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Development of benchmarking system for the wastewater sector in the Kingdom of Bahrain

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ABSTRACT

International benchmarking procedures are useful and effective tools to assess the performance of wastewater services. Wastewater treatment plants (WWTPs) are large resource consumers and are perceived as a promising effort to detain the global resources crisis through sustainable action. The economics of wastewater management and treatment is the subject of growing interest to protect the environment from the adverse effects. According to international water bodies, the challenges facing the governments are rapid population growth, worsening of the climate, severity of freshwater scarcity, rising costs, aging infrastructure, increasingly stringent regulatory requirements, and a rapidly changing workforce, varying influent due to storm water, etc. are global challenges. In this study, wastewater collection, treatment and discharge related to Tubli sewage treatment plant at Tubli Water Pollution Control Center were analyzed with the aim of developing key performance indicators, which are used for benchmarking purposes. This analysis helps improving the understanding of how individual scores of efficiency and operating variables are related. The study describes the development of a benchmark for the evaluation of control strategies in WWTPs. This study is intended to be useful to decision-makers in the wastewater treatment sector. The benchmarking methodology and empirical application developed by performance indicators (PIs) for wastewater services published by International Water Association (IWA) is used for improving the management of WWTPs and contribute to save operational costs. The study assessed the benchmarking of the wastewater services in the Kingdom of Bahrain. Performance assessment and benchmarking have developed as key aspects of WWTP management. Benchmarking is a data-driven process, and can only be successful if careful consideration is given to data availability and accuracy. Four teams have contributed to the development of the benchmark and have obtained results. The only data readily available and accurate are supplied for regulatory purposes. There are 184 PIs detailed by IWA. In the study 25 PIs were analyzed for the year 2017 where the data are readily available. The results indicated that, without sufficient data, assessing the accuracy of the data and identifying comparable WWTPs, the PIs analysis becomes increasingly complex. Improved data management practices can be achieved through WWTP benchmarking. Enabling the successful benchmarking in the present-day can (i) accelerate the improvement of data collection practices, (ii) improve WWTP management practices and (iii) lead the way to the inclusion of more advanced benchmarking applications in the years to come, when data availability and accuracy issues are corrected. Optimizing the investments and developing regional experiences are key factors to promote the scientific research.

Keywords: Benchmarking; Treatment plant; Efficiency and effectiveness; Stakeholders; ACWUA; IWA

1. Introduction

Sanitation services in Bahrain are provided at commendable rates reaching more than 90% of the population. Sanitation services are delivered at high professional standards and are operating modern treatment facilities with high standards for tertiary and advanced treatment capabilities. However, these services are provided to the public with highly subsidized rates with almost zero cost recovery, despite the government many attempts to charge for its sanitation services. These conditions make sanitation services

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almost completely dependent and captive to government funding and allocations, which ultimately affects the sector financial sustainability and hence its performance.

According to the GCC Unified Water Sector Strategy (GCC UWS) 2015–2035, sanitation authorities find themselves in stressful working conditions. These conditions do not provide the authorities with an opportunity to look at the overall utility management and performance in terms of the many attributes of effectively managed utilities (EMU), which help utilities, respond to both current and future challenges and ensure their sustainability. These EMU attributes and performance measures include environmental, personnel, physical, operational, quality of services, economic and financial aspects of wastewater. By 2035, the GCC countries shall establish sustainable, efficient, equitable, and secure water resources management systems contributing to their sustainable socio-economic development. This shall be achieved through GCC supreme council for water with the support of technical advisory committee. To achieve the highest management standards for sanitation utilities the GCC countries shall adopt and implement the best practice benchmarking system for sanitation utilities. The benchmarking rank of sanitation utilities in the GCC countries shall be in comparison to those countries which use benchmarking in the world. In this regard, benchmarking of the sanitation sector becomes crucial to improve its sustainability and enhance its services. International experiences have proven that benchmarking can be a good instrument to stimulate performance wastewater management. Therefore, adopting an EMU approach and principles can help wastewater utilities enhance the stewardship of their infrastructure, improve performance in many critical areas, and respond to current and future challenges.

Sanitation services in Bahrain are provided to the public with free of charges. These services are provided in a professional standard to meet the public satisfaction. The cost recovery for the sanitation services has to be collected from the public. Although the government is trying to charge the public for the services, still the full subsidy is in force. Presently sanitary utilities in Bahrain do not follow the best practices for benchmarking/quality assurance system for the wastewater utility management. To begin with, the approach of Arab Countries Water Utilities Association (ACWUA) is well-thought-out initially as a gap analysis. The ACWUA is a global center of excellence that partners with water supply and wastewater utilities in the Arab Countries on building capacities within the utilities and on instituting best practices in order for the utilities to achieve their objectives. In this sense, this survey explored the current situation in sanitary wastewater services in the Kingdom of Bahrain. This represents Phase 1 of the study. Phase 2 of the study utilized the manual - performance indicators (PIs) for wastewater services – International Water Association (IWA) to analyze and select the most appropriate benchmark.

- To achieve the highest International Standards of Water and Wastewater Services
- Identifying key PIs as per the manual for best practices
- Implementing effective water governance
- Providing the capability for utilities to identify targets associated with each leading practice
- Developing a benchmarking framework and assessment methodology
- Developing a supporting benchmarking tool
- Making the tool available for the use and benefit of the water sector

The National Master Plan for Sanitary Engineering Services (NMPSES) that conforms to the National Planning Development Strategies (NPDS, 2007) provides a more holistic view of the entire Sanitary Engineering Services (SES) in the Kingdom of Bahrain, to ensure that the SES meet the current and projected loads for the next 20 years. In 2008, following a two year process of research, analysis, consultation and design, the related "Bahrain 2030 NPDS" was published (GTZ, 2008)

The wastewater management system is a foundation of modern public health and environment protection. PIs are used to identify where organizational performance is meeting desired standards and where performance requires improvement. It is to encourage meaningful sustainability, best practices and industrial benchmarking to establish within the wastewater management community. Survey has been conducted to gather information about current handling of wastewater system to identify the gaps. Further sanitary department shall identify PIs to measure and monitor the performance. The indicators shall be aligned with international best practices for benchmarking. A framework of PIs are developed to identify a reasonable set of environmental, social, economic and technical indicators for wastewater treatment by following IWA best practices (Matos, et al., 2012).

The objective of this study is to develop/adopt and implement a benchmarking system that is suitable to Bahrain sanitation sector, and compare the findings with that from the best practices in the world. Moreover, within the framework and in line with the implementation plan of the GCC UWS, this will serve the 3rd policy of the 4th strategic objective aiming at "achieving the highest International Standards of Water and Wastewater Services", which calls for "adopting and implementing the highest benchmarking system for sanitation utilities in the GCC countries". A first step to achieve this policy is to develop a national benchmarking system in each GCC country as a prerequisite to the establishment of the joint GCC wastewater benchmarking system.

2. Methodological approach

The development of a benchmarking system for the sanitation sector in Bahrain would involve the adoption of generally accepted procedures and methodologies, able to provide decision makers with an overall perception of the utility performance as a sound basis for making strategic choices from water organization bodies and the best international practices. In the literature, there are three relevant references available for the approach of EMU; these are namely:

- The ACWUA - TSM – Arab requirements for wastewater treatment facilities
- PIs for wastewater services, operations and maintenance specialist group - IWA

- Performance benchmarking for effectively managed water utilities – Water Research Foundation (WRF)

Presently there is no benchmarking/quality assurance system for the wastewater utility management in Bahrain. To begin with, the approach of (ACWUA, 2015) will be accomplished initially as a gap analysis exercise. This will represent phase 1 of the study. Phase 2 of the study will utilize the literatures in determining the PIs using the IWA manual (Matos, et al., 2012) to analyze and select the most appropriate benchmark based on their relevance to the sanitation sector in Bahrain.

2.1. Phase 1: gap analysis (ACWUA Survey)

Any undertaking needs to strive for high degree of efficiency and effectiveness to achieve its management goals. In addition, other stakeholders, such as regulators or customers require assurance that the undertaking is performing appropriately (Merkel, 2002; Matos et al., 2012). In this frame, a survey was launched by Ministry of Works, Municipalities Affairs and Urban Planning (MOWMAUP), Sanitary Engineering Department to obtain the facility staff feedback regarding the performance management of the wastewater system in the Kingdom of Bahrain. The survey was based on the guidelines of (ACWUA, 2015). Technical sustainable management (TSM) (Arab) is a quality management system (QMS). TSM (Arab) requirements aims at the development of water and wastewater facilities in the members countries of ACWUA to reach conformity to the Arabian regulations, codes, laws and standards in fields of management of the following activities:

- Human resources
- Occupational health and safety
- Operation
- Maintenance
- Quality assurance

ACWUA QMS questionnaire shall be considered as the survey form. The questionnaire shall be sent to all the sanitary units to gather the information. The survey questions had four options namely yes, no, I don't know and not applicable. Based on the observed responses out of ten if five or more respondents replied yes it was considered normal. On the other hand if four or less respondents replied yes, it is considered as a gap. The main objective of the survey is to assess the current management of wastewater system:

- Align existing PIs with international best practices for benchmarking by using the manual PIs for wastewater services published by IWA.
- To follow applicable PIs from the manual PIs for wastewater services published by IWA.
- To benchmark the performance of sanitation services from collection, treatment, transmission and distribution of treated effluent and compare the findings with that from the best practices in the world.

The survey was administered face to face by Ministry of Works (MOW) engineer from July 23, 2017 until August 28, 2017. The analysis was done in two steps:

- Review all the literatures, conduct workshops, group discussions and surveys
- Analyze, find gaps, identify data source, identify data owner, data accuracy, data reliability, data forms

2.2. Framework

The survey questionnaires are based on TSM requirements which aim at the improvement of water and wastewater facilities in the member countries of ACWUA. The main purpose of the survey by ACWUA is to reach conformity to the Arabian regulations, codes, laws and standards in fields of QMS. The survey questions are published by: the ACWUA under the guidance of the ACWUA task force (QMS)/(TSM-Arab) with support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH – December 2015.

The survey questionnaires are grouped by the following categories:

- Human resources
- Occupational health and safety
- Operation
- Maintenance
- Quality assurance/quality control

The targeted positions for the survey are chiefs, heads and potential senior engineers from sanitary engineering operation and maintenance directorate (SEOMD) as a pilot survey. Information requested in this questionnaire refers to activities relating to collection, treatment, transmission and distribution of treated effluent. This survey was conducted with the following four sections in the directorate with total ten respondents:

- Sewage network section
- Treatment plants section
- Treated sewage effluent section
- Quality control group

3. Results of phase 1

The results of the survey are shown in Figs. 1 to 5. Based on the survey results, the categories of identified gaps are shown in Table 1.

3.1. Phase 2: determining the PIs using the IWA manual and select the appropriate benchmark

Using IWA manual of best practice for wastewater services (Matos et al., 2012), the performance shall be evaluated using key PIs. PIs are measures of efficiency and effectiveness of the delivery of services by an undertaking that result from a combination of several variables. A PI consists of a value which is a ratio between variables expressed in specific units. PIs can be analyzed interpreted and compared by taking into consideration context information and the quality of data for each utility.

3.2. Performance indicators

PIs may be considered as providing key information needed to define the efficiency and effectiveness of the

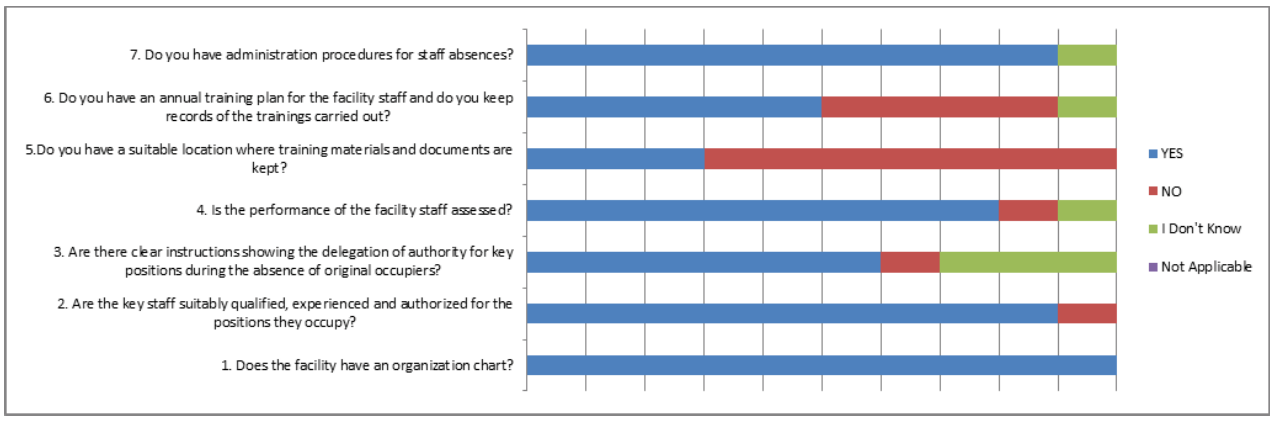

Fig. 1. Human resources.

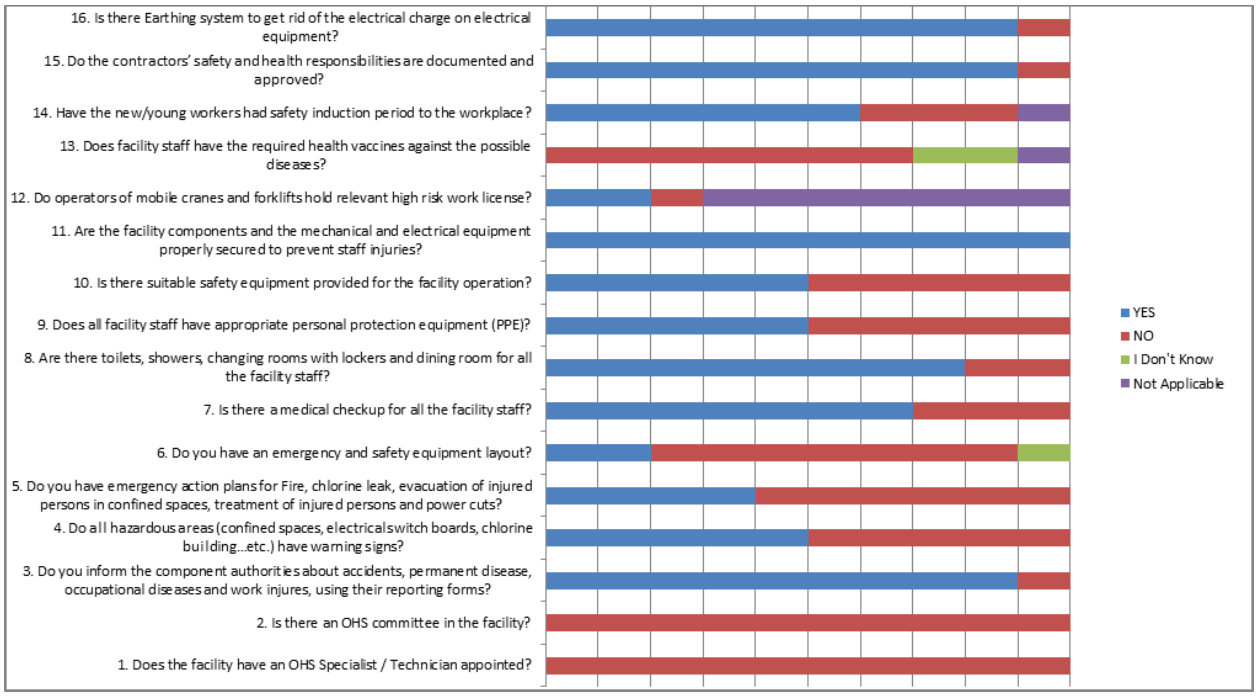

Fig. 2. Occupation health and safety.

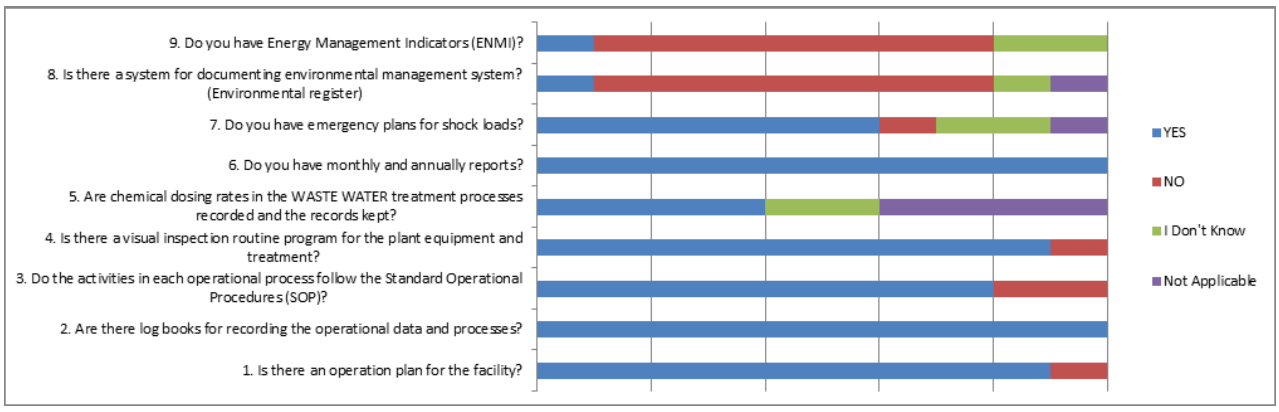

Fig. 3. Operation.

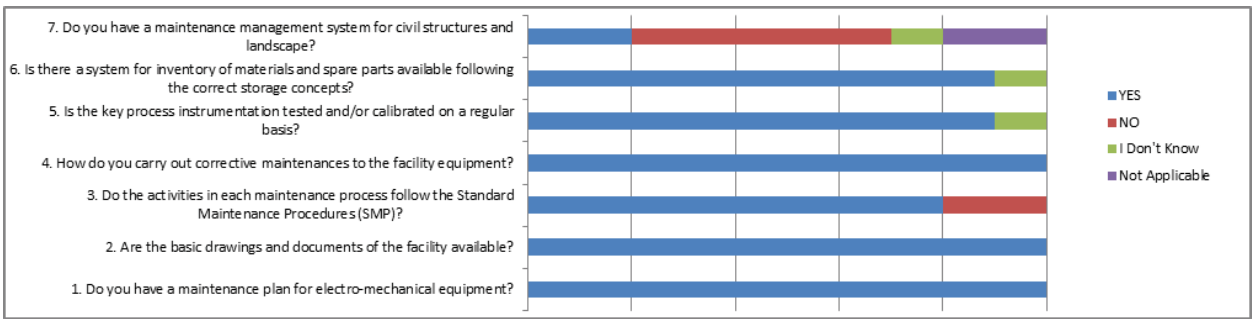

Fig. 4. Maintenance.

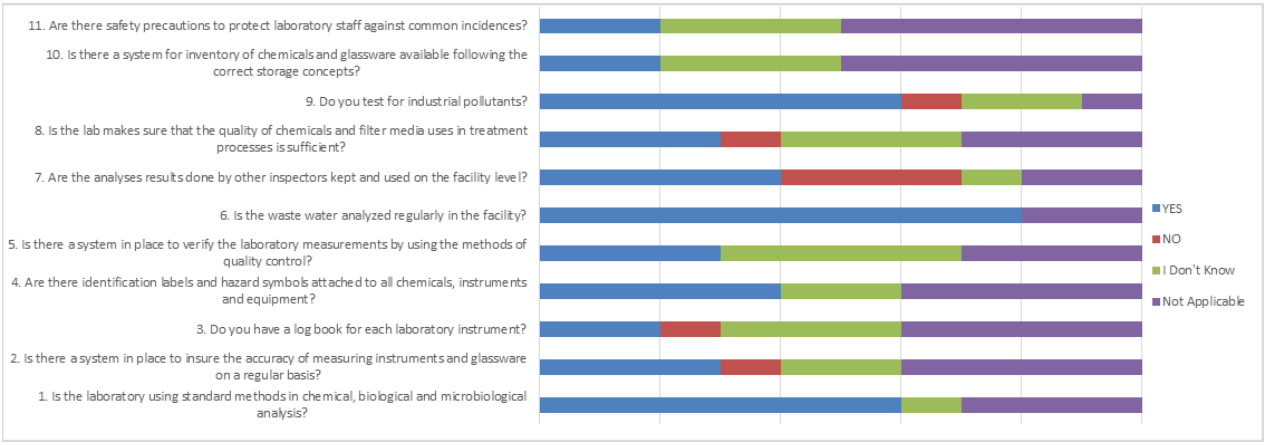

Fig. 5. Quality assurance and quality control.

delivery of services by an undertaking (Deb and Cesario, 1997). Efficiency is the extent to which the resources of an undertaking are utilized to provide the service, for example, maximizing service delivery for the minimum use of available (possibly natural) resources. Effectiveness is the extent to which declared or imposed, objectives, such as levels of service, (specifically and realistically defined) are achieved. PIs may also be considered as providing information for metric benchmarks (quantitative comparative assessment of performance) (Larsson et al., 2002). The actual comparison of performance between similar service provision is undertaken via process benchmarking (examining business processes, comparing the activities of different organizations and seeking to identify best practices). A PIs may thus be used as a quantitative (or in some cases qualitative) measure of a particular aspect of an undertaking's performance or standard of service. PIs may be used to compare performance historically, or against some pre-defined target (Matos et al., 2012). PIs are pieces of information that summarize the characteristics of a system or highlight what is happening in a system. They are often a compromise between scientific accuracy and the information available.

3.3. Benchmarking process

Benchmarking is the systematic process of searching for best practices and effective operating procedures that lead to increased performance and the adaption of these practices to improve the performance of one's own organization (Cabrera et al., 2009; Parena et al., 2002). However, despite the importance of benchmarking of the water sector in the GCC countries to evaluate performance and identify best practices, it has not been developed and adopted yet in the municipal water utility services, especially in the sanitation (wastewater) sector. Treated wastewater are considered as a promising water source and has large potential in alleviating the global water crisis, being pressured by an ever-increasing demands and reduction of freshwater resources due to pollution and depletion. Currently, the economics of wastewater management and treatment is the subject of growing interest to protect the environment from the adverse effects, and also to contribute to meeting water demands. Wastewater treatment plants (WWTPs) typically operate continually and are subject to several pressures (e.g. population changes, varying influent due to storm water, more stringent environmental regulation, and other pressures), making the implementation of resource efficiencies uniquely challenging. In this present study, wastewater collection, treatment and discharge of wastewater related to Tubli sewage treatment plant at Tubli Water Pollution Control Center were analyzed with the aim of developing some key PIs, which is used for benchmarking purposes. Performance assessment is a key area of WWTP management; a common method of conducting performance assessment is through the use of key performance indicators (Alegre et al., 2009).

Table 1
Categories of identified gaps

S. No.	Gaps	Validation
	Human resources	
1	Suitable location for training materials and documents	Confirmed
	Occupation health and safety	
2	OHS specialist/technician appointment in the facility	Confirmed
3	OHS committee in the facility	Confirmed
4	Emergency action plans for fire, chlorine leak, evacuation of injured persons in confined spaces, treatment of injured persons and power cuts	Confirmed
5	Emergency and safety equipment layout	Confirmed
6	Operators of mobile cranes and forklifts hold relevant high risk work license	Confirmed
7	Staff health vaccinations against the possible diseases	Confirmed
	Operation	
8	Chemical dosing rates in the wastewater treatment processes records	Confirmed
9	System for documenting environmental management system (environmental register)	Not confirmed
10	Energy management indicators (ENMI)	Confirmed
	Maintenance	
11	Maintenance management system for civil structures and landscape	Confirmed
	Quality assurance/quality control	
12	Accuracy of measuring instruments and glassware	Not confirmed
13	Log book for each laboratory instrument	Not confirmed
14	Identification labels and hazard symbols for all chemicals, instruments and equipment	Not confirmed
15	Verification of the laboratory measurements by using the methods of quality control	Not confirmed
16	Record of the analyses results by other inspectors	Not confirmed
17	Quality of chemicals and filter media in treatment processes	Not confirmed
18	System for inventory of chemicals and glassware available following the correct storage concepts	Confirmed
19	Safety precautions to protect laboratory staff against common incidences	Confirmed

This analysis helps improve the understanding of how individual scores of efficiency and operating variables are related. This study describes the development of a benchmark for the evaluation of control strategies in WWTPs. This study is intended to be useful to decision-makers in the wastewater treatment sector. The benchmarking methodology and empirical application developed by PIs for wastewater services published by IWA is used for improving the management of WWTPs and contribute to save operational costs. The first step is to assign relative significance levels to each PI depending upon the objective and context of the PI application by the wastewater undertaking. This should be done in consultation with the various stakeholders to:

- Comparing the processes and performance metrics to industrial best practices.
- Measurement of the quality of an organization's policies, products, programs, strategies, etc. and their comparison with standard setup.
- Quantitative comparative assessment that enables utilities to track internal performance over time and to compare this performance against that of similar utilities.

Overall objective of the benchmarking process is to trigger implementation of appropriate actions that will improve its current performance (http://www.businessdictionary.com/definition/benchmarking.html)

- To determine what and where improvements are essential
- To analyze how other organizations achieve their high performance levels
- To use this information to improve performance

This is to benchmark the performance of sanitation services from collection, treatment, transmission and distribution of treated effluent and compare the findings with that from the best practices in the world. This is also to adopt generally accepted procedures and methodologies, able to provide decision makers with an overall perception of the utility performance as a sound basis for making strategic choices from water organization bodies and the best international practices. The following international four benchmarking practices were considered to select an appropriate one for ministry approach.

3.3.1. Effective utility management (EUM) (a primer for water and wastewater utilities)

The effective utility management (EUM): a primer for water and wastewater utilities ("primer") is the foundation of EUM. It is designed to help water and wastewater utility managers make informed decisions and practical, systematic changes to achieve excellence in utility performance in the face of everyday challenges and long-term needs for the utility and the community it serves. EUM can help utilities respond to both current and future challenges and support utilities in their common mission of being successful 21st century service providers. Based on these challenges, EPA and six national water and wastewater associations signed an historic agreement in 2007 to jointly promote EUM based on the ten attributes of effectively managed water sector utilities (M. Matichich, 2014):

- Product quality
- Customer satisfaction
- Employee and leadership development
- Operational optimization
- Financial viability
- Operational resiliency
- Community sustainability
- Infrastructure stability
- Stakeholder understanding support
- Water resource adequacy

3.3.2. European benchmarking co-operation (EBC) - 2012 water and wastewater benchmark

European benchmarking co-operation (EBC's) benchmarking- and improvement program offers participants a comprehensive analysis of the performance of its utility in comparison with colleague utilities from across Europe. This "fitness check" helps participants finding improvement areas and -priorities in a structured and objective way (EBC, 2016)

3.3.3. Metric benchmarking

It is a numerical measurement of performance levels and comparison with other water undertakings to identify areas needing improvement (e.g. staffing numbers/connection, % leakage level, % supply coverage, etc.), the steps are (D. Milnes, 2006):

- Identification of those areas where there is an apparent performance gap.
- Understanding of explanatory factors, such as physical characteristics, geography, weather, population, all key to understanding the apparent performance gap, and may add to or diminish that gap, generating a real performance gap.
- All metric benchmarking data should therefore be treated with a degree of caution and not necessarily taken at face value.

3.3.4. PIs for wastewater services - IWA - operations and maintenance specialist group

The manual of best practice PIs for wastewater services provides guidelines for the establishment of a management tool for wastewater utilities based on the use of PIs. The focus is on those PIs considered to be the most relevant for the majority of wastewater utilities, to be used routinely at management level and potentially for metric benchmarking practices. Phase 2 of the study utilized the manual - PIs for wastewater services – IWA (Matos et al., 2012) to analyze and select the most appropriate benchmark due to the following reasons. The IWA PI system for water services is now recognized as a worldwide reference. Since it first appearance in 2000, the system has been widely quoted, adapted and used in a large number of projects both for internal performance assessment and metric benchmarking. Water professionals have benefited from a coherent and flexible system, with precise and detailed definitions that in many cases have become a standard. The system has proven to be adaptable and it has been used in very different contexts for diverse purposes. The PIs system can be used in any organization regardless of its size, nature (public, private, etc.) or degree of complexity and development. It contains a reviewed and consolidated version of the indicators, resulting from the real needs of water companies worldwide that were expressed during the extensive field testing of the original system. The indicators now properly cover bulk distribution and the needs of developing countries, and all definitions have been thoroughly revised. The confidence grading scheme has been simplified and the procedure to assess the results- uncertainty has been significantly enhanced. In addition to the updated contents of the original edition, a large part of the manual is now devoted to the practical application of the system. Complete with simplified step-by-step implementation procedures and case studies, the manual provides guidelines on how to adapt the IWA concepts and indicators to specific contexts and objectives.

3.4. Benchmarking approach

The data collection and benchmarking were conducted with the following four sections in the directorate with total 11 team members: sewage network section; treatment plants section; treated sewage effluent section and quality control group. To avoid any bias or spurious misinterpretation of the benchmarking results, it is strongly recommended that only those PIs based on variables with 1 year data record should be used for benchmarking performance with other undertakings. In this study, the following steps were performed to:

- benchmark the performance of sanitation services from collection, treatment, transmission and distribution of treated effluent and compare the findings with that from the best practices in the world.
- collect data and align with international best practices for benchmarking by using the manual PIs for wastewater services published by IWA.
- follow applicable PIs from the manual PIs for wastewater services published by IWA.

4. Results of phase 2

The performance shall be evaluated using PIs as per IWA. PIs are measures of efficiency and effectiveness of the

delivery of services by an undertaking that result from a combination of several variables. A PIs consists of a value which is a ratio between variables expressed in specific units. PIs can be analyzed interpreted and compared by taking into consideration context information and the quality of data for each utility. There are six categories with a total of 182 PI as per IWA manual (Matos et al., 2012):

- Environmental indicators (wEn)

  Environmental indicators evaluate the performance of the undertaking regarding environmental impacts, including the compliance with wastewater discharge standards, intermittent overflow discharges and final disposal of solid wastes (sludge, sediments and screenings). The environmental indicators include 15 PIs.
- Personal indicators (wPe)

  Personal indicators assess efficiency and effectiveness of the wastewater undertaking personal, considering functions, activities and qualifications. Matters like training, health and safety and absenteeism are also taken into account. Correct interpretation of these personal indicators entail a cross-reference to outsourcing

Table 2
Performance indicators categories

S. No	Category	Total PI	PI - data available
1	Environmental indicators	15	8
2	Personal indicators	25	1
3	Physical indicators	12	2
4	Operational indicators	56	13
5	Quality of service indicators	29	1
6	Economic and financial indicators	45	0
Total		182	25

Table 3
Performance indicators results

S. No.	PI	PI description	Unit	Result
1	wEn1	WWTP compliance with discharge consents	%/year	20.636
2[a]	wEn2	Wastewater reuse	%	29.933
3	wEn6	Sludge production WWTP	Kg DS/p.e/year	3.963
4	wEn7	Sludge utilization	%	0.000
5	wEn8	Sludge disposal	%	100.000
6	wEn9	Sludge going to landfill	%	100.000
7	wEn10	Sludge thermally processed	%	76.785
8	wEn11	Other sludge disposal	%	0.000
9	wPe12	Wastewater quality monitoring personnel	(No/(1000 tests/year))	0.228
10	wPh1	Preliminary treatment utilization	%	176.911
11	wPh3	Secondary treatment utilization	%	153.836
12[b]	wOp2	Sewer cleaning	%/year	25.261
13	wOp34	Sewer blockages	No/100 km sewer/year	249.351
14	wOp37	Flooding from sanitary sewers	No/100 km sewer/year	15.365
15	wOp44	Wastewater quality tests carried out	(-/year)	0.995
16	wOp45	BOD tests	(-/year)	0.992
17	wOp46	COD tests	(-/year)	0.980
18	wOp47	TSS tests	(-/year)	0.996
19	wOp48	Total phosphorus tests	(-/year)	0.784
20	wOp49	Nitrogen tests	(-/year)	0.988
21	wOp50	Fecal *E.coli* tests	(-/year)	0.996
22	wOp51	Other tests	(-/year)	0.999
23	wOp52	Sludge tests carried out	(-/year)	0.622
24	wOp53	Industrial discharges tests carried out	(-/year)	0.781
25*	wQS9	Tertiary treatment	%	36.697

[a]Volume of wastewater treated by undertaking -the data is for the wastewater collected from Tubli WPCC only.
[b]Measured for main lines only.

data. Employees include every person who works for the undertaking in return for a wage. The personal indicators include 25 PIs.

- Physical indicators (wPh)

  Physical indicators aim to evaluate if wastewater treatment and sewerage assets still have enough capacity (headroom) to operate correctly and safely, assuring that their service targets can be attained. The utilization of preliminary, primary, secondary and tertiary treatment is considered as well as the degree of surcharging in the sewers. Pumping capacity utilization and automation and the degree of control are also included. The physical indicators include 12 PIs.
- Operational indicators (wOp)

  In this group, PIs are intended to assess the performance of the undertaking as regards operation and maintenance activities. The areas to be assessed include sewers, ancillaries, pumps and pumping station inspection and maintenance, equipment calibration, electrical equipment inspection, energy consumption, sewer and pump rehabilitation, inflow/infiltration/exfiltration, failures, wastewater and sludge quality monitoring, vehicle availability and safety equipment. The operational indicators include 56 PIs.
- Quality of service indicators (wQS)

  Quality of service PIs measure the level of service provided to customers. Areas include level of service coverage, flooding and relations with customers, such as reply to requests, complaints, third party damage and traffic disruption caused by undertaking activities. The quality of service indicators include 29 PIs.
- Economic and financial indicators (wFi)

  Indicators in this group deal with the effectiveness and efficiency of the use of financial resources. Additionally, they provide means to interpret the business management, indicating the company financial behavior and ability to expand. Revenues, costs, composition of running costs per type of cost, per main function and per technical activity, composition of running costs per type of cost, leverage, liquidity and profitability indicators are included. The economic and financial Indicators include 45 PIs.

The team members provided the data for benchmarking regarding the PIs related to their units. In order to collect the data a simple template was sent to the team members based on the understanding and for easy approach. Some of the team members provided the data in the template form. Some team members provided the data in the available format for them.

Benchmarking procedures are useful tools to assess the performance of these facilities and help identify best practices to ensure the management of efficient facilities and improve the sustainability of these facilities and enhance their services in the present and future. With the available data for 25 PIs for the year 2017, the data for benchmarking were used. In the future, the other related data shall be recorded to benchmark all the necessary requirements as per IWA manual of best practice for PIs for wastewater services (Tables 2 and 3).

In fact, the availability of the data/information is a crucial factor in the metrics of benchmarking. In this regard, future additional data and information collection should be identified for the continuous implementation of the benchmarking system in Bahrain.

5. Conclusion

Each year, the network of participating wastewater utilities is growing further, but the goal is not to grow as large as possible. It is more important to keep individual utilities for a longer period, since performance improvement is a continuous activity. This requires that the constant development to fulfil the needs and expectations of the participants and to introduce new elements that are relevant from internal- or external perspectives. For instance, PIs are accustomed determine wherever structure performance is meeting desired standards and wherever performance needs improvement. It is to encourage meaning property, best practices and industrial benchmarking to ascertain among the waste product management community and to spot an inexpensive set of environmental, social, economic and technical indicators for waste product treatment by following IWA best practices.

This study assessed the benchmarking of the wastewater services in the Kingdom of Bahrain. Performance assessment and benchmarking has developed as a key aspect of WWTP management. Benchmarking is a data-driven process, and can only be successful if careful consideration is given to data availability and accuracy. Four teams have contributed as data owners and have provided the data. The only data readily available and accurate is that which is supplied for regulatory purposes. Without sufficient data, assessing the accuracy of the available data and identifying comparable WWTPs becomes increasingly complex. Improved data management practices can be achieved through WWTP benchmarking. Enabling the successful benchmarking in the present-day can (i) improve WWTP management practices, (ii) accelerate the improvement of data collection practices and (iii) lead the way to the inclusion of more advanced benchmarking applications in the years to come, when data availability and accuracy issues are corrected. With the available data for 25 PIs for the year 2017, the data for benchmarking were used. In the future, the other related data shall be recorded to benchmark all the necessary requirements as per IWA manual for PIs for wastewater services. The main recommendations of the study are:

- Gap analysis shall be conducted in detail for the non-confirmed gaps
- Continue with the 25 PIs measurement and to improve the performance wherever applicable
- Set action plan to collect data for remaining PIs
- Secure and archive the collected information for future use and analysis

Use of SIGMA Lite professional software by IWA developed by ITA to enter the PI data and obtain the results with the following features;

- Incorporation of the complete set of PIs from the IWA as a stand-alone PI evaluation system

- Facility to export the results to MS-Excel spread sheet for further interpretation and processing
- Easy to operate with automatic calculation of PIs

References

ACWUA, (2015), Arab Countries Water Utilities Association under the guidance of the ACWUA Task Force Quality Management Systems (QMS)/Technical Sustainable Management (TSM-Arab) with support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

GTZ/Dornier Consulting, (2008), Bahrain 2030 National Planning Development Strategies, National Master Plan for Sanitary Engineering Services (NMPSES), Kingdom of Bahrain 2008.

D. Milnes, (2006), Metric and Process Benchmarking for Utility Optimization. Retrieved from: http://www.ewa-online.eu/tl_files/_media/content/documents_pdf/Publications/E-WAter/documents/32_Pres_7_Milnes.pdf.

Deb, A., Cesario, L., (1997), Water distribution systems performance assessment. IWSA workshop on performance indicators for transmission and distribution systems, Lisbon, Portugal, Project funded by the AWWA research foundation.

European Benchmarking Co-operation, (2016), Retrieved from https://www.waterbenchmark.org/content/the-programme-explained__programme-benefits.

Larsson, M., Parena, R., Smeets, E., Troqet, I., (2002), Process benchmarking in the water industry. Manual of best practice series, IWA publishing, London, ISBN 1 84339 010 8.

Merkel, W., (2002), International report: performance assessment in the water industry, Water Science and Technology: Water Supply, 2(4): 151–162.

Matos, R., Cardoso, A., Ashley, R., Duarte, P., Molinari, A., Schulz, A., (2012), Performance indicators for wastewater services: Manual of best practice, IWA publishing, London, ISBN: 9781900222907, 192pp.

M. Matichich., (2014), Performance Benchmarking for Effectively Managed Water Utilities, Sponsored by: Water Research Foundation, 6666 West Quincy Avenue, Denver, CO 80235.