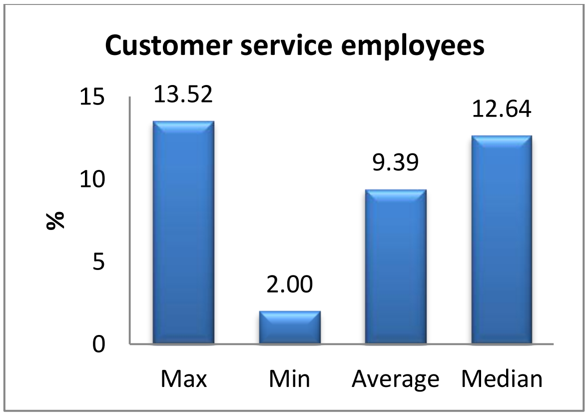

Figure 98. Customer service employees

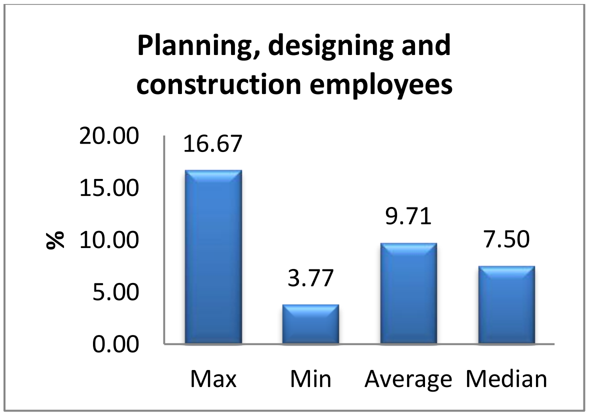

Figure 99. Planning, designing and construction employees

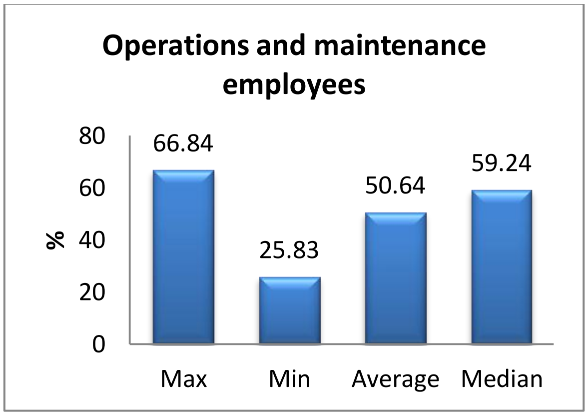

Figure 100. Operations and maintenance employees

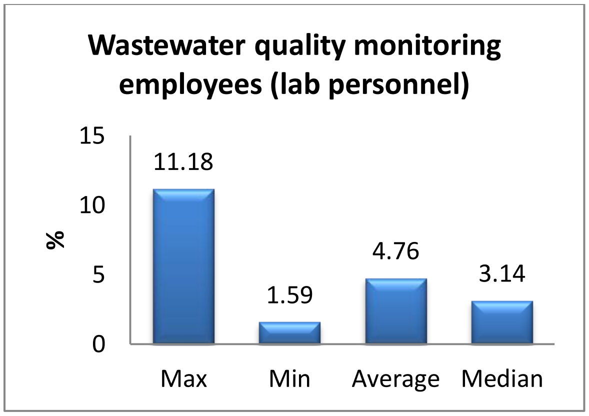

Figure 101. Wastewater quality monitoring employees (lab personnel)

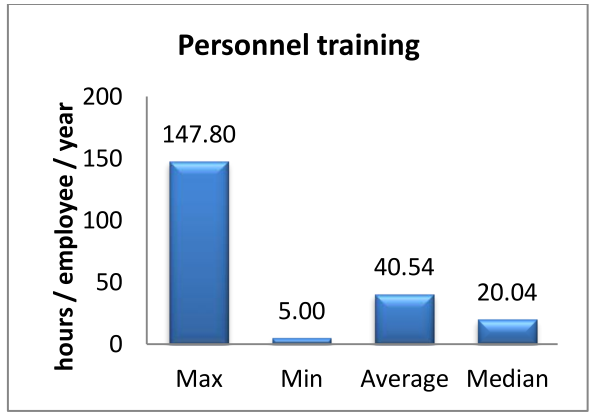

Figure 102. Personnel training

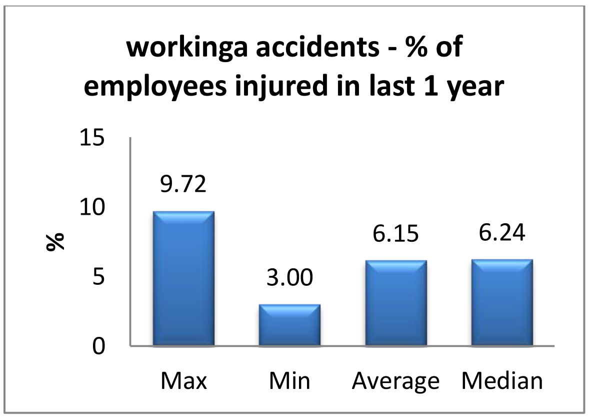

Figure 103. Working accidents - % of employees injured in last 1 year

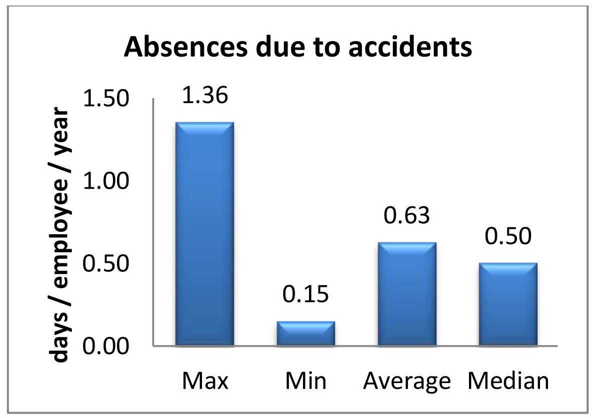

Figure 104. Absences due to accidents

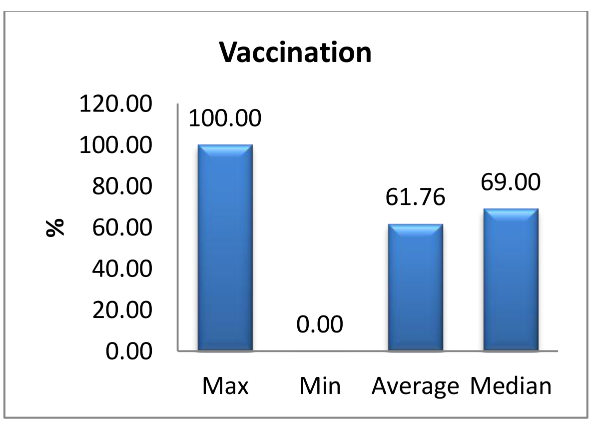

Figure 105. Vaccination

5.3 TREATMENT PROCESS

Results and analysis:

These indicators are used to evaluate the treatment capacity currently in use by utilities and energy consumption by the utilities. The results for this category of indicators are summarized in Table 18. Treatment plant utilization for primary, secondary, and tertiary treatment is defined as percentage of volume of wastewater treated daily with respect to daily capacity. The results for primary, secondary and tertiary treatment plant utilization are summarized in Figure 106, Figure 107 and Figure 108. It shows that utilities have unused capacity of treatment which can be used when the demand increases. It was also found that many responding utilities do not have tertiary treatment. Energy consumption shows the variation of energy used to treat wastewater (million gallons) by various utilities (Figure 109). Most of the utilities have different energy use depending on regulation of treatment in the region they serve, size of the utility, and treatment process used. The indicator for pumping utilization has been discarded because there was insufficient to make conclusions.

Table 18. List of indicators, definition and results for treatment process

Indicator	Definition	Unit	Max	Min	Average	Median
Treatment plant utilization - primary treatment	Average daily volume of wastewater which received primary treatment / Total daily capacity for primary treatment x 100	%	77.59	16.70	51.18	52.00
Treatment plant utilization - secondary treatment	Average daily volume of wastewater which received secondary treatment / Total daily capacity for secondary treatment x 100	%	77.59	16.70	51.74	54.18
Treatment plant utilization - tertiary treatment	Average daily volume of wastewater which received tertiary treatment / Total daily capacity for tertiary treatment x 100	%	77.87	0	66.82	77.59
Energy consumption	Monthly energy used by the utility / Million gallons of wastewater treated every month	kwh / Mgal	2614	1396	2037	1921

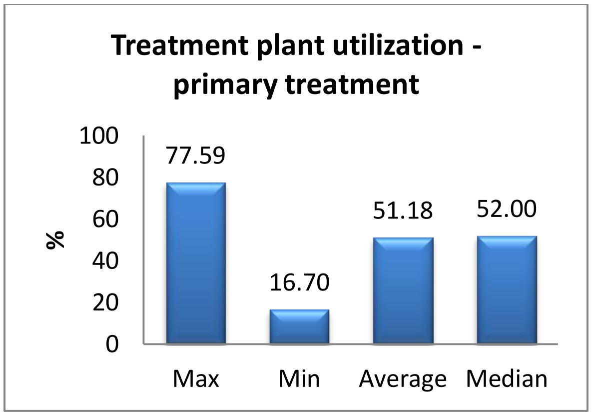

Figure 106. Treatment plant utilization - primary treatment

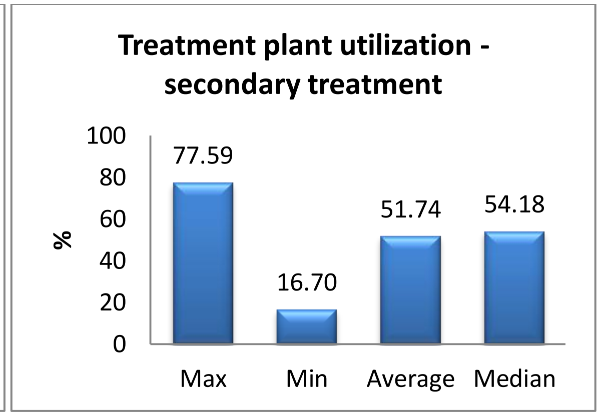

Figure 107. Treatment plant utilization - secondary treatment

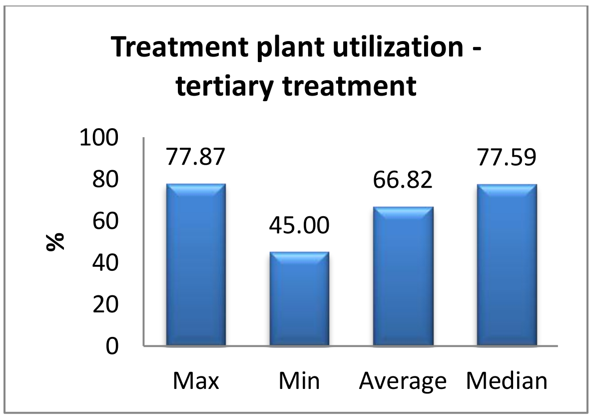

Figure 108. Treatment plant utilization - tertiary treatment

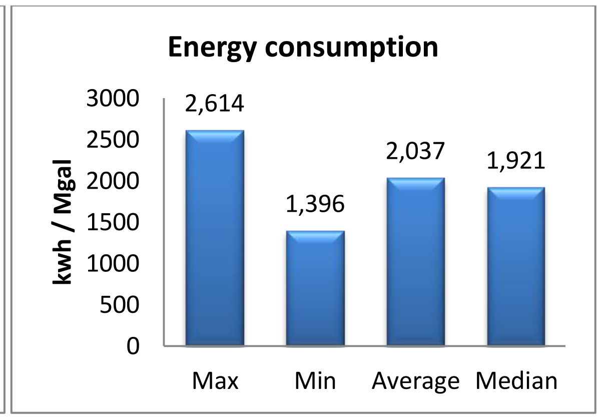

Figure 109. Energy consumption

5.4 TREATMENT PERFORMANCE

Results and analysis:

Quality of service is a vital ingredient in a utility's ability to maintain profitability and continued success. Service quality is a very important aspect of the water industry (Chen, 2005).

The results for indicators in this category are summarized in Table 19. Population coverage is the percentage of population served in the service area and for most of the utilities this number is high which shows a good coverage of population as summarized in Figure 110. Total treatment level (Figure 111), primary treatment (Figure 112), secondary treatment (Figure 113), and tertiary treatment (Figure 114) are the percentage of wastewater treated which entered the treatment plant. The values for all these treatment levels are close to 100% and it was found that few utilities do not have tertiary treatment. Only 40% of participating utilities reported to use tertiary treatment.

The quality of treated water is very important for wastewater treatment facility, and for every test two factors are important. The first one is to perform required number of tests, and the second is to comply with the defined permit conditions. The results for all the utilities show that more than the required numbers of test were performed. The result of percentage of tests complying with the standard for total tests (Figure 115), BOD test (Figure 117), COD test (Figure 119), TSS test (Figure 121), phosphorus test (Figure 123), nitrogen test (Figure 127), fecal E.coli test (Figure 125), other tests (Figure 129), Biosolids tests (Figure 131) and Industrial discharge tests (Figure 133) has been summarized. The result for compliance with standards is close to 100% for most of the utilities with few exceptions as shown for each type of test in Figure 116, Figure 118, Figure 120, Figure 122, Figure 124, Figure 128, Figure 126, Figure 130, Figure 132, and Figure 134.

Limitations:

1. Many utilities that have higher population coverage do not have effective competition in a given area and there may be no market incentive to cut costs. So the utility with higher population coverage does not necessarily mean a good performance.

Table 19. List of indicators, definition and results for treatment performance

Indicator	Definition	Unit	Max	Min	Average	Median
Population coverage	Total Population served / Total population of the service area x 100	%	100.00	48.25	88.88	100.00
Wastewater Treatment levels						
Total treatment level	Million gallons of wastewater treated daily / total daily volume of wastewater entering the treatment plant x 100	%	100.00	91.07	98.01	100.00
Primary treatment level	Average daily volume of wastewater which received primary treatment / total daily volume of wastewater entering the treatment plant x 100	%	100.00	95.00	99.29	100.00

Secondary treatment level	Average daily volume of wastewater which received secondary treatment / total daily volume of wastewater entering the treatment plant x 100	%	100.00	95.00	99.29	100.00
Tertiary treatment level	Average daily volume of wastewater which received tertiary treatment / total daily volume of wastewater entering the treatment plant x 100	%	100.00	0.00	64.05	92.15
Quality of testing						
Total tests						
Total tests-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	86.62	97.89	100.00
Total tests-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	118.39	100.00	103.00	100.00
Wastewater - BOD test						
Wastewater - BOD test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	99.00	99.84	100.00
Wastewater - BOD test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.00	100.00	100.00	100.00

Wastewater - COD test						
Wastewater - COD test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	98.98	99.49	99.49
Wastewater - COD test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.00	100.00	100.00	100.00
Wastewater - TSS test						
Wastewater - TSS test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	98.99	99.83	100.00
Wastewater - TSS test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.00	100.00	100.00	100.00
Wastewater - phosphorus test						
Wastewater - phosphorus test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	98.99	99.75	100.00
Wastewater - phosphorus test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.00	100.00	100.00	100.00
Wastewater - nitrogen test						

Wastewater - nitrogen test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	75.62	94.92	100.00
Wastewater - nitrogen test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	132.23	100.00	113.91	111.71
Wastewater - fecal E.coli test						
Wastewater - Fecal E.coli test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	98.99	99.80	100.00
Wastewater - Fecal E.coli test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.00	100.00	100.00	100.00
Wastewater - other tests						
Wastewater - other tests-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	99.00	99.77	100.00
Wastewater - other tests-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.64	100.00	100.13	100.00
Biosolids tests						

Biosolids tests- Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	99.00	99.83	100.00
Biosolids tests- Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	100.00	100.00	100.00	100.00
Industrial discharge tests						
Industrial discharge tests- Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%	100.00	50.00	86.14	97.27
Industrial discharge tests- Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%	200.00	100.00	125.00	100.00

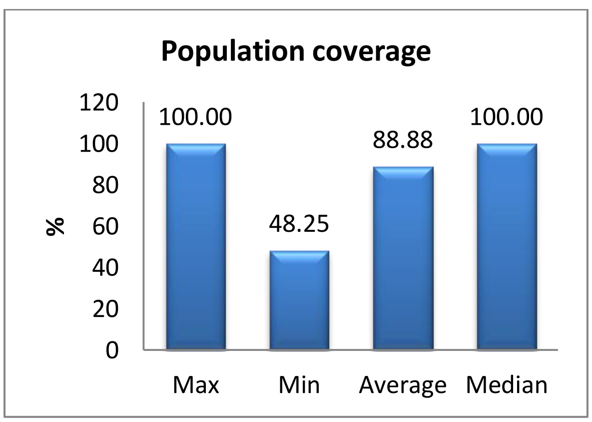

Figure 110. Population coverage

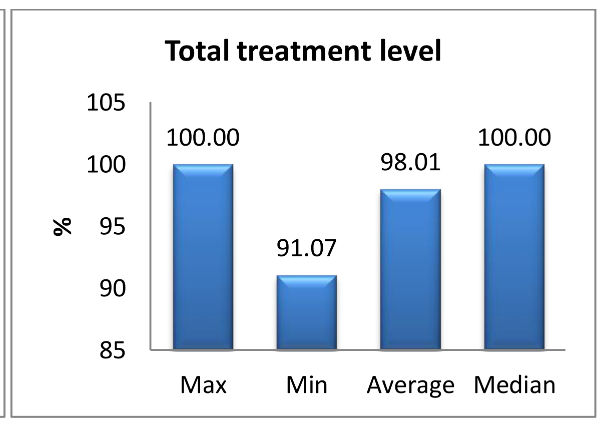

Figure 111. Total treatment level

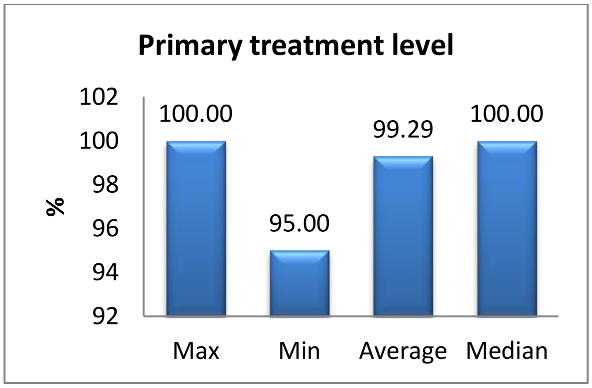

Figure 112. Primary treatment level

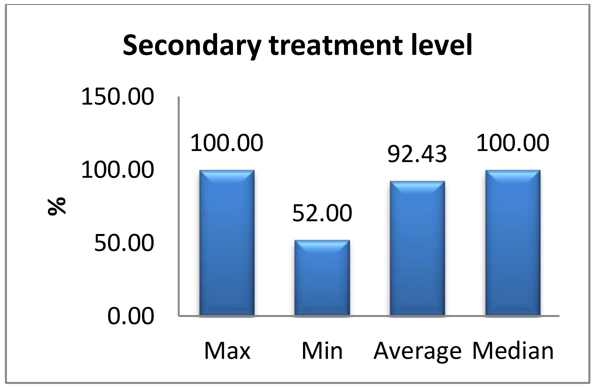

Figure 113. Secondary treatment level

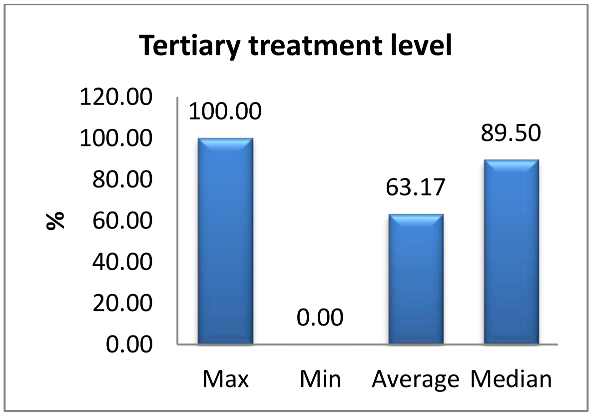

Figure 114. Tertiary treatment level

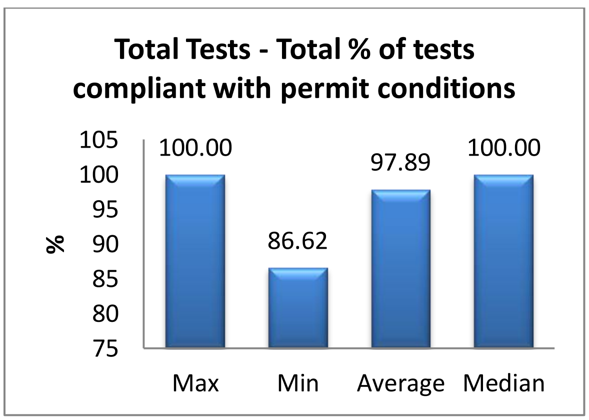

Figure 115. Total tests - total % of tests compliant with permit conditions

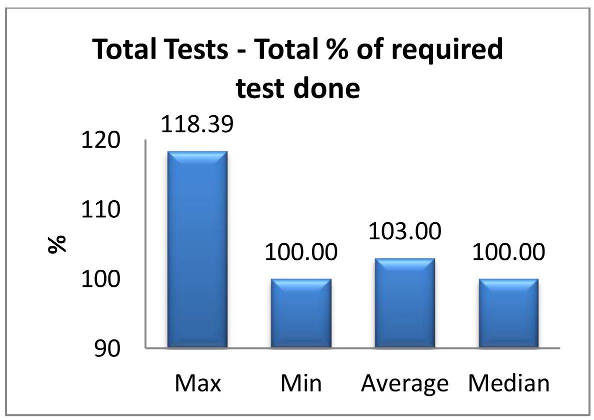

Figure 116. Total tests - total % of required test done

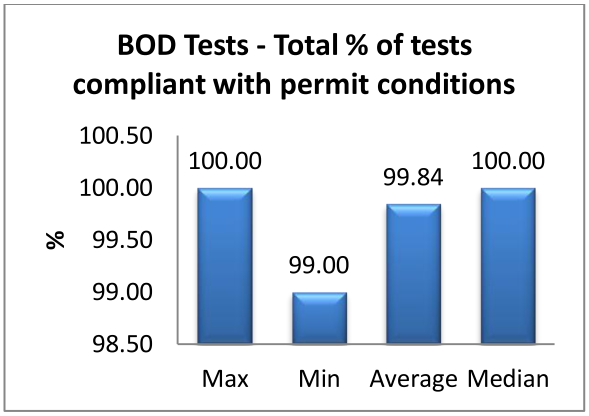

Figure 117. BOD tests - total % of tests compliant with permit conditions

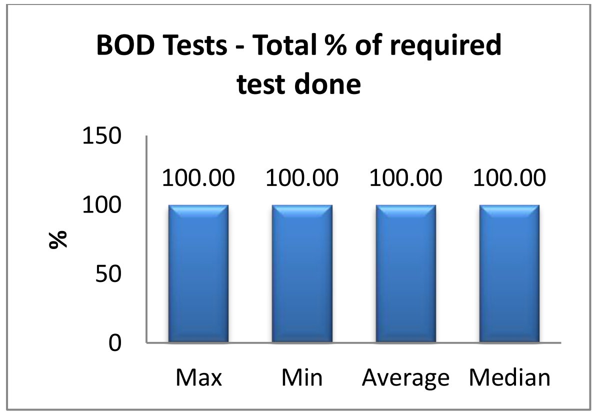

Figure 118. BOD tests - total % of required test done

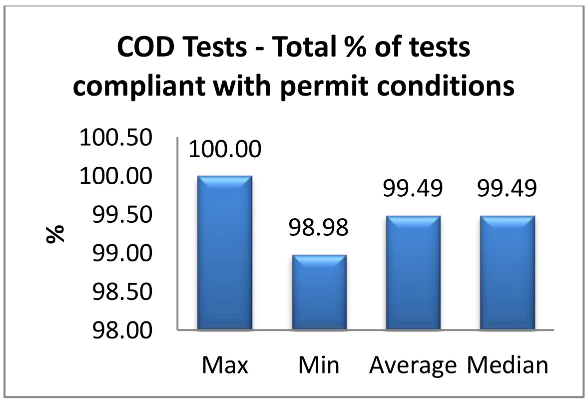

Figure 119. COD tests - total % of tests compliant with permit conditions

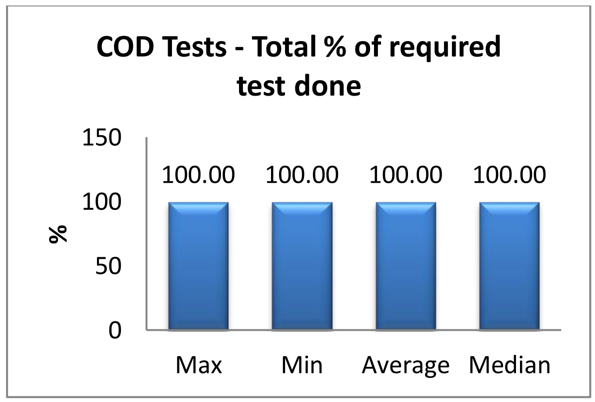

Figure 120. COD tests - total % of required test done

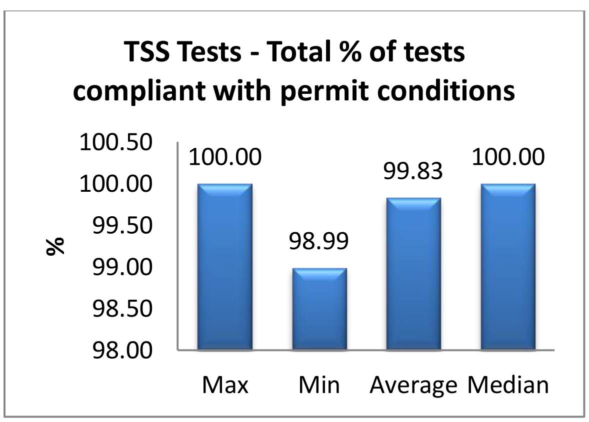

Figure 121. TSS tests - total % of tests compliant with permit conditions

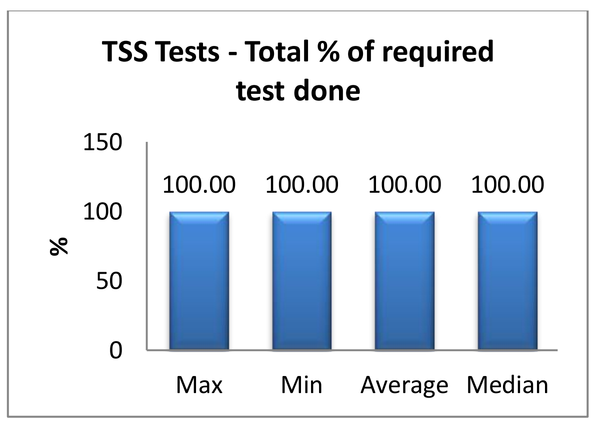

Figure 122. TSS tests - total % of required test done

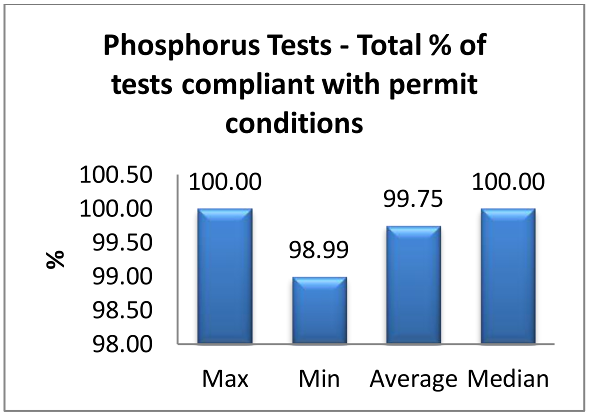

Figure 123. Phosphorus tests - total % of tests compliant with permit conditions

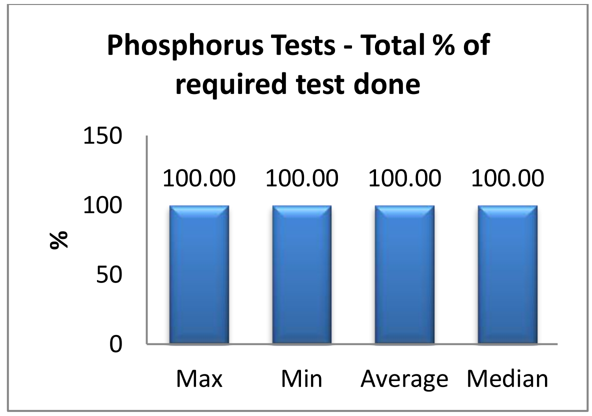

Figure 124. Phosphorus tests - total % of required test done

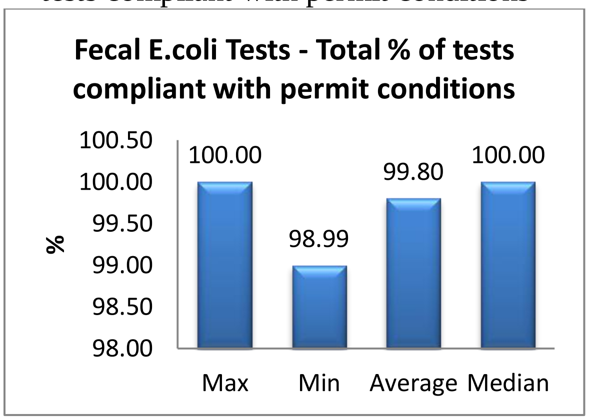

Figure 125. Fecal E.coli tests - total % of tests compliant with permit conditions

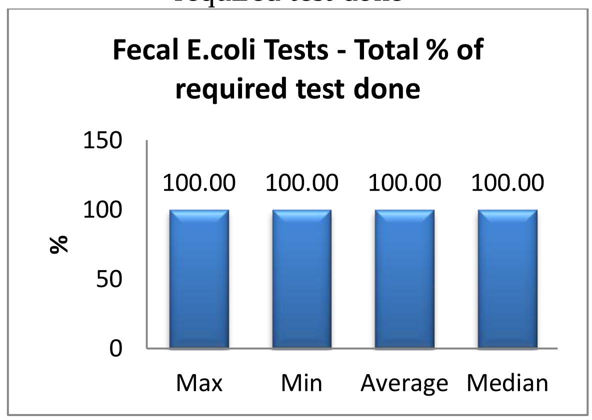

Figure 126. Fecal E.coli tests - total % of required test done

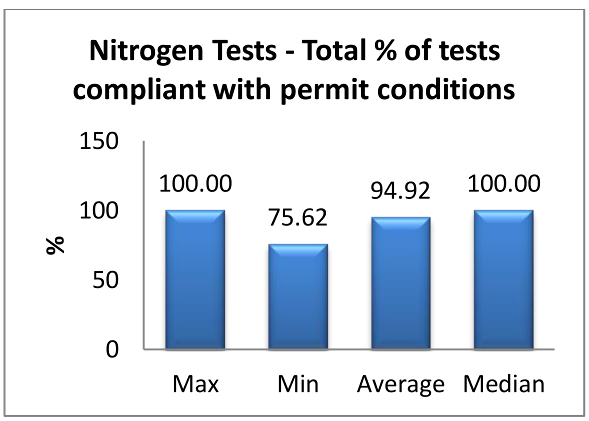

Figure 127. Nitrogen tests - total % of tests compliant with permit conditions

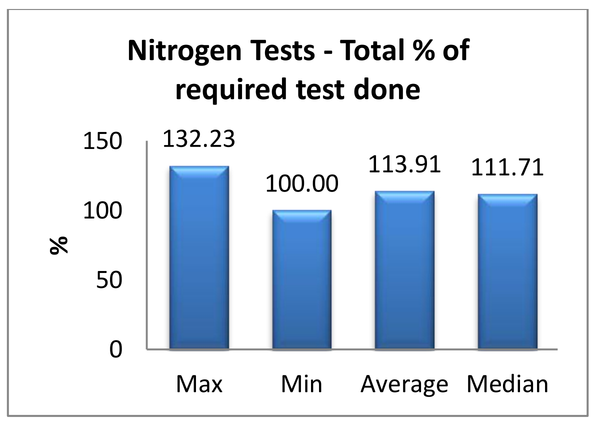

Figure 128. Nitrogen tests - total % of required test done

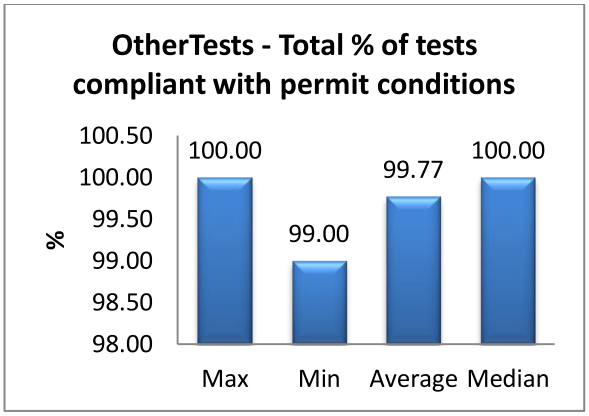

Figure 129. Other tests - total % of tests compliant with permit conditions

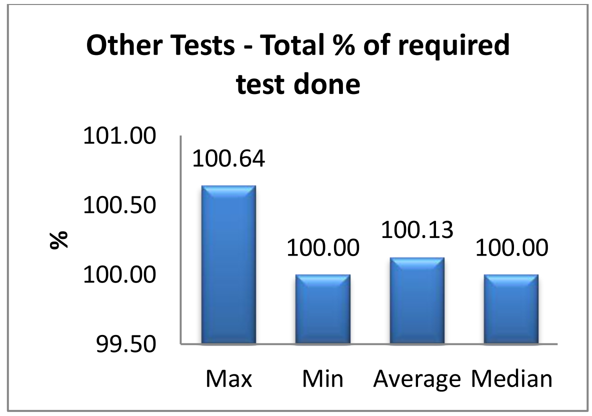

Figure 130. Other tests - total % of required test done

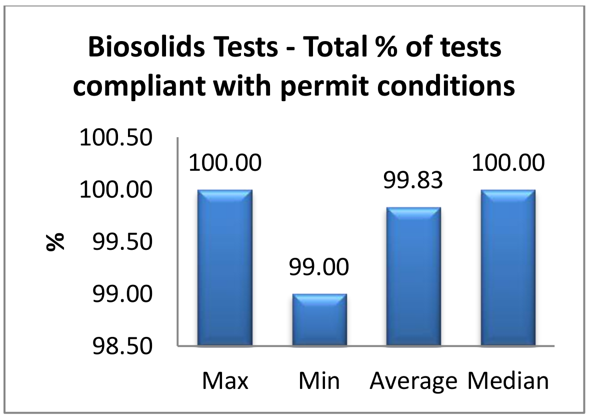

Figure 131. Biosolids tests - total % of tests compliant with permit conditions

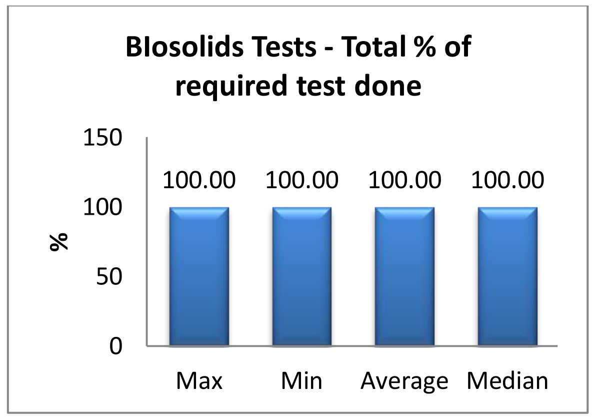

Figure 132. Biosolids tests - total % of required test done

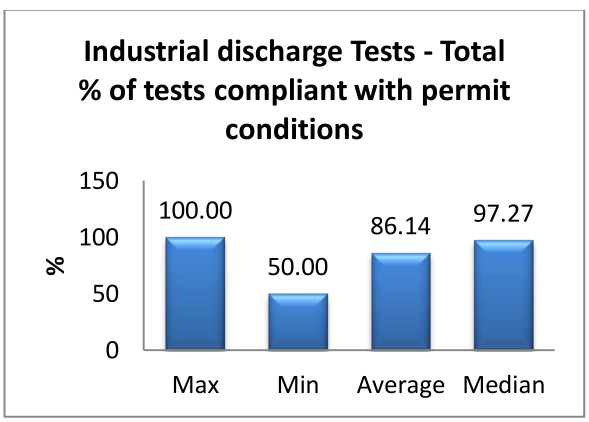

Figure 133. Industrial discharge tests - total % of tests compliant with permit conditions

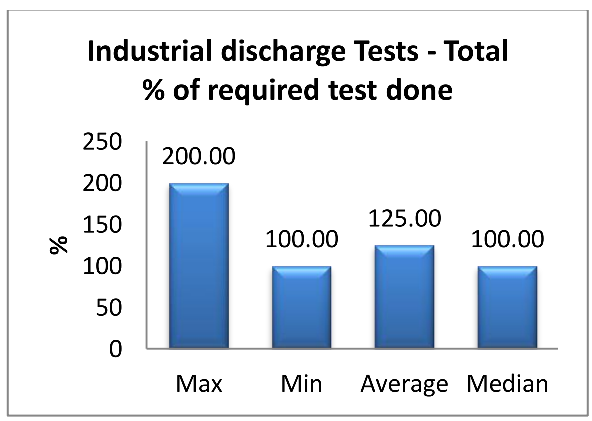

Figure 134. Industrial discharge tests - total % of required test done

5.5 OPERATIONAL PERFORMANCE

Results and analysis:

Berg et al. (2007) suggested that those responsible for utility operations can only manage what they measure, so having information on productivity trends and relative performance enables utility managers to direct attention to shortfalls. The indicators related to operational performance evaluate efficient use of resources, reliability, inspection of current assets, rehabilitation of existing assets, and losses due to low operational performance. Inefficient or ineffective operations lead to higher costs.

The result for each indicator is summarized in Table 20. Sewer inspection is the percentage of sewer inspected and sewer cleaning is the percentage of sewer cleaned by the utilities. Manhole chamber inspection is the percentage of manhole inspected by utilities. Sewer inspection (Figure 135), sewer cleaning (Figure 136), and manhole inspection (Figure 137) show a low percentage. Aside from being impossible to inspect a high percentage of these assets, it is unnecessary to do so. Utilities with good asset management programs direct these activities where they are required, as opposed to achieving a numbers goal. Pump inspection (Figure 138), system flow meters calibration (Figure 139), and wastewater quality monitoring instrument calibration (Figure 140) show a very high percentage and are close to 100% for all the utilities.

The renewal related indicators shows the variation of sewer replaced or rehabilitated (Figure 141), manhole chamber replaced or rehabilitated (Figure 142), and manhole covers replaced (Figure 143). These indicators are calculated as percentage replaced or rehabilitated in the last one year.

Indicators for sewer blockage (Figure 144) and sewer breaks (Figure 145) show high values for a few utilities and close to zero value for a few utilities. Utilities can inspect the sewers on a regular basis and can plan to maintain sewers.

Limitation:

1. Sewer blockage and breaks are dependent on variables like the quality of material used, age, location and others.
2. Higher values in the inspection and maintenance related indicators may mean a higher concern by a utility regarding the current asset condition, but a lower value does not always mean lower concern by a utility. It is a function of resources and age of the system, and it may mean that a utility has a more robust asset management system.
3. For every asset, there is an optimal replacement and/or renewal time. Replacing it too soon wastes some of the remaining value of the asset and replacing it too late leads to higher cost of replacement and maintenance. This should be considered while analyzing the sustainability and rehabilitation related indicators.

Table 20. List of indicators, definition and results for operational performance

Indicator	Definition	Unit	Max	Min	Average	Median
Inspection and maintenance						
Sewer Inspection	length of sewer inspected (miles) /checked in last 1 year / total length of sewer (miles) x 100	%	8.47	2.73	6.26	6.81
Sewer Cleaning	length of sewer (miles) cleaned in last 1 year / total length of sewer (miles) x 100	%	24.87	3.75	12.01	10.03
Manhole chamber inspection	Total number of Manhole chamber inspected or checked in last 1 year / Total number of Manhole chamber x 100	%	27.88	1.30	10.47	8.29
Pump inspection	Total number of pumps inspected or checked in last 1 year / Total number of pumps x 100	%	100.00	100.00	100.00	100.00
Calibration						
System flow meters	total number of flow meters calibrated in last 1 year / total no. of flow meters x 100	%	100.00	100.00	100.00	100.00
Wastewater quality monitoring	total number of quality monitoring instrument calibrated in last 1	%	100.00	100.00	100.00	100.00

instrument	year / total number of quality monitoring instrument x 100					
Renewal						
Sewer replaced/rehabilitated - in last 1 year	length of Sewer (miles) replaced or rehabilitated - in last 1 year / total length of sewer (miles) x 100	%	3.47	0.00	1.23	0.97
Manhole chamber replaced/rehabilitated - in last 1 year	total no. of manhole chambers replaced or rehabilitated - in last 1 year / total no. of manhole chambers x 100	%	1.93	0.00	0.85	0.43
Manhole covers replaced - in last 1 year	no. of manhole covers replaced - in last 1 year / total no. of manhole covers x 100	%	12.88	0.04	2.56	0.96
Blockages and breaks						
Sewer blockage - in last 1 year	total number of sewer blocks occurred - in last 1 year / total length of sewer x 100	number / 100 mile	82.45	0.00	26.77	7.70
Sewer breaks - in last 1 year	Total number of sewer breaks or damage to the sewer - in last 1 year / total length of sewer x 100	number / 100 mile	38.51	0.76	7.96	1.79

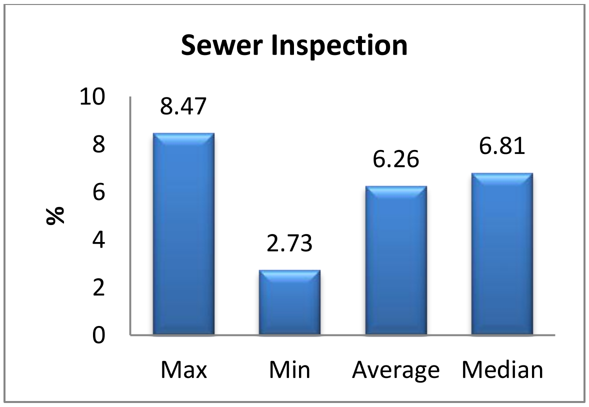

Figure 135. Sewer inspection

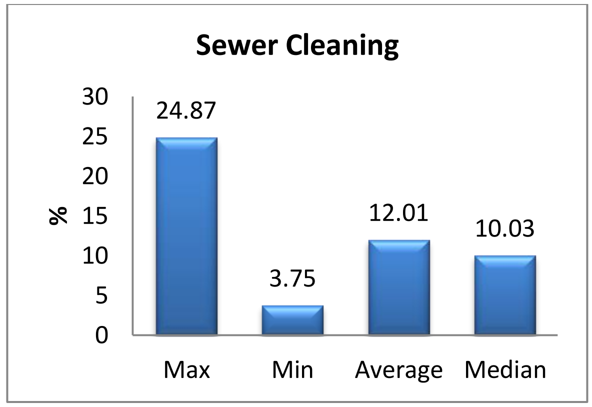

Figure 136. Sewer cleaning

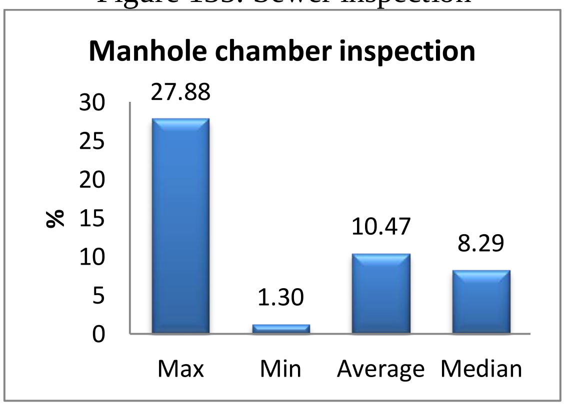

Figure 137. Manhole chamber inspection

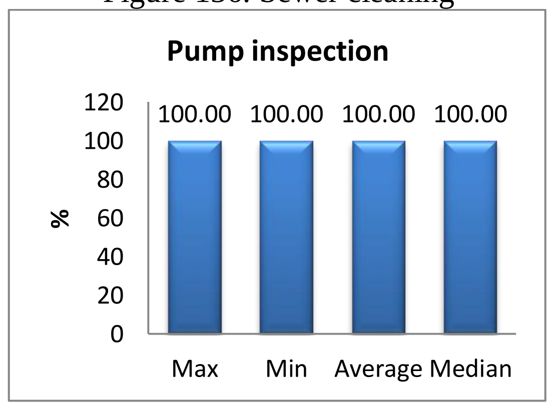

Figure 138. Pump inspection

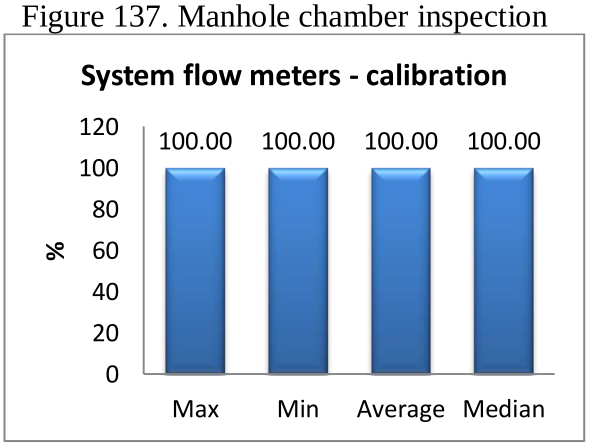

Figure 139. System flow meters

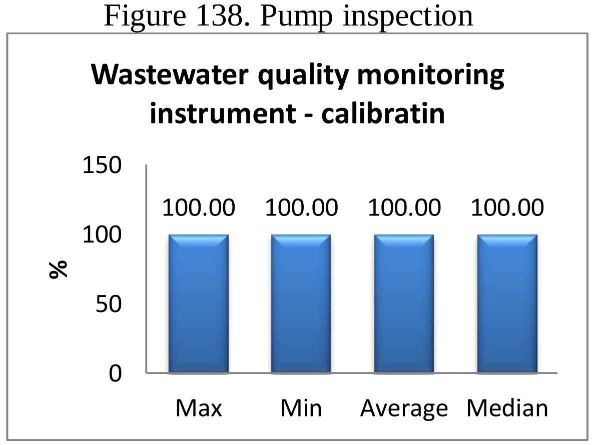

Figure 140. Wastewater quality monitoring instrument

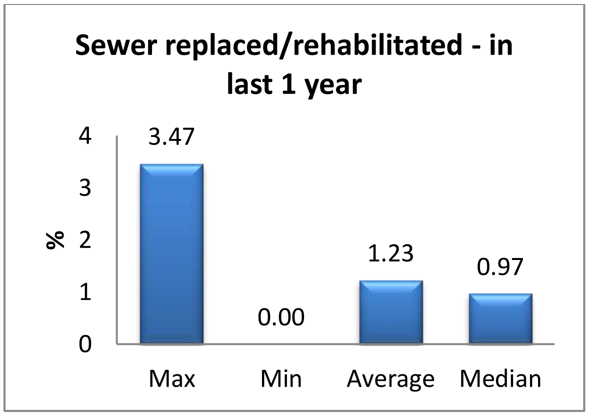

Figure 141. Sewer replaced/rehabilitated - in last 1 year

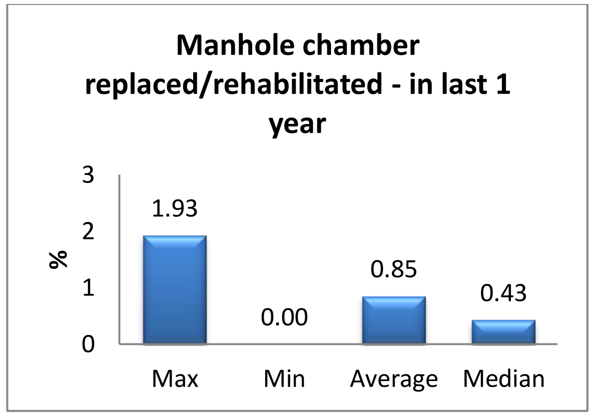

Figure 142. Manhole chamber replaced/rehabilitated - in last 1 year

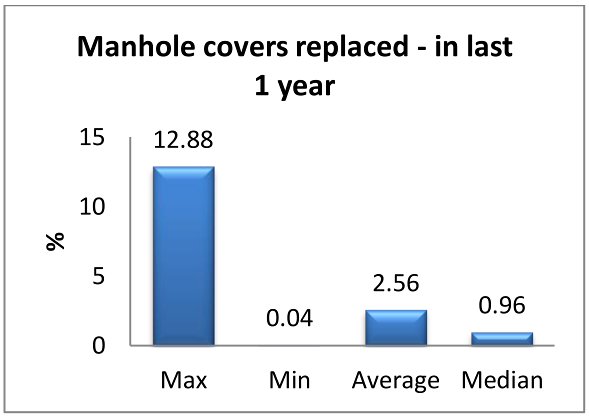

Figure 143. Manhole covers replaced - in last 1 year

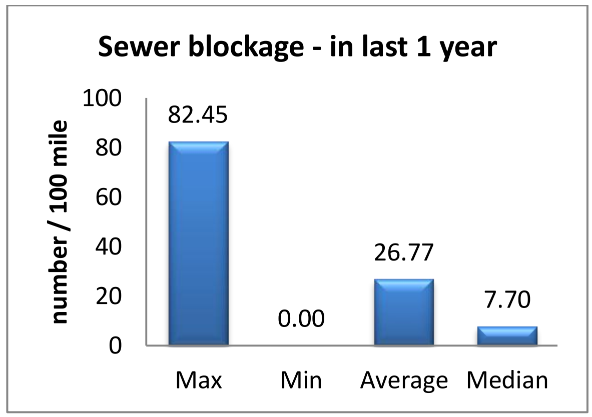

Figure 144. Sewer blockage - in last 1 year

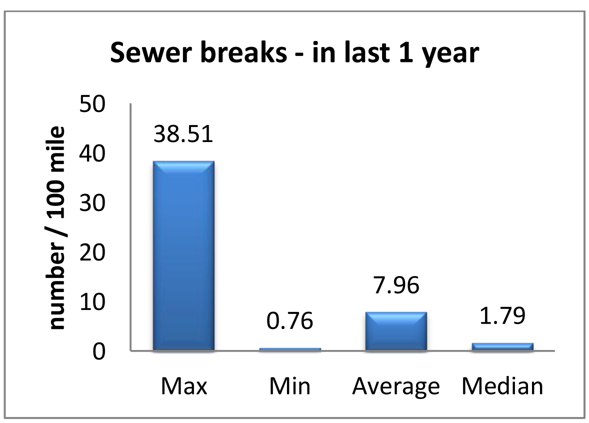

Figure 145. Sewer breaks - in last 1 year

5.6 CUSTOMER ENQUIRIES

Results and analysis:

Customer satisfaction is defined as "the number of customers, or percentage of total customers', whose reported experience with a firm, its products, or its services (ratings) exceeds specified satisfaction goals (Farris 2010). In a survey of nearly 200 senior marketing managers, 71 percent responded that they found a customer satisfaction metric very useful in managing and monitoring their businesses (Farris 2010).

The results for each indicator are summarized in Table 21. The most basic indicator is total service enquiries per 1000 population equivalent (PE) served and the results show a low number for customer enquiries or reports per 1000 PE served as shown in Figure 146. Percent of reports related to odor, flooding, pollution, rodent, and blockage are summarized in Figure 147, Figure 148, Figure 149, Figure 150 and Figure 151. A few utilities showed a high percentage of blockage related reports. The indicator for discarded billing related reports was excluded because of insufficient data.

Limitations:

1. Customer enquiries are always not for complaints. It can be due to many reasons like asking general questions, bringing in notice some issues, following up for a new connection and many more. All these should be considered while evaluating the values for the indicators in this category.

Table 21. List of indicators, definition and results for customer enquiries

Indicator	Definition	Unit	Max	Min	Average	Median
Total Service enquiries per 1000 Population Equivalent served	total number of enquiries - in last 1 year / Total population equivalent (PE) served x 1000	number / 1000 PE served	11.42	0.04	3.75	0.87
Reports related to odor	no. of odor related reports - in last 1 year / total no. of reports x 100	%	25.00	0.00	10.38	7.10
Reports related to flooding	no. of flooding related reports - in last 1 year / total no. of reports x 100	%	20.00	0.00	11.34	15.00
Reports related to pollution	no. of pollution related reports - in last 1 year / total no. of reports x 100	%	15.00	0.00	5.00	0.00
Reports related to rodent	no. of rodent related reports - in last 1 year / total no. of reports x 100	%	8.33	0.00	2.15	1.19
Blockage	no. of blockage related reports - in last 1 year / total no. of reports x 100	%	46.04	0.00	18.13	8.64

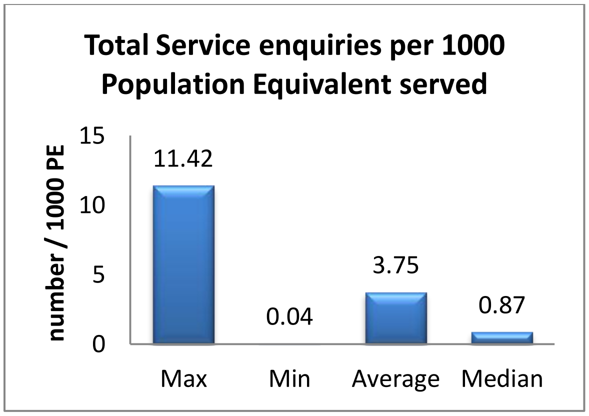

Figure 146. Total service enquiries per 1000 population equivalent served

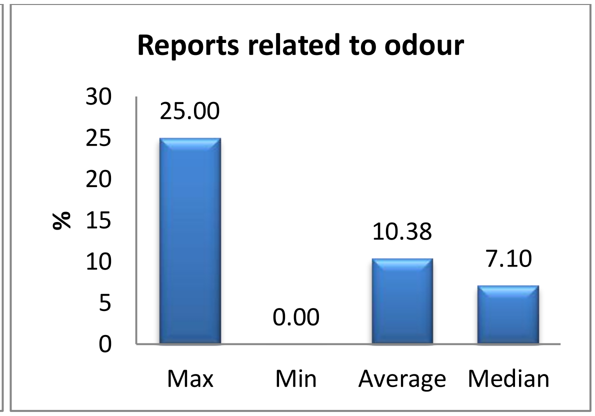

Figure 147. Reports related to odor

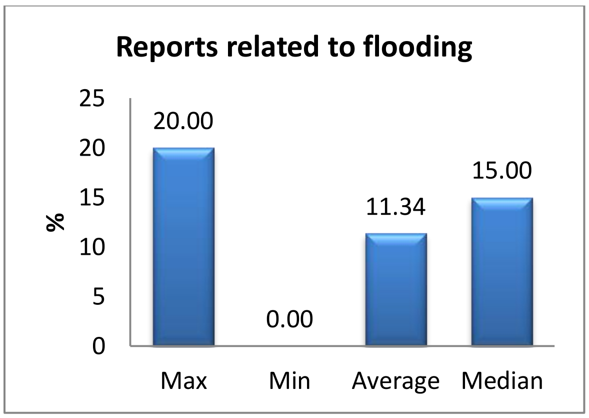

Figure 148. Reports related to flooding

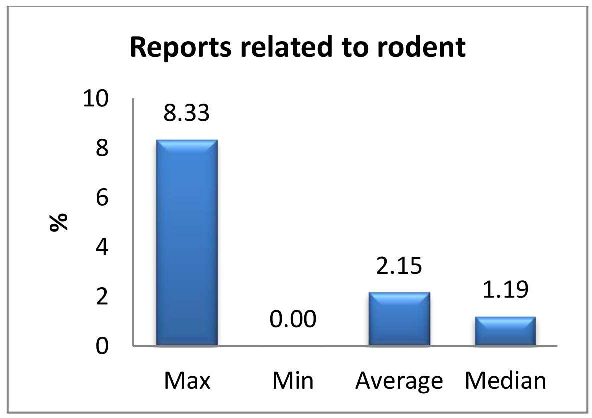

Figure 149. Reports related to rodent

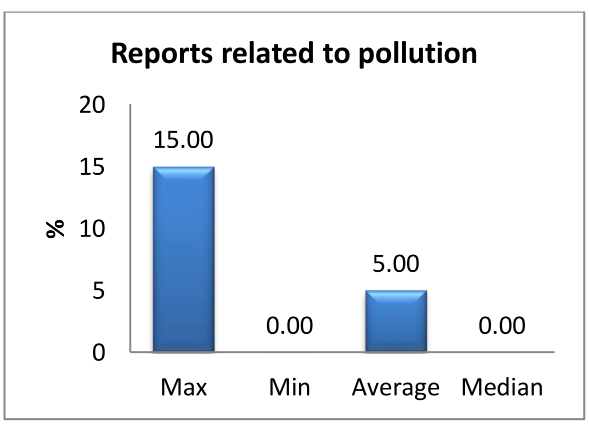

Figure 150. Reports related to pollution

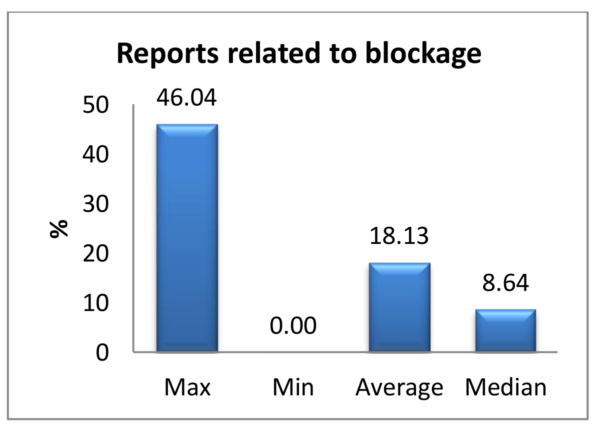

Figure 151. Reports related to Blockage

5.7 FINANCIAL PERFORMANCE

Analysis and Results:

Financial performance is a measure of how well a utility can use assets from its primary mode of business and generate revenues. Measuring the results of a utility's policies and operations in monetary terms is a brief definition of financial performance. Financial results are reflected in the utility's return on investment, return on assets, value added, total cost, revenue generated, cost coverage, profit etc.

The results are summarized in Table 22. The indicators in the revenue section are revenue per population equivalent (PE), percentage of service revenue, and percentage of other revenue. The revenue per PE show an irregular trend and varies with the size and location of the utility as summarized in Figure 152. It was observed that most of the revenue generated by utilities comes from service and other revenue sources show a low percentage as summarized in Figure 153 and Figure 154. The indicators in the cost section summarize total cost per population equivalent (PE) served (Figure 155), capital cost per million gallons (mgal) treated wastewater (Figure 156) and operating cost per mgal treated wastewater (Figure 157). Operational cost is defined by the type of operation, which are operation cost for sewer system (Figure 158, treatment (Figure 159), electricity or energy (Figure 160), testing (Figure 161), and other (Figure 162). The results show that a major cost belongs to sewer system operation and wastewater treatment.

Expenses related indicators summarize total expenses (Figure 163), percentage of expenses on new assets (Figure 164) and percentage of total expenses on replacement and renovation (Figure. 165). Some utilities show high values for percentage of expenses on new assets and some utilities show a high value for percentage of expenses on replacement and renovation of existing assets. The expenses on new and existing assets depend on the age and current condition or existing assets. Sewer collection rate is summarized in Figure 166. Total cost coverage is summarized in Figure 167. Operational cost coverage is summarized in Figure 168. Liquidity ratio and asset turnover ratios have been shown in Figure 169 and Figure 170. Earning per million gallons of wastewater treated is summarized in (Figure 171). A few utilities show profit value as zero because those utilities are publically owned and some of them cannot have net income.

Limitations:

1. In general, high values for indicators related to revenue show better financial performance but these values vary with the number of PE served, size of utility, location of utility and others. Hence utilities with high revenue are not always the best performers.
2. In general, lower values for indicators related to cost show better financial performance but these values vary with the number of PE served, size of utility, location of utility and others. So utilities with low cost are not always the best

performers. Cost is also dependent on the revenue, so these indicators should be analyzed together to understand the whole story.

Table 22. List of indicators, definition and results for financial performance

Indicator	Definition	Unit	Max	Min	Average	Median
Revenue						
Revenue per population equivalent (PE) served - in last 1 year	Total revenue in last 1 year / Total Population Equivalent (PE) served	$ / PE	320.65	82.75	162.53	109.20
Service revenue in last 1 year	revenue generated by Service / Total revenue x 100	%	100.00	65.40	90.08	96.09
Other revenue in last 1 year	revenue generated which are not from sales / Total revenue x 100	%	34.60	2.18	14.89	11.19
Cost						
Total cost per population equivalent (PE) served - in last 1 year	Capital cost plus Operating cost - in last 1 year / Total Population Equivalent (PE) served	$ / PE	473.54	80.05	223.17	157.71
Capital cost per PE served - in last 1 year	Total Capital cost in last 1 year / Total Population Equivalent (PE) served	$ / PE	184.83	13.50	77.75	66.96
Operating cost PE served - in last 1 year	Total Operating cost in last 1 year / Total Population Equivalent (PE) served	$ / PE	329.87	51.20	145.42	93.87
% Operational Cost by type						
% of sewer system cost - in last 1 year	total cost related to sewer system operation / Total Operational cost x 100	%	54.19	15.74	29.25	24.18

% of Treatment cost - in last 1 year	total cost related to Treatment and testing cost / Total Operational cost x 100	%	62.00	3.45	38.67	49.64
% of Energy / Electricity used cost - in last 1 year	total cost related to Energy or Electricity used / Total Operational cost	%	19.22	4.33	8.29	5.42
% of testing related cost - in last 1 year	total cost related to testing / Total Operational cost x 100	%	5.37	0.24	3.10	3.70
Any other operational cost - in last 1 year	any other cost / Total Operational cost x 100	%	55.35	10.74	34.62	37.79
Expenses						
Total expenses - in last 1 year	Total expenses on plant and equipment - new + replacement + renovation - In the last 1 year / Total Population Equivalent (PE) served	$ / PE	184.83	5.54	86.57	102.42
% on New assets - in last 1 year	Expenses on new assets / Total investment x 100	%	100.00	0.79	35.78	20.12
% on Replacement and renovation - in last 1 year	Expenses on replacement and renovation of existing assets / Total investment x 100	%	99.21	34.07	68.82	71.00
Sewer collection rate						
Sewer collection rate which utility charges the consumer	as per the standard utility rate	$ / 1000 gal	5.27	2.33	3.96	4.77
Efficiency						

Total cost coverage	total revenue in last 1 year / total cost in last 1 year	-	1.40	0.74	1.02	0.98
Operational cost coverage	total revenue in last 1 year / total operational cost in last 1 year	-	3.44	0.97	1.67	1.42
Current Ratio (Liquidity measure)	total current assets value / total current liabilities value	-	7.15	1.11	3.07	1.80
Asset turnover ratio	Sales revenue in last 1 year / total current assets value	-	0.60	0.18	0.43	0.47
Earnings						
Earnings per million gallons of wastewater treated	Total earning - in last 1 year / Total wastewater treated in last 1 year	$ / Mgal	1891.92	0.00	569.57	106.64

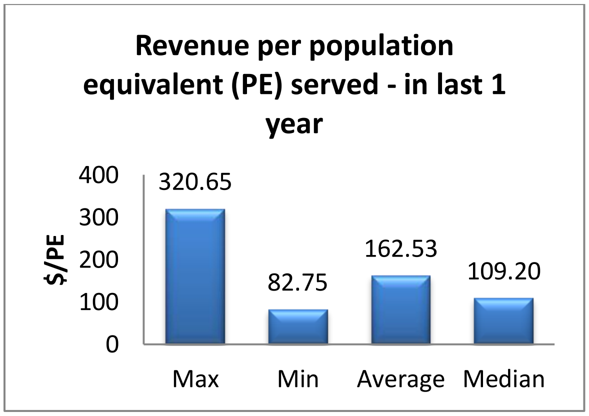

Figure 152. Revenue per population equivalent (PE) served - in last 1 year

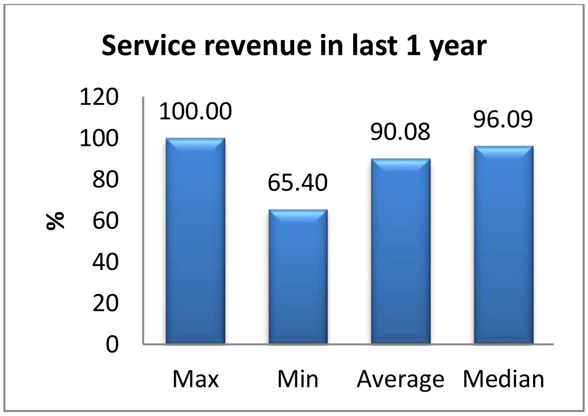

Figure 153. Service revenue in last 1 year

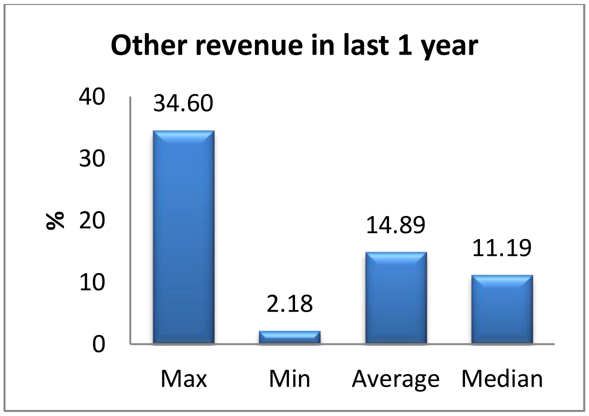

Figure 154. Other revenue in last 1 year

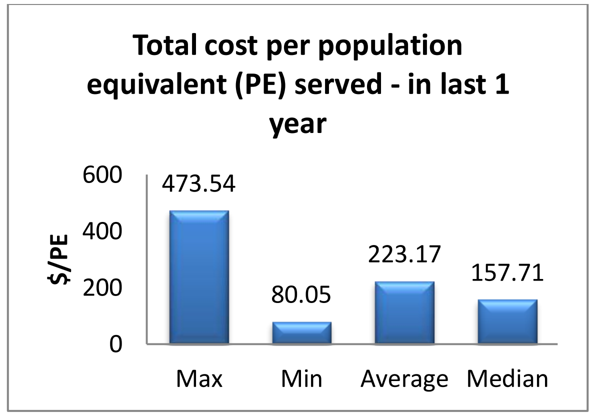

Figure 155. Total cost per population equivalent (PE) served - in last 1 year

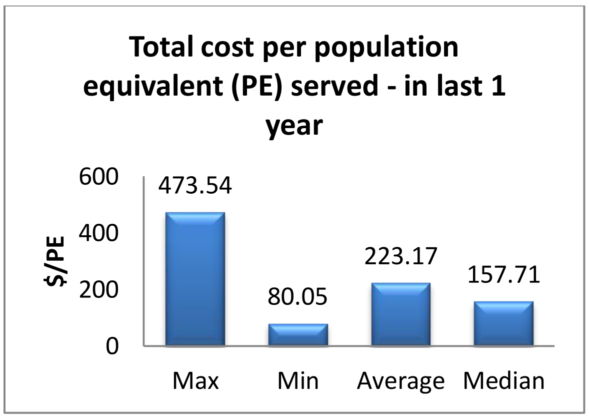

Figure 156. Capital cost per PE served - in last 1 year

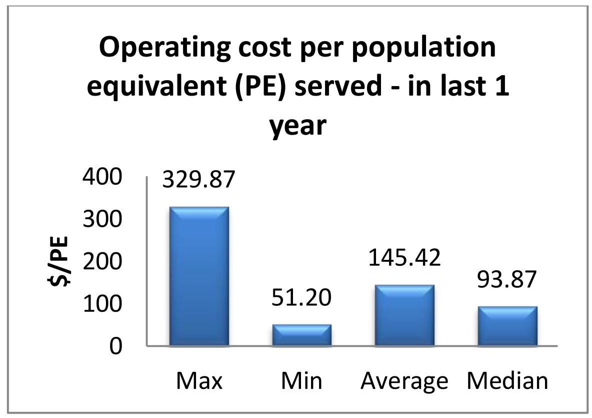

Figure 157. Operating cost per PE served - in last 1 year

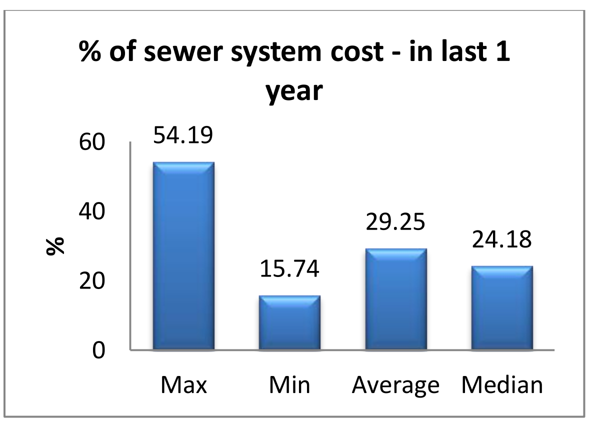

Figure 158. % of sewer system cost - in last 1 year

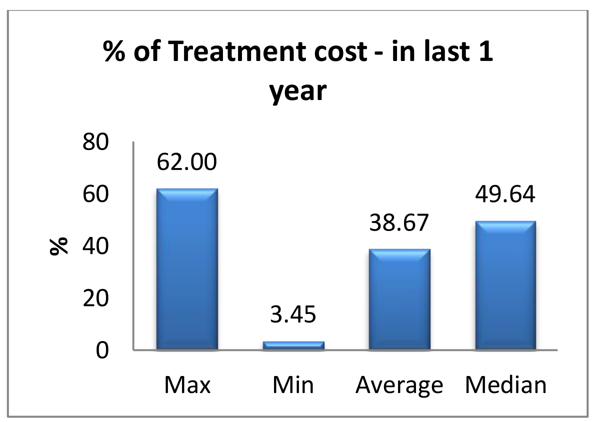

Figure 159. % of treatment cost - in last 1 year

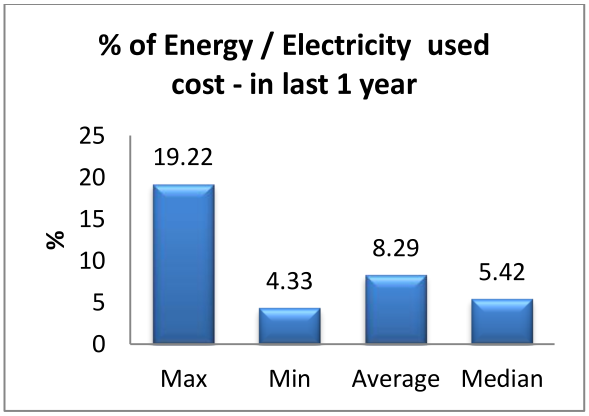

Figure 160. % of energy / electricity used cost - in last 1 year

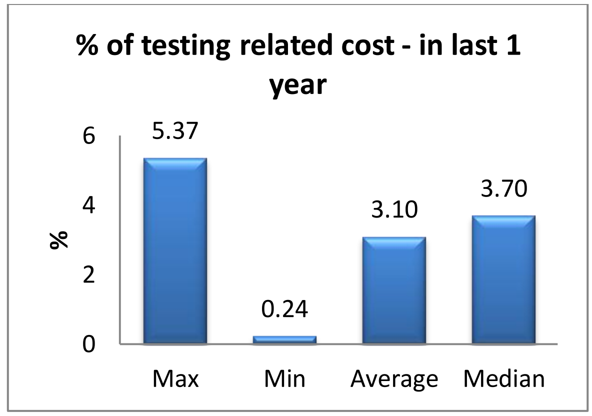

Figure 161. % of testing related cost - in last 1 year

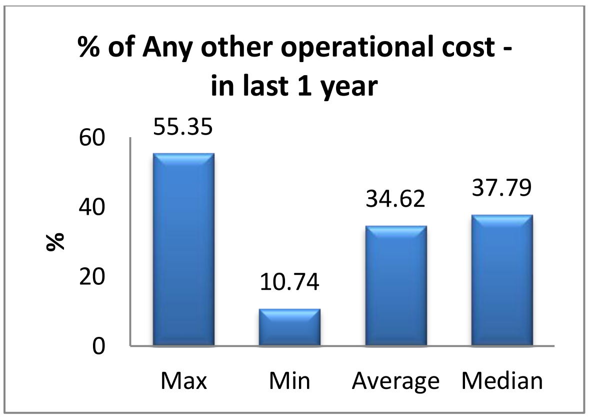

Figure 162. Any other operational cost - in last 1 year

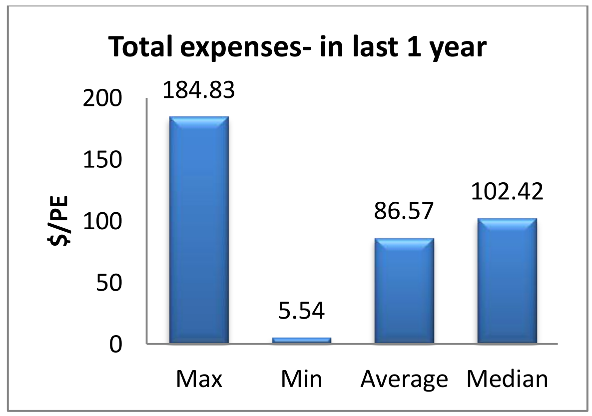

Figure 163. Total expenses - in last 1 year

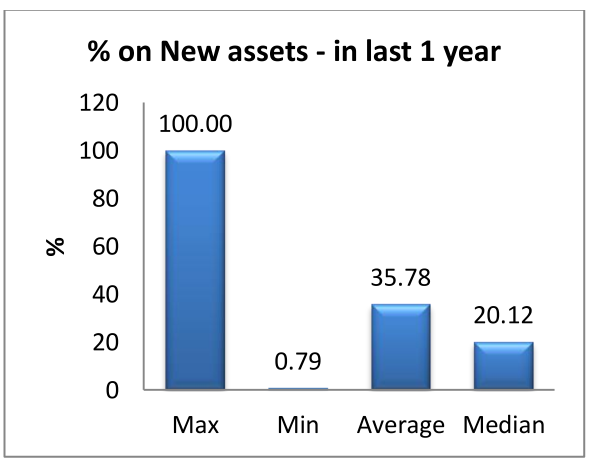

Figure 164. % on new assets - in last 1 year

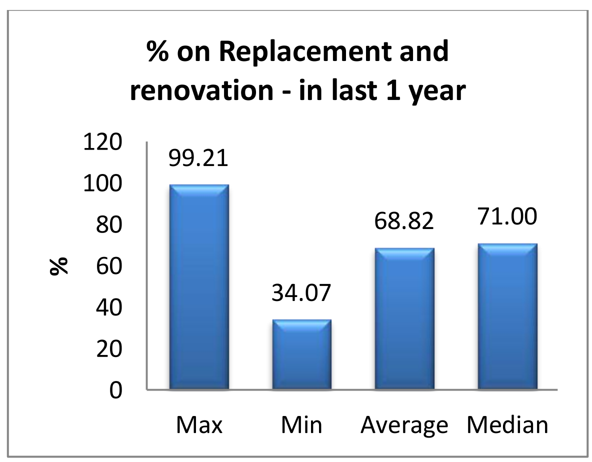

Figure. 165 % on replacement and renovation - in last 1 year

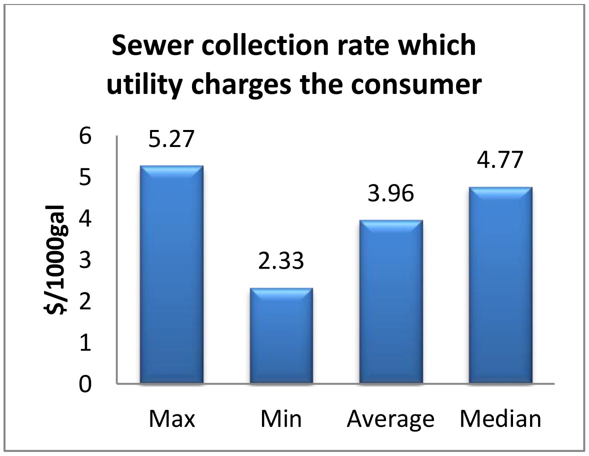

Figure 166. Sewer collection rate which utility charges the consumer

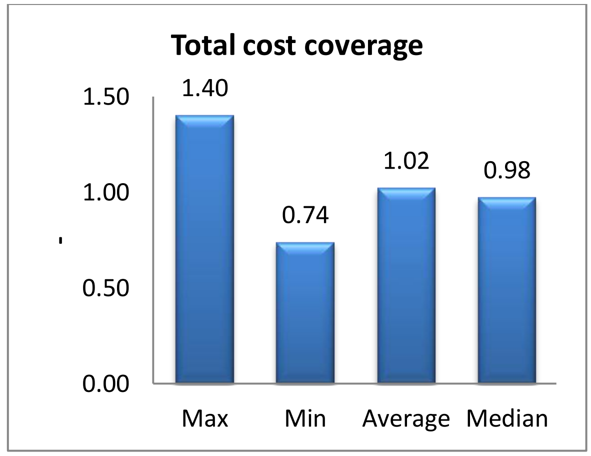

Figure 167. Total cost coverage

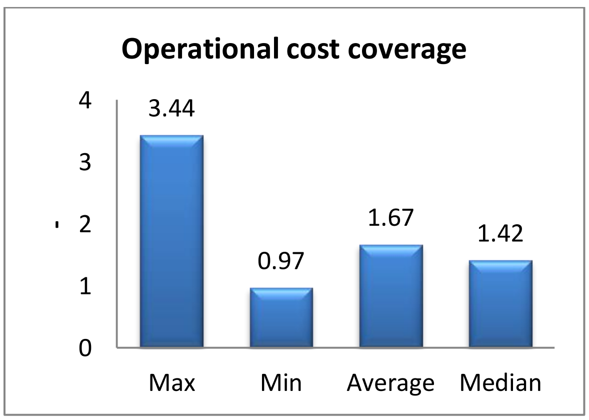

Figure 168. Operational cost coverage

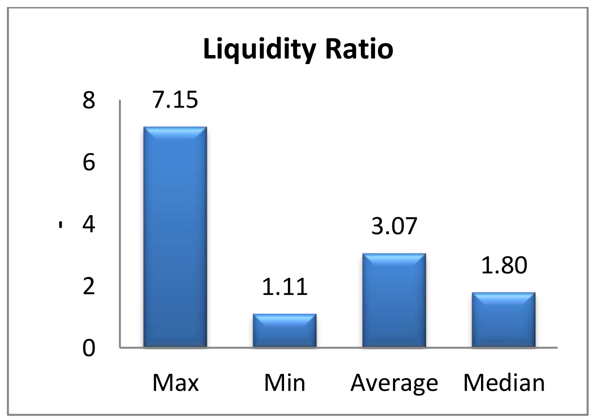

Figure 169. Liquidity ratio

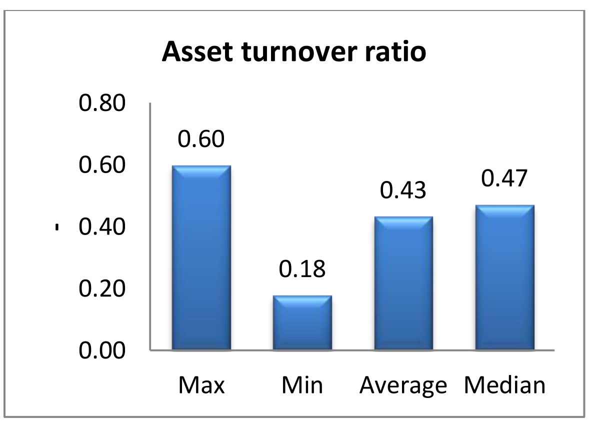

Figure 170. Asset turnover ratio

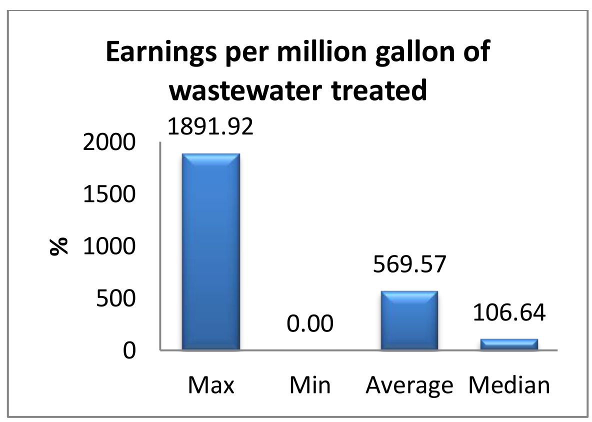

Figure 171. Earnings per million gallons of wastewater treated

CHAPTER 6. WEB-BASED PERFORMANCE BENCHMARKING FOR DRINKING WATER AND WASTEWATER

A web interface is developed where utilities can compare self-performance with other similar utilities. Based on the analysis results of performance indicators utilities can evaluate the areas of underperformance. Utilities have the option of comparing performance for every indicator with overall maximum, overall minimum, average, and median for defined indicators. Utilities have access to their respective data but cannot access data of any other utilities. Interested utilities can participate using the link – http://waterid.org/content/drinking-water-and-wastewater-utility-benchmarking

This web-based benchmarking platform is a part of WATER*i*D project. WATERiD is a knowledge database and contains information on both drinking water and wastewater infrastructure. Information about utility performance benchmarking, pipeline condition assessment, pipeline renewal engineering, subsurface utility engineering information for locating pipelines, management practices, models and tools, costs, and product qualification are parts of the project. The different categories in WATER*i*D are summarized in Figure 172 and utility benchmarking is highlighted.

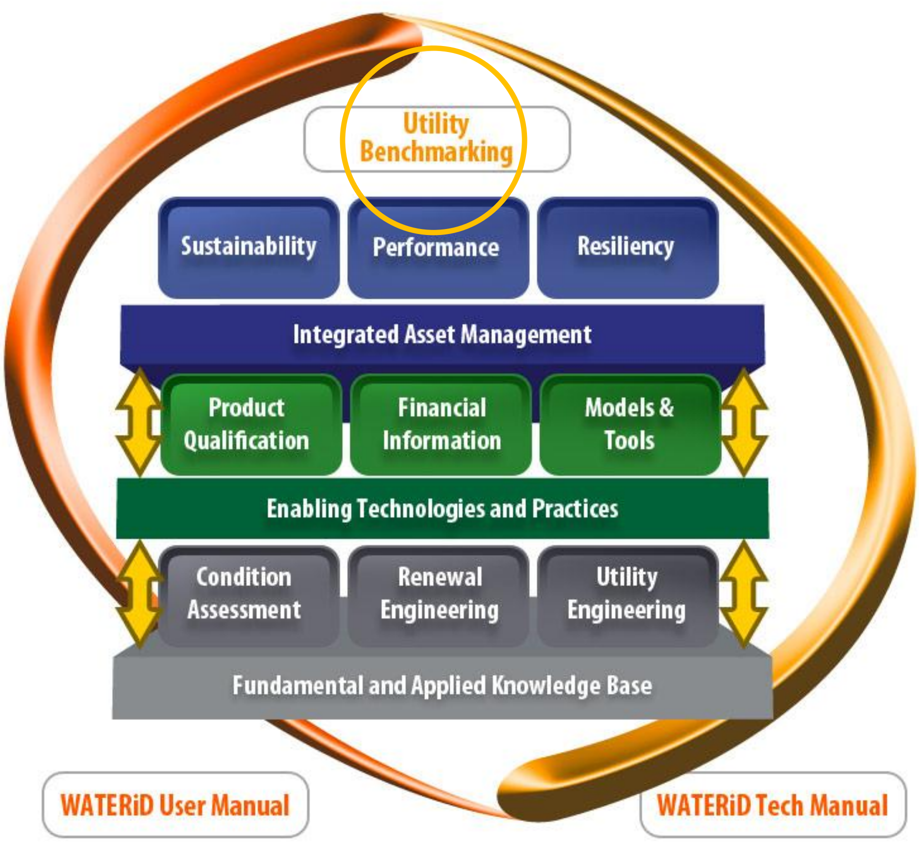

Figure 172. WATER*i*D categories

6.1 WEB INTERFACE

The data was collected from 10 drinking water and 9 wastewater utilities using benchmarking data-mining sheets. This process of data collection and result display is done using web interface on WATER*i*D and the process involves:

1. **Data Collection**: Utilities interested in participation can access the WATERiD – Benchmarking page (http://waterid.org/content/benchmarking-participation) to download the data mining sheet and send the data mining sheets with data for the indicators to the benchmarking team at Virginia Tech. Data is saved at a secured location on WATER*i*D which is accessible by utility personnel and the benchmarking team at Virginia Tech. The data provided by utilities is analyzed and benchmarking results are made available to the participating utilities.
2. **Visualization of results:** Once the data is collected and analyzed, it is converted to useful information and that should be easily accessible to the participating utilities. This was achieved by using a web interface using which utility personnel can access the results and make comparisons. A web interface gives user a flexible way of generating and visualizing results. Only the overall benchmarking results are shared on the WATERiD website. The utility specific information is shared with the respective utilities using the Google Fusion tables.

6.2 DATASHEETS

Performance indicators were defined based on literature sources and were used in the data-mining process. The data-mining sheet was reviewed by utility personnel. The data sheet has formulas defined to evaluate the value of the indicator based on the input data. In the example below (Figure 173), the utility personnel provide the data and predefined formula calculates the value for indicator. There is also a comment box for the utility personnel to provide feedback, comments and suggestions on the indicator for further clarification and for future improvement of the indicator.

automatically calculates the value - please do not edit

Sr. no	Indicator	Unit	Response	Comment
1	**Employee per million gallons of water produced**	number / Mgal	please enter value for a and b	
1a	Total number of employee	number		
1b	Average water produced per day	Mgal		

Please provide your comments here on the values

Figure 173. Sample indicator for data collection

Please provide your response here

6.3 LINKS TO RESOURCES

Many resources have been used like journal and conference papers, books and reports on benchmarking to develop the methodology, process and indicators for benchmarking. The resources related to drinking water and wastewater is available at http://waterid.org/content/drinking-water-utility-benchmarking-results and http://waterid.org/content/wastewater-utility-benchmarking-results

6.3.1 Synthesis Reports

Synthesis reports were developed for each area of research in the WATER*i*D project. These areas of research are performance benchmarking, condition assessment, renewal engineering, management practice, subsurface utility engineering, product qualification and cost. These reports contain a summary of the research findings and were developed for the funding agencies (EPA and WERF).

6.3.2 Participating Utility Information

WATER*i*D has been able to collect and present a huge amount of information with the help of utilities. List of participating utilities for all studies in WATER*i*D project are available at http://waterid.org/content/participating-utilities-0. Utility profile page for each participating utilities were created and information about the participants are available at http://waterid.org/directory/util.

6.3.3 Other benchmarking initiatives

Links to major benchmarking initiatives around the globe are available on WATER*i*D to gain knowledge about other initiatives. Link to other benchmarking initiatives are available at – http://waterid.org/content/drinking-water-and-wastewater-utility-benchmarking.

CHAPTER 7. SUMMARY

This thesis presents the results of a web-based performance benchmarking for drinking water and wastewater utilities. The work involved an extensive utility data mining process for gathering information on performance indicators. This data was used to evaluate and compare performance of utilities with other participants. The results helped the participating utilities to evaluate the overall performance and identify the areas with scope of improvement. The major contribution of this research is the creation of a database, and development of a web-based data collection and result display benchmarking platform which is part of national WATER*i*D database.

7.1 CONCLUSION

Research shows that aging drinking water and wastewater infrastructure has become a problem and requires a substantial investment to maintain as well as to keep up with demands. Evaluating the overall performance of utility is a key component to helping utilities understand the areas of underperformance. In the study a process of benchmarking that could meet the needs of utility performance evaluation is defined. To achieve this, a list of comprehensive and quantitative indicators was identified and used for the process of data collection. A robust methodology was used which provides a holistic view of utility performance. A web-based data collection and result display process that can be used repeatedly to support future benchmarking efforts has been defined. A data base for indicator values has been created using the data gathered for this study, and future participants can make comparisons for the performance indicators using this database. Over time, more data will be collected and that will provide utilities with access to a better database to make comparisons. Overall, this research provides information to implement benchmarking methodologies among utilities to evaluate and improve performance. Along with this, it will help to educate personnel of the utilities on the use of benchmarking for performance evaluation, performance improvement, resource allocation, and better future planning.

7.2 RECOMMENDATIONS AND FUTURE WORK

This research produced valuable insights into the benefits of benchmarking for performance evaluation of drinking water and wastewater utilities, despite the fact that the indicator data obtained through data mining was limited. This project is a step which provides utilities a web-based performance benchmarking platform for quantitative and comprehensive performance evaluation. It is recommended that drinking water and wastewater utilities use benchmarking for performance evaluation. Although, these indicators provide good information, practice benchmarking is also important to improve performance. The web-based benchmarking will enable online data collection which will be used to evaluate the change in performance of the utilities in future benchmarking.

Indicators, methodology, and the process of benchmarking can be improved based on the recommendation of utilities and users. The visualization platform can be improved based on the suggestions from drinking water and wastewater utilities.

Future work involves an expansion of the utilities involved in data mining, which will produce results and trends with more confidence, and will improve the database. When initially targeting utilities for data mining purposes, care should be taken to gather data from a variety of utility sizes in a variety of geographical locations. Apart from this, this research focuses only on the performance evaluation and potential solutions for improvement. It does not identify the reasons for underperformance of utilities. The next phase in this research can be analyzing the results for each participant for each set of indicators, and finding possible reasons for underperformance, followed by suggesting solutions for improvement using the best practices. Finally, the participants have not been given a score based on a predetermined scale. The next step can include evaluating a score using mathematical techniques like DEA (data envelope analysis). By using this technique, the score for each set of indicators can be calculated and used to evaluate an overall score for each participant.

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APPENDIX A: DATA MINING SHEET – GENERAL INFORMATION OF UTILITIES

Sr No	Information	Response	Comment
1	**Name of the Utility**		
2	**Type of Utility** (Drinking water, Wastewater or both - Drinking water and Wastewater)		
3	**Address of the utility**		
	Address 1		
	Address 2		
	City		
	State		
	Zip Code		
4	**Representative for further discussions**		
	Representative 1		
	Designation		
	email		
	phone		
	Representative 2		
	Designation		
	email		
	phone		
	Representative 3		
	Designation		
	email		
	phone		
	Representative 4		
	Designation		
	email		
	phone		
5	**Areas in which utility provides service**		
	County		
	City		

APPENDIX B: DATA MINING SHEET – DRINKING WATER

Essential
Preferable

Water resource utilization

	Indicator	Definition	Unit	Response	Comment
1	Inefficiency of use of water resource	total Water lost due to leakage and overflow / Total treated water produced x 100	%		
2	Reused or recycled supplied water	volume of water reused or recycled / total volume of water entering the utility for treatment x 100	%		
3	Water resources availability	total volume of water entering the utility for treatment / Total volume of water available as per withdrawal permit from lakes, river and other sources x 100	%		

Employee information

	Indicator	Definition	Unit	Response	Comment
	Total employee				
4	Employee per 1000 connection	total no. of employees / number of connections x 1000	number / 1000		
5	Employee per million gallons of water produced per day	total no. of employees / Million gallons of water produced daily	number / Mgal		
	Employee as per function				

6	Higher management employees	number of full time equivalent employees dedicated to directors, central administration, strategic planning, marketing and communications, legal affairs, environmental management, business development / total number of employee x 100	%		
7	Human resources employees	number of full time employees dedicated to personnel administration, education and training, occupational safety and social activities / total number of employee x 100	%		
8	Financial and commercial employees	number of full time equivalent employees dedicated to economic and financial planning, economic administration, economic controlling and purchasing / total number of employee x 100	%		
9	Customer Service employees	number of full time equivalent employees dedicated to customer relations / total number of employee x 100	%		
10	Planning, designing and construction employees	number of employees working in planning, designing & construction / total number of employee x 100	%		

11	Operations and maintenance employees	number of employees working in operations & maintenance of the utility / total number of employee x 100	%		
12	Water quality monitoring employees (lab personnel)	number of lab testing employees / total number of employee x 100	%		
	Training				
13	Personnel training	total training hours for all the employees in last 1 year / total number of employees	hours / employee/ year		
	Personnel health and safety				
14	working accidents - % of employees injured in last 1 year	number of employees injured on the job in the last 1 year / total number of employees x 100	%		
15	Absences due to accidents	sum of all the absences due to all the employees due to reasons related to accident in last 1 year / total number of employees	number / employee / year		

Physical assets

	Indicator	Definition	Unit	Response	Comment
16	Treatment plant utilization	average Volume of water treated daily / Maximum daily water treatment capacity x 100	%		
17	Water produced vs. Treated water storage capacity	average Volume of water treated daily / capacity of treated water storage reservoir x 100	%		
18	Capacity of Raw	average of daily raw	%		

	water storage reservoir	water input to treatment system / capacity of raw water reservoirs x 100			
19	Pumping utilization	sum, for all installed pumps, of the number of average daily operation hours multiplied by the per hour pumping capacity for 1 day / Sum, for all installed pumps, 24 multiplied by the per hour pumping capacity x 100	%		
20	Total Main length	length of total main	miles		
20 a	Transmission main	length of transmission main	miles		
20 b	Distribution main	length of distribution main	miles		
21	Valve density	total no of isolating valves / total miles of distribution main length	number / mile		
22	Hydrant density	total no of hydrants / total miles of distribution main length	number / mile		
23	Meters	total number of meters / total number of connections x 100	%		
24	Energy consumption	monthly energy used by the utility / Total Population served	Kwm/ month / person		

Service quality

	Indicator	Definition	Unit	Response	Comment
25	Population coverage	total Population served / Total population of the service area x 100	%		
	Water supply Reliability				
26	Main breaks	total number of main breaks in last 1 year / Total main length x 100	number / 100 miles		
27	Water interruptions - unplanned				
27a	% connections with interruptions of less than 4 hours in last 1 year	number of connections experiencing disruptions of less than 4 hours in last 1 year / Total number of connections x 100	%		
27b	% connections with interruptions between 4-12 hours in last 1 year	number of connections experiencing disruptions of between 4-12 hours in last 1 year / Total number of connections x 100	%		
27c	% connections with interruptions of greater than 12 hours in last 1 year	number of connections experiencing disruptions of greater than 12 hours in last 1 year / Total number of connections x 100	%		
28	Total % of connections experiencing disruption in last 1 year	total number of connections experiencing disruption in last 1 year / Total number of connections x 100	%		
	Quality of Supplied water				

29	Total % of tests compliant with permit conditions for treated water	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
30	Total % of required tests done	total no. of tests done / total no. of water quality tests required by standards x 100	%		
31	Total % of Aesthetic tests compliant with permit conditions for treated water	total no. of Aesthetic tests complying with permit conditions / total no. of Aesthetic tests done x 100	%		
32	Total % of required Aesthetic tests done	total no. of Aesthetic tests done / total no. of Aesthetic tests required by standards x 100	%		
33	Total % of Microbiological tests compliant with permit conditions for treated water	total no. of Microbiological tests complying with permit conditions / total no. of Microbiological tests done x 100	%		
34	Total % of required Microbiological tests done	total no. of Microbiological tests done / total no. of Microbiological tests required by standards x 100	%		
35	Total % of Physical-chemical tests compliant with permit conditions for treated water	total no. of Physical-chemical tests complying with permit conditions / total no. of Physical-chemical tests done x 100	%		

36	Total % of required Physical-chemical tests done	total no. of Physical-chemical tests done / total no. of Physical-chemical tests required by standards x 100	%		
37	Total % of Radioactive tests compliant with permit conditions for treated water	total no. of Radioactive tests complying with permit conditions / total no. of Radioactive tests done x 100	%		
38	Total % of required Radioactive tests done	total no. of Radioactive tests done / total no. of Radioactive tests required by standards x 100	%		

Operational performance

	Indicator	Definition	Unit	Response	Comment
	Inspection and maintenance				
39	Pump inspection	total number of pumps inspected or checked in last 1 year / Total number of pumps x 100	%		
40	Storage tank cleaning - number	total number of storage raw water and treated water tanks cleaned in last 1 year / Total number of raw water and treated water storage tanks x 100	%		

41	Storage tank cleaning - volume	total volume of raw water and treated water storage tanks cleaned in last 1 year / Total volume of all raw water and treated water storage tanks x 100	%		
42	Main inspection	total length of transmission and distribution main pipes inspected - physical inspection for proper working condition, internal inspection by video, flow measurements to calculate head loss etc. / Total length of mains x 100	%		
43	Valve Inspection	number of valves inspected - checked to insure it is operational / Total number of valves x 100	%		
44	Hydrant inspection	number of hydrants inspected - checked to insure it is operational / Total number of hydrants x 100	%		
	Instrumentation calibration				
45	System flow meter calibration - in last 1 year	number of meters calibrated / total number of meters x 100	%		
46	Meter replacement rate - in last 1 year	number of meters calibrated / total number of meters x 100	%		
47	Pressure meter calibration - in last 1 year	number of meters calibrated / total number of meters x 100	%		

48	Water level meter calibration - in last 1 year	number of meters calibrated / total number of meters x 100	%		
49	Online water quality monitoring equipment calibration - in last 1 year	number of equipment calibrated / total number of equipment x 100	%		
	Sustainability/ rehabilitation				
50	Leakage control	number of leaks or main breaks detected and repaired - in last 1 year / total length of main x 100	number / 100 miles		
51	Transmission Main replaced / rehabilitated - in last 1 year	length of transmission mains replaced or rehabilitated- in last 1 year (miles) / Total length of transmission mains (miles) x 100	%		
52	Distribution Main replaced / rehabilitated - in last 1 year	length of distribution mains replaced or rehabilitated- in last 1 year (miles) / Total length of distribution mains (miles) x 100	%		
53	Valves replacement - in last 1 year	no. of valves replaced / total no. of valves x 100	%		
54	Service connection rehabilitation - in last 1 year	no. of service connections replaced or renovated / total number of connections x 100	%		
55	Pump refurbishment - in last 1 year	number of pumps refurbished / total number of pumps x 100	%		
56	Pump replacement - in last 1 year	number of pumps replaced / total number of pumps x	%		

		100			
	Water losses				
57	Water loss per connection	total water lost in gallons or total non-revenue water - in last 1 year / Total number of connections	gallons / connection		
58	% water lost	total water lost or total non-revenue water - in last 1 year / Total treated water produced - in last 1 year	%		
	Water meter				
59	Operational meters	no. of working customer meters/total customer meters x 100	%		
60	Unmetered water - volume which is charged but not metered	volume of supplied water which is not metered - daily average / Total volume of treated water supplied - daily average x 100	%		

Customer enquiries

	Indicator	Definition	Unit	Response	Comment
61	Service enquiries per 100 connection	total number of enquiries - in last 1 year / total number of connections	number / 100 connection		
62	Pressure related reports	no. of pressure related reports - in last 1 year / total no. of reports x 100	%		
63	Continuity related reports	no. of Continuity related reports - in last 1 year / total no. of reports x 100	%		

64	Water quality - taste related reports	no. of taste related reports - in last 1 year / total no. of reports x 100	%		
65	Water quality - odor related reports	no. of odor related reports - in last 1 year / total no. of reports x 100	%		
66	Interruption related reports	no. of Interruption related reports - in last 1 year / total no. of reports x 100	%		
67	Billing related	no. of Interruption related reports - in last 1 year / total no. of reports x 101	%		

Financial performance

	Indicator	Definition	Unit	Response	Comment
	Revenue				
68	Revenue per Mgal treated water produced - in last 1 year	total revenue in last 1 year / Total treated water produced in last 1 year	$ / Mgal		
69	Sales revenue in last 1 year	revenue generated by sales / Total revenue x 100	%		
70	Other revenue in last 1 year	revenue generated which are not from sales / Total revenue x 100	%		
	Cost				
71	Total cost per Mgal treated water produced - in last 1 year	capital cost plus Operating cost - in last 1 year / Total treated water produced in last 1 year	$ / Mgal		
72	Capital cost per Mgal treated water produced - in last 1 year	total Capital cost in last 1 year / Total treated water produced in last 1 year	$ / Mgal		

73	Operating cost per Mgal treated water produced - in last 1 year	total Operating cost in last 1 year / Total treated water produced in last 1 year	$ / Mgal		
	% Operational Cost by type				
74	% of Transmission, storage and distribution cost - in last 1 year	total cost related to Transmission, storage and distribution process / Total Operational cost	%		
75	% of Water Treatment and water testing cost - in last 1 year	total cost related to Water Treatment and water testing / Total Operational cost	%		
76	% of Energy / Electricity used cost - in last 1 year	total cost related to Energy / Electricity used / Total Operational cost	%		
77	% of Meter management and connection related cost - in last 1 year	total cost related to Meter management and connection related / Total Operational cost	%		
78	Any other operational cost - in last 1 year	any other cost / Total Operational cost	%		
	Expenses on assets				
79	Total expenses - in last 1 year	total expenses on plant and equipment – new / replacement / renovation - In the last 1 year / Total treated water produced in last 1 year	$ / Mgal		
80	% on New assets - in last 1 year	expenses on new assets / Total expenses x 100	%		
81	% on Replacement and renovation - in last 1 year	expenses on replacement and renovation of existing assets / Total expenses x100	%		

	Water rate (calculated using sales revenue and water produced)				
82	Average Water charges from direct consumption	total Sales revenue - in last 1 year / Total treated water produced in last 1 year	$ / Mgal		
83	Water rate which utility charges the consumer	as per the standard utility rate	$ / Mgal		
	Efficiency				
84	Total cost coverage	total revenue in last 1 year / total cost in last 1 year	-		
85	Operational cost coverage	total revenue in last 1 year / total operational cost in last 1 year	-		
86	Current Ratio (Liquidity measure)	total current assets value / total current liabilities value	-		
87	Asset turnover ratio	sales revenue in last 1 year / total current assets value	-		
88	Water Loss cost - non revenue water cost	estimated cost of non-revenue water - in last 1 year / Total Operating cost in last 1 year x 100	%		
	Earnings				
89	Earnings per million gallons of treated water produced	total earnings - in last 1 year /Total treated water produced in last 1 year	$ / Mgal		

APPENDIX C: DATA MINING SHEET – WASTEWATER

Essential
Preferable

Wastewater and biosolids

Sr. No	Indicator	Definition	Unit	Response	Comment
	Wastewater				
1	Compliance with discharge consents - last 1 year	current number of Population Equivalent (PE) served by WW treatment plant complying with discharge consents / Total Population Equivalent (PE) served x 100	%		
2	Reuse	volume of wastewater reused after treatment in last 1 year / Total volume of wastewater treated in last 1 year x 100	%		
	Biosolids				
3	Biosolid production	dry weight of biosolids produced in last 1 year / Total Population Equivalent (PE) served	lbs / PE / year		
4	Biosolid use	dry weight of produced biosolids used for agriculture, products, materials etc. - in last 1 year / dry weight of Biosolids produced in last 1 year x 100	%		

5	Biosolid disposal	dry weight of Biosolids disposed - in last 1 year / dry weight of Biosolids produced in last 1 year x 100	%		

Employee information

Sr. No	Indicator	Definition	Unit	Response	Comment
	Total employee				
6	Employee per 1000 population equivalent served	total no. of employees / total population equivalent served x 1000	number / 1000		
7	Employee per million gallons of wastewater treated	total no. of employees / Million gallons of wastewater treated daily	number / Mgal		
	Employee as per function				
8	Higher management employees	number of full time equivalent employees dedicated to directors, central administration, strategic planning, marketing and communications, legal affairs, environmental management, business development / total number of employee x 100	%		

9	Human resources employees	number of full time employees dedicated to personnel administration, education and training, occupational safety and social activities / total number of employee x 100	%		
10	Financial and commercial employees	number of full time equivalent employees dedicated to economic and financial planning, economic administration, economic controlling and purchasing / total number of employee x 100	%		
11	Customer Service employees	number of full time equivalent employees dedicated to customer relations / total number of employee x 100	%		
12	Planning, designing and construction employees	number of employees working in planning, designing & construction / total number of employee x 100	%		
13	Operations and maintenance employees	number of employees working in operations & maintenance of the utility / total number of employee x 100			

14	Wastewater quality monitoring employees (lab personnel)	number of lab testing employees / total number of employee x 100	%		
	Training				
15	Personnel training	total training hours for all the employees in last 1 year / total number of employees	hours / employee / year		
	Personnel health and safety				
16	Working accidents - % of employees injured in last 1 year (%)	number of employees injured on the job in the last 1 year / total number of employees x 100	%		
17	Absences due to accidents	sum of all the absences due to all the employees due to reasons related to accident in last 1 year / total number of employees	days / employee / year		
18	Vaccination	total number of maintenance, operations and lab testing employees with vaccination for sewage and waste related diseases / total number of employees in maintenance, operations and lab testing x 100	%		

Treatment process

Sr. No	Indicator	Definition	Unit	Response	Comment
19	Treatment plant utilization - primary treatment	average daily volume of wastewater which received primary treatment / Total daily capacity for primary treatment x 100	%		
20	Treatment plant utilization - secondary treatment	average daily volume of wastewater which received secondary treatment / Total daily capacity for secondary treatment x 100	%		
21	Treatment plant utilization - tertiary treatment	average daily volume of wastewater which received tertiary treatment / Total daily capacity for tertiary treatment x 100	%		
22	Energy consumption	monthly energy used by the utility / Million gallons of wastewater treated every month	kwh / Mgal		
23	Pumping utilization	sum, for all installed pumps, of the number of average daily operation hours multiplied by the per hour pumping capacity for 1 day / Sum, for all installed pumps, 24 multiplied by the per hour pumping capacity x 100	%		

Treatment performance

Sr. No	Indicator	Definition	Unit	Response	Comment
24	Population coverage	total Population served / Total population of the service area x 100			
	Wastewater Treatment levels				
25	Total treatment level	million gallons of wastewater treated daily / total daily volume of wastewater entering the treatment plant x 100	%		
26	Primary treatment level	average daily volume of wastewater which received primary treatment / total daily volume of wastewater entering the treatment plant x 100	%		
27	Secondary treatment level	average daily volume of wastewater which received secondary treatment / total daily volume of wastewater entering the treatment plant x 100	%		
28	Tertiary treatment level	average daily volume of wastewater which received tertiary treatment / total daily volume of	%		

		wastewater entering the treatment plant x 100			
	Quality of testing				
	Total tests				
29	Total tests-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
30	Total tests-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - BOD test				
31	Wastewater - BOD test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
32	Wastewater - BOD test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - COD test				
33	Wastewater - COD test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
34	Wastewater - COD test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - TSS test				
35	Wastewater - TSS test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		

36	Wastewater - TSS test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - phosphorus test				
37	Wastewater - phosphorus test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
38	Wastewater - phosphorus test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - nitrogen test				
39	Wastewater - nitrogen test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
40	Wastewater - nitrogen test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - fecal E.coli test				
41	Wastewater - Fecal E.coli test-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
42	Wastewater - Fecal E.coli test-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Wastewater - other tests				
43	Wastewater - other tests-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests	%		

		done x 100			
44	Wastewater - other tests-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Biosolids tests				
45	Biosolids tests-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
46	Biosolids tests-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		
	Industrial discharge tests				
47	Industrial discharge tests-Total % of tests compliant with permit conditions	total no. of tests complying with permit conditions / total no. of tests done x 100	%		
48	Industrial discharge tests-Total % of required test done	total no. of tests done / total no. of quality tests required by permit conditions x 100	%		

Operational performance

Sr. No	Indicator	Definition	Unit	Response	Comment
	Inspection and maintenance				
49	Sewer Inspection	length of sewer inspected (miles) /checked in last 1 year / total length of sewer (miles) x 100	%		

50	Sewer Cleaning	length of sewer (miles) cleaned in last 1 year / total length of sewer (miles) x 100	%		
51	Manhole chamber inspection	Total number of Manhole chamber inspected or checked in last 1 year / Total number of Manhole chamber x 100	%		
52	Storage and CSOs inspection rate	no. of storage tanks and CSOs inspected or checked in last 1 year / total no. of storage tanks and CSOs x 100	%		
53	Storage and CSOs inspected volume	volume of Storage tanks and CSOs inspected or checked in last 1 year / total volume of storage tanks and CSOs x 100	%		
54	Storage and CSOs cleaning	volume of Storage tanks and CSOs cleaned / total volume of storage tanks and CSOs x 100	%		
55	Pump inspection	total number of pumps inspected or checked in last 1 year / Total number of pumps x 100	%		
	Calibration				
56	System flow meters	total number of flow meters calibrated in last 1 year / total no. of flow meters x 100	%		

57	Wastewater quality monitoring instrument	total number of quality monitoring instrument calibrated in last 1 year / total number of quality monitoring instrument x 100	%		
	Renewal				
58	Sewer replaced/rehabilitated - in last 1 year	length of Sewer (miles) replaced or rehabilitated - in last 1 year / total length of sewer (miles) x 100	%		
59	Manhole chamber replaced/rehabilitated - in last 1 year	total no. of manhole chambers replaced or rehabilitated - in last 1 year / total no. of manhole chambers x 100	%		
60	Manhole covers replaced - in last 1 year	no. of manhole covers replaced - in last 1 year / total no. of manhole covers x 100	%		
	Blockages and breaks				
61	Sewer blockage - in last 1 year	total number of sewer blocks occurred - in last 1 year / total length of sewer x 100	number / 100 mile		
62	Sewer breaks - in last 1 year	total number of sewer breaks or damage to the sewer - in last 1 year / total length of sewer x 100	number / 100 mile		

Customer enquiries

Sr. No	Indicator	Definition		Response	Comment
63	Total Service enquiries per 1000 Population Equivalent served	total number of enquiries - in last 1 year / Total population equivalent (PE) served x 1000	number / 1000 PE served		
64	Reports related to odor	no. of odor related reports - in last 1 year / total no. of reports x 100	%		
65	Reports related to flooding	no. of flooding related reports - in last 1 year / total no. of reports x 100	%		
66	Reports related to pollution	no. of pollution related reports - in last 1 year / total no. of reports x 100	%		
67	Reports related to rodent	no. of rodent related reports - in last 1 year / total no. of reports x 100	%		
68	Blockage	no. of blockage related reports - in last 1 year / total no. of reports x 100	%		
69	Billing related	no. of Billing related complains - in last 1 year / total no. of reports x 100	%		

Financial performance

Sr. No	Indicator	Definition	Unit	Response	Comment
	Revenue				
70	Revenue per population equivalent (PE) served - in last 1 year	total revenue in last 1 year / Total Population Equivalent (PE) served	$ / PE		
71	Service revenue in last 1 year	revenue generated by Service / Total revenue x 100	%		
72	Other revenue in last 1 year	revenue generated which are not from sales / Total revenue x 100	%		
	Cost				
73	Total cost per population equivalent (PE) served - in last 1 year	capital cost plus Operating cost - in last 1 year / Total Population Equivalent (PE) served	$ / PE		
74	Capital cost per PE served - in last 1 year	total Capital cost in last 1 year / Total Population Equivalent (PE) served	$ / PE		
75	Operating cost PE served - in last 1 year	total Operating cost in last 1 year / Total Population Equivalent (PE) served	$ / PE		
	% Operational Cost by type				
76	% of sewer system cost - in last 1 year	total cost related to sewer system operation / Total Operational cost x 100	%		

77	% of Treatment cost - in last 1 year	total cost related to Treatment and testing cost / Total Operational cost x 100	%		
78	% of Energy / Electricity used cost - in last 1 year	total cost related to Energy or Electricity used / Total Operational cost	%		
79	% of testing related cost - in last 1 year	total cost related to testing / Total Operational cost x 100	%		
80	Any other operational cost - in last 1 year	any other cost / Total Operational cost x 100	%		
	Expenses				
81	Total expenses - in last 1 year	total expenses on plant and equipment - new + replacement + renovation - In the last 1 year / Total Population Equivalent (PE) served	$ / PE		
82	% on New assets - in last 1 year	expenses on new assets / Total investment x 100	%		
83	% on Replacement and renovation - in last 1 year	expenses on replacement and renovation of existing assets / Total investment x 100	%		
	Sewer collection rate				
84	Sewer collection rate which utility charges the consumer	as per the standard utility rate	$ / 1000 gal		
	Efficiency				

85	Total cost coverage	total revenue in last 1 year / total cost in last 1 year	-		
86	Operational cost coverage	total revenue in last 1 year / total operational cost in last 1 year	-		
87	Current Ratio (Liquidity measure)	total current assets value / total current liabilities value	-		
88	Asset turnover ratio	Sales revenue in last 1 year / total current assets value	-		
	Earnings				
89	Earnings per million gallons of wastewater treated	total earning - in last 1 year / Total wastewater treated in last 1 year	$ / Mgal		