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Benchmarking Resource Efficiency in Wastewater Treatment Plants: Developing Best Practices

E. Doherty[1]*, G. McNamara[2], T. Phelan[2], M. Horrigan[2], L. Fitzsimons[2], B. Corcoran[2] and Y. Delaure[2], E. Clifford[1].

* *Department of Civil Engineering, National University of Ireland, Galway, (University Road, Newcastle, Co. Galway, Ireland)*
*** School of Mechanical and Manufacturing Engineering, Dublin City University, (Glasnevin, Dublin 9, Ireland)*

**Corresponding author, e-mail e.doherty4@nuigalway.ie*

ABSTRACT

Energy and water are inextricably linked global resources which are under stress; water is required to generate electricity, and energy is required to purify water. Wastewater treatment plants (WWTPs) are an integral part of the water resources chain. Individual plants operate continually and are subject to a number of pressures (e.g. population changes, varying influent due to storm water, more stringent requirements for WWTP managers to meet discharge limits etc.) making the implementation of resource efficiencies uniquely challenging. Implementing efficiencies in WWTPs requires robust benchmarking and key performance indicator (KPI) tools, in order to implement more effective control, and identify opportunities for improvement. In Ireland, and internationally, these challenges have long been recognised, therefore a great deal of attention is focused on developing benchmarking tools suitable for the wastewater sector.

This study presents a unique benchmarking system that enables WWTP managers and engineers isolate where and how resources are used and identify potential resource consumption mitigation measures within WWTPs. A unique and critical element of this benchmarking system is a tool (KPIAdvisor) that enables stakeholders to easily (i) assess the current level and accuracy of data collection undertaken at a WWTP; (ii) decide whether opting into a benchmarking system would be feasible based on the level of data collection on-site; (iii) identify data sources which may require corrective action prior to the adoption of a benchmarking system.

KPIAdvisor automatically informs the construction and customisation of a KPI calculation and reporting tool (KPICalc) in order to ensure its applicability in a wide variety of WWTPs. This feature ensures that KPICalc users will not be presented with modules which are irrelevant, and streamlines data entry, thus increasing the toolkit’s usability.

As part of the resource benchmarking system, KPIAdvisor enables resource efficiencies to be identified with ease, owing to the automated customisation of the benchmarking system achieved from KPIAdvisor outputs.

KEYWORDS: Key Performance Indicators; KPIs; Benchmarking; Wastewater Treatment; Energy; Water; Resource Consumption.

INTRODUCTION

Energy and water are inextricably linked resources; water is required to generate electricity and energy is required to purify water (World Economic Forum 2011). Wastewater treatment plants (WWTPs) are a challenging part of this water-energy link. Implementing efficiencies to reduce resource consumption in WWTPs requires robust benchmarking systems (Balmér & Hellström 2012). Current benchmarking systems look extensively at multiple areas of WWTPs (staffing, capital cost etc.); however these broad boundaries can act as a hindrance.

Reliable benchmarking requires standardised and accurate information on WWTP performance (Lindtner et al. 2008). However it is recognised that a key challenge in the development of KPIs utilised for benchmarking, is the identification of reliable data sources for KPI variables (Matos et al. 2003). Inaccurate data acquisition can significantly impact on the reliability of benchmarking, especially in the case of decentralised WWTPs which can commonly display limited data availability (O'Reilly et al. 2012). Resource consumption in traditional wastewater treatment systems, can vary depending on the processes utilized; however energy, chemicals and water are three main resources which have been identified as those of greatest concern (US EPA 2010; World Economic Forum 2011). Thus there is a need for benchmarking systems that focus on developing key performance indicators (KPIs) for energy, chemical and water consumption in tandem with operational performance KPIs.

This research has developed a benchmarking system, which utilises key performance indicators (KPIs) to aid in the reduction of resource consumption in WWTPs while stabilising and improving wastewater treatment performance. The benchmarking system is comprised of two toolkits named KPIAdvisor and KPICalc. KPIAdvisor, which is presented in this paper, provides a means of surveying WWTPs to (1) account for the level of available data, (2) identify available KPIs from analysing this data and more importantly, (3) highlight the confidence involved in KPI calculation due to the accuracy of the data provided. Subsequently KPICalc calculates, validates and reports KPIs to the user (Doherty et al. 2014).

Challenges with wastewater treatment plant benchmarking systems

A number of key challenges have been identified which can affect both the usability and validity of a benchmarking system (Doherty et al. 2014); KPIAdivsor has been designed to overcome these challenges.

Broad all-inclusive boundaries in terms of KPI development can act as a hindrance as they can impede on the usability of the benchmarking system. Implementing expansive lists of KPIs as part of a benchmarking scheme can initially appear justified in order to adequately encapsulate a WWTPs performance. However, previous literature has found that where possible, KPIs should be kept to a minimum to ensure a focused approach to benchmarking and also to prevent users from becoming inundated with KPI data requirements (Parmenter 2007; Peterson 2006).

Permitting the user to manually select the KPIs that can be incorporated into a benchmarking system in an undefined manner can reduce the relevance of the benchmarking system. In the instance where a WWTP manager aims to assess their own plant's performance irrespective of other WWTPs, allowing the user to select their own KPIs is acceptable due to the study's independence from a benchmarking system. However, when the objective is to benchmark WWTPs against one another, KPIs should be selected using a framework in order to ensure that WWTPs do not become alienated from a benchmarking system due to irregular selection or exclusion of individual KPIs.

Data availability and data accuracy can restrict the success of benchmarking, often in a substantial but undetected manner. The lack of data management can often be the key limiting factor for benchmarking wastewater treatment plants (Beltrán et al. 2012; O'Reilly et al. 2012). This is especially the case in both decentralised and small-scale (less than 500 Population Equivalent) WWTPs (O'Reilly et al. 2012). As a consequence of poor data management, the feasibility of a KPI/benchmarking system must be assessed prior to investing time and money in WWTP benchmarking.

These challenges were assessed during the development of KPIAdvisor; resulting in a toolkit which offers the ability to overcome these obstacles prior to the implementation of a benchmarking system in a WWTP. The entire benchmarking system is primarily focused on resource consumption in terms of energy, chemicals and water followed by an overview WWTP performance (in terms of removal capacities and effluent discharge requirements), which ensures that the number of KPIs utilised is within a manageable range. The automatic selection of KPIs based on data availability and data accuracy, which is shown in the KPIAdvisor framework accounts for the difficulty of assessing benchmarking feasibility, often affected by poor data management. KPIAdvisor overcomes the challenge of safeguarding the performance of a benchmarking system across numerous WWTPs through the implementation of a rigid and unaltered framework for the automated selection of KPIs in each WWTP.

KEY PERFORMANCE INDICATOR ADVISOR (KPIADVISOR) SYSTEM ARCHITECTURE

Overall description of the benchmarking system

The resource benchmarking system can be broken into two components; the preliminary WWTP survey toolkit, KPIAdvisor, and the KPI calculation, analysis and reporting toolkit, KPICalc. These toolkits encapsulate the entire benchmarking system and have been designed to be easy to implement. KPICalc employs up to 47 KPIs which encapsulate the plant's performance in terms of discharged effluent quality, chemical, energy and water consumption along with associated costs. These KPIs have been split into 5 separate categories; (i) wastewater/sludge volume and water consumption data, (ii) regulatory compliance, (iii) contaminant removal rates, (iv) chemical consumption and (v) energy usage for both the treatment plant and pump house. A schematic of the resource benchmarking system is shown below in Figure 1.

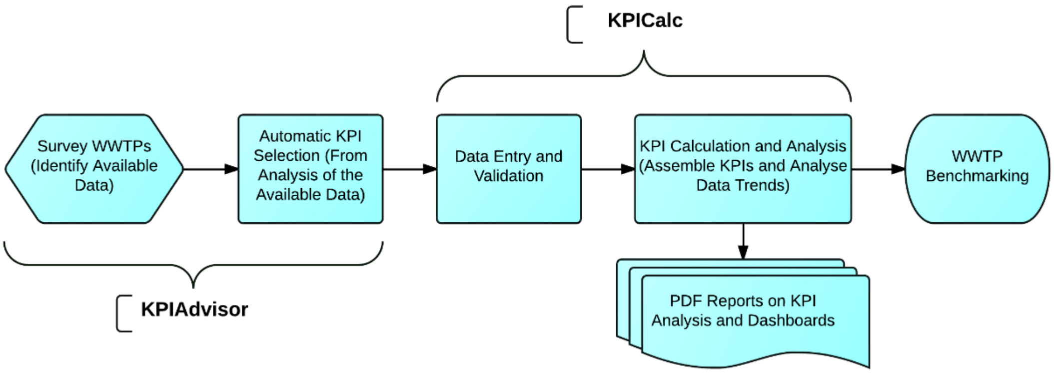


Figure 1. *A basic overview to the benchmarking and KPI system*

Overview of KPIAdvisor

The development of KPIAdvisor came about from numerous stakeholder meetings which strongly identified the need for a tool which could distinguish between KPIs which could be measured in a standardised manner, for any particular WWTP, and KPIs which could not be calculated due to the accuracy and frequency of available data. The key goals of KPIAdvisor are shown in Figure 2.

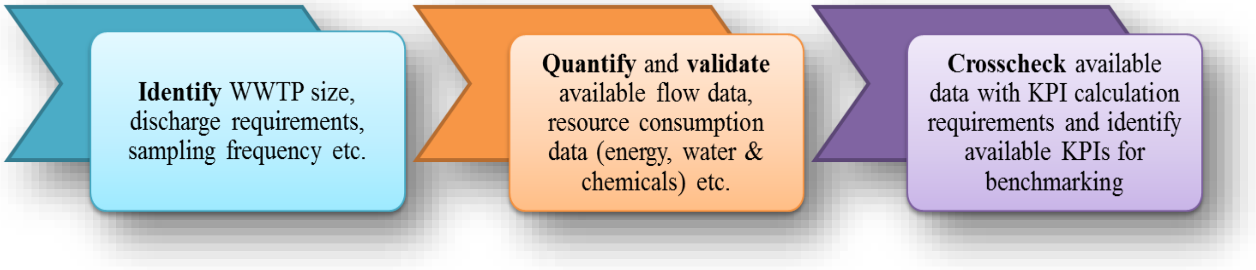


Figure 2. *Key goals of the WWTP survey tool KPIAdvisor.*

Initially the end-user (engineer, facility manager etc.) completes a short excel-based survey as part of KPIAdvisor. This survey asks users to identify data which is readily available for KPI analysis and also requests that the user rates their self-perceived accuracy of the data on a provided scale. The survey can be completed in minutes with the use of simple user inputs. Some of the key details required include:

1. Population equivalent (PE) of the WWTP;
2. Flow data availability;
3. Various treatment processes used on-site from a predefined list, with the option to add additional information if desired;
4. Enforced regulatory discharge licence requirements for effluent contaminant concentrations;
5. Chemicals used as part of the wastewater treatment process and their unit cost;
6. Energy consumption monitoring actively taking place on-site.

Once the survey is complete, KPIAdvisor then informs the end-user of KPIs that can be accurately utilised in the benchmarking system based on data availability and on-site processes and KPIs which require attention due to data inaccuracies prior to being utilised in the benchmarking system.

KPIAdvisor architecture

KPIAdvisor, is an excel-based survey toolkit that utilises common excel features in order to increase the usability of the toolkit. The toolkit is highly automated without the use of excel macros, which can increase the time required to complete the survey due to looping code delays. KPIAdvisor was designed to be both user-friendly and visually simplistic. Each automated stage in the KPIAdvisor framework is hidden from the user, presenting only the initial survey and the final outputs of KPIAdvisor to the user.

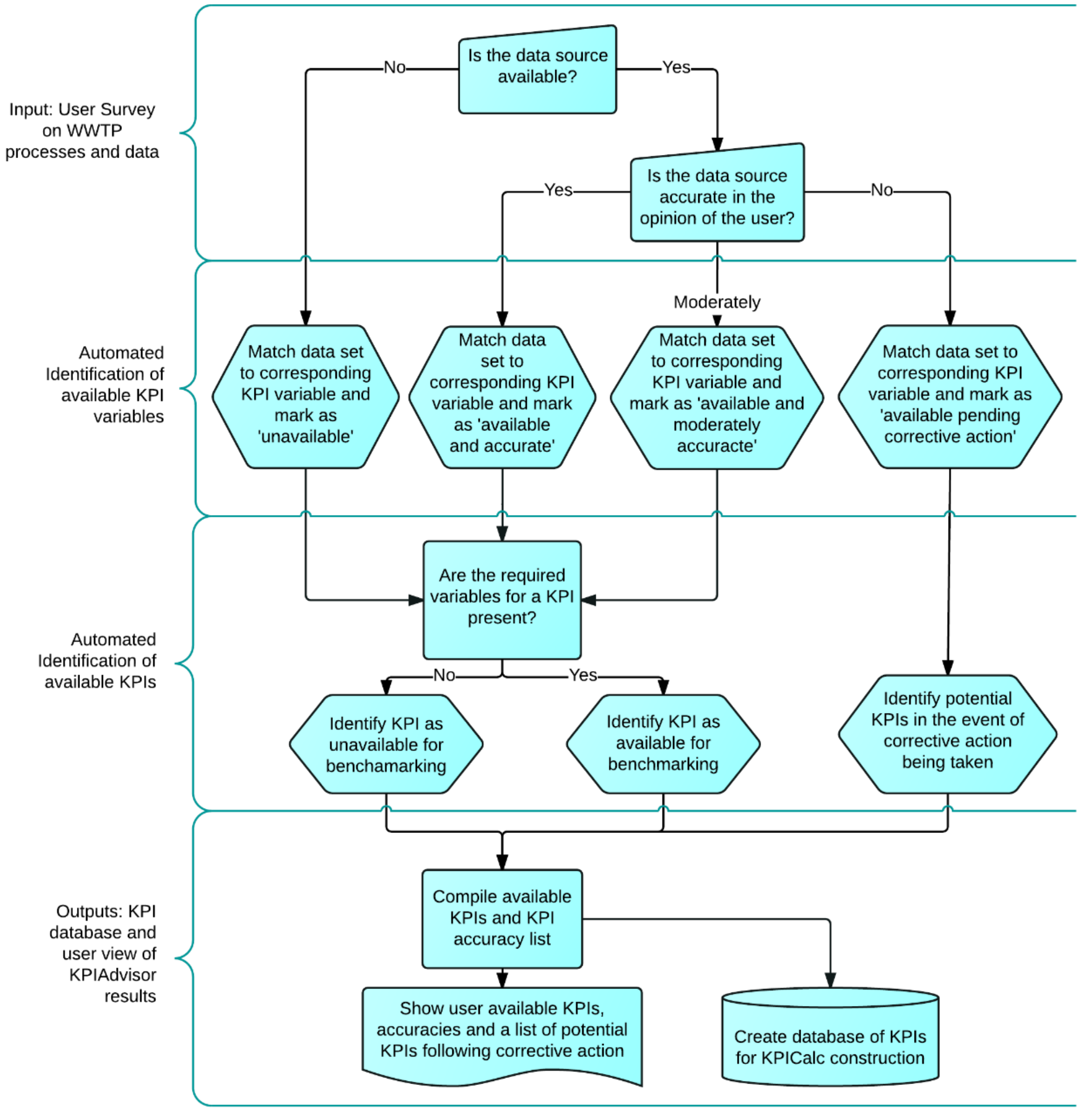


Figure 3. *KPIAdvisor framework.*

KPIAdvisor has the ability to identify KPIs that can be readily and accurately benchmarked using both the data availability outputs and data accuracy outputs of the user survey. Once the available data sets have been identified from the user survey, KPIAdvisor then prompts the user to define their self-perceived accuracy of each data set as either “accurate”, “potentially inaccurate” and “inaccurate” From this information, each data-set is linked to the matching KPI variable, which is then assigned an availability and an accuracy rating.

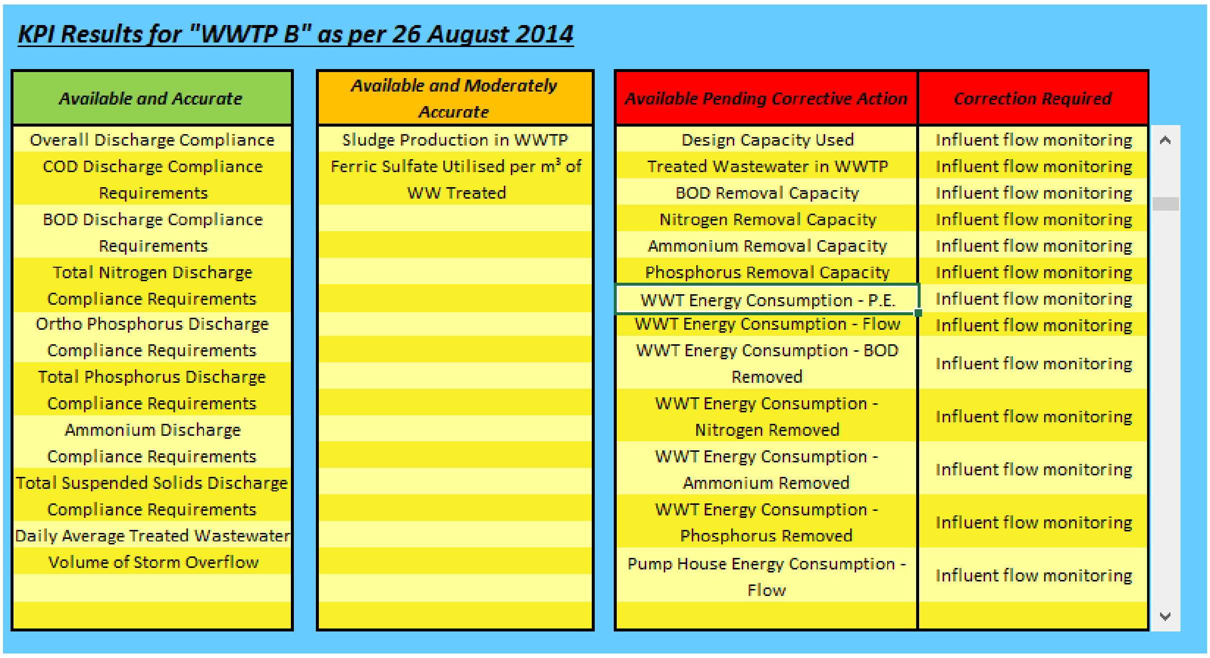
KPIAdvisor then identifies the KPIs which can be constructed from the available KPI variables and further inspects the accuracy of each variable in order to define the accuracy of each KPI. KPI accuracy is defined under three headings; “accurate” (all the required variables have been identified as accurate by the user), “moderately accurate” (the user may have identified one or more variables as potentially inaccurate) and “inaccurate” (one or more of the variables has been identified by the user as inaccurate).

Once KPI accuracy and availability has been established using KPIAdvisor’s internal processes, KPIs are ranked into 4 unique KPI groups:

i. “Available and accurate for benchmarking” (eligible for benchmarking due to the variable requirements being met);
ii. “Available and moderately accurate for benchmarking” due to moderately reliable variables;
iii. “Available for benchmarking pending corrective action” due to the identification of one or more variables as inaccurate and
iv. “Unavailable” as they provide detail on aspects of wastewater treatment which are not present in the WWTP.

KPIAdvisor outputs

The four groups of KPIs identified in KPIAdvisor are the final outputs of the toolkit. These outputs are accompanied by selected survey results which provide context on the ranking of each KPI by showing the user the variables identified as inaccurate etc. for each KPI. These outputs are presented to the user in a clear and concise manner. A sample of these outputs are shown in Figure 4.



KPI Results for "WWTP B" as per 26 August 2014

Available and Accurate	*Available and Moderately Accurate*	*Available Pending Corrective Action*	*Correction Required*
Overall Discharge Compliance	Sludge Production in WWTP	Design Capacity Used	Influent flow monitoring
COD Discharge Compliance Requirements	Ferric Sulfate Utilised per m^3 of WW Treated	Treated Wastewater in WWTP	Influent flow monitoring
BOD Discharge Compliance Requirements		BOD Removal Capacity	Influent flow monitoring
Total Nitrogen Discharge Compliance Requirements		Nitrogen Removal Capacity	Influent flow monitoring
Ortho Phosphorus Discharge Compliance Requirements		Ammonium Removal Capacity	Influent flow monitoring
Total Phosphorus Discharge Compliance Requirements		Phosphorus Removal Capacity	Influent flow monitoring
Ammonium Discharge Compliance Requirements		WWT Energy Consumption - P.E.	Influent flow monitoring
Total Suspended Solids Discharge Compliance Requirements		WWT Energy Consumption - Flow	Influent flow monitoring
Daily Average Treated Wastewater		WWT Energy Consumption - BOD Removed	Influent flow monitoring
Volume of Storm Overflow		WWT Energy Consumption - Nitrogen Removed	Influent flow monitoring
		WWT Energy Consumption - Ammonium Removed	Influent flow monitoring
		WWT Energy Consumption - Phosphorus Removed	Influent flow monitoring
		Pump House Energy Consumption - Flow	Influent flow monitoring

Figure 4. *A screenshot from testing showing the outputs of KPIAdivsor for WWTP B*

These outputs are essential for the construction of KPICalc; the KPI data collection, calculation and reporting element of the benchmarking system as shown in Figure 5. The result of implementing KPIAdvisor's findings is the presentation of a more streamlined KPICalc toolkit along with increased usability due to the removal of unnecessary modules in KPICalc such as data entry modules for variables which are inaccurate and KPI calculation modules of irrelevant KPIs.

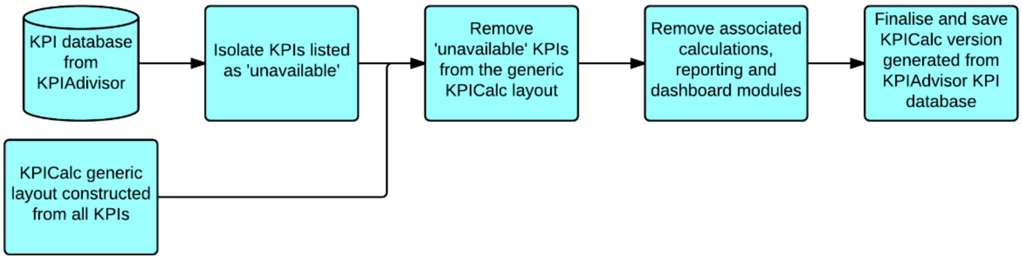


Figure 5. *KPICalc construction framework*

A key benefit of these outputs is the list of KPIs which cannot be utilised in the benchmarking system due to inaccuracies in the data available. This list incentivises users such as WWTP managers and engineers to correct any data inaccuracies prior to commencing benchmarking. In the case where data set accuracy can be improved, KPIAdvisor prompts the user to implement any corrective actions and also to correct the user-perceived accuracy in the original survey prior to proceeding with benchmarking as these actions may alter the list of available KPIs.

KEY PERFORMANCE INDICATOR ADVISOR (KPIAdvisor) TESTING

WWTPs selection for testing

In order to effectively test KPIAdvisor, a number of Irish WWTPs were selected with the purpose of incorporating the various combinations of treatment processes which WWTPs in Ireland display. This step was essential in order to certify the benchmarking system's applicability across a variety of WWTP sizes and process combinations. Key Stakeholders were involved in this selection process, including the Irish Environmental Protection Agency (EPA) government regulatory bodies and experts with a regulatory background and Irish WWTP managers. During WWTP selection, stakeholders identified a number of WWTP characteristics which are often noted to cause data availability issues, including:

- WWTP scale in terms of population equivalent (PE);
- permanent or part-time staffing levels at WWPTs;
- flow data management and flowmeter calibration;
- EPA discharge licence requirements;
- WWTPs capable of on-site sludge treatment.

With these critical characteristics in mind, a number of WWTPs were selected due to their varied characteristics in order to provide an indication of the flexibility of the benchmarking system. These WWTPs are detailed in Table 1.

Table 1. *Sample characteristics of the treatment plants selected for KPI analysis testing*

WWTP	WWTPs A and B	WWTP and C	WWTP D
Population Equivalent (PE)	20,000 – 25,000 PE	5000 PE	300 PE
Treatment Technology	Activated sludge & chemical phosphorus removal	Activated sludge	Biofilm-based batch treatment system
Plant Type	Municipal	Municipal	Municipal and research facility
Location	Centralised	Centralised	Decentralised
Operational Personnel	Manned	Manned	Unmanned
Discharge licence reporting requirements	Monthly	Fortnightly (with OFGs quarterly)	N/A
Sludge Treatment	Yes	Yes	No

Testing methods

Four WWTPs engaged in the testing of KPIAdvisor. This testing was conducted during stakeholder meetings with WWTP managers and operators. In each plant, the survey element of KPIAdvisor was populated with up-to-date information which was accompanied by user comments on various elements of this information. These additional comments aided in identifying why certain data was either unavailable or unreliable.

As part of KPIAdvisor testing, stakeholders were asked to detail how they perceived the usability of the toolkit. Feedback from this section of testing informed changes that were adopted into proceeding toolkit versions.

RESULTS

KPIAdvisor underwent testing in the WWTPs shown in Table 1. The resulting KPIs identified at each plant based on their survey data are shown in Table 2, with the complete list of KPIs and respective calculation methods shown in Appendix A. KPIs identified as “available” are marked as a ‘tick’. Accompanying each KPI availability, a rating is displayed which shows the user how reliable each KPI is based on the user-perceived accuracy of the data detailed during the survey. The accuracy rating of each KPI, is portrayed using a traffic light system with green markers identifying KPIs calculated from accurate and reliable data sources, orange markers showing KPIs which may present slight discrepancies due to data accuracy issues and red markers which identify KPIs which cannot be calculated due to unreliable data sources.

Table 2. *Sumarised outputs from KPIAdisor when applied to each WWTP*

Key Performance Indicator	**Units**	**WWTP A**	**WWTP B**	**WWTP C**	**WWTP D**
		Available	**Available**	**Available**	**Available**
Average Daily Treated Wastewater	*m^3/day*	🟩 ✓	🟩 ✓	🟩 ✓	🟧 ✓
Design Capacity Utilised	*%*	🟩 ✓	🟥 ✓	🟩 ✓	🟧 ✓
Treated Wastewater in WWTP	*%*	🟩 ✓	🟥 ✓	🟩 ✓	
Volume of Storm Overflow	*%*	🟩 ✓	🟩 ✓	🟧 ✓	🟧 ✓
Sludge Production in WWTP	*Kg/m^3*	🟧 ✓	🟧 ✓	🟧 ✓	
Overall Compliance with Discharge Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	▨
COD Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	
BOD Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	▨
Ammonium Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	
Total Nitrogen Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	▨
Orthophosphate Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	
Total Phosphorus Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	▨
Total Suspended Solids Discharge Compliance Requirements	*%*	🟩 ✓	🟩 ✓	🟩 ✓	
Oil, Fats and Grease Discharge Compliance Requirements	*%*			🟩 ✓	▨
BOD Removal Capacity	*%*	🟩 ✓	🟥 ✓	🟩 ✓	
Nitrogen Removal Capacity	*%*	🟩 ✓	🟥 ✓	🟩 ✓	▨
Phosphorus Removal Capacity	*%*	🟩 ✓	🟥 ✓		
Mains Water Volume Consumed	*Litres/m^3*	🟩 ✓	🟥 ✓	🟩 ✓	🟩 ✓
Wastewater Reuse	*%*			🟩 ✓	
Ferric Sulfate Utilised	*Kg/m^3*	🟧 ✓	🟧 ✓	▨	▨
WWTP Energy Consumption per PE	*kWh/PE/ year*	🟩 ✓	🟥 ✓	🟧 ✓	🟧 ✓
WWTP Energy Consumption per Unit Flow	*kWh/m^3*	🟩 ✓	🟥 ✓	🟧 ✓	🟧 ✓
WWTP Energy Consumption per Unit BOD Removed	*kWh/kg BOD*	🟩 ✓	🟥 ✓	🟧 ✓	
WWTP Energy Consumption per Unit Nitrogen Removed	*kWh/kg N*	🟩 ✓	🟥 ✓	🟧 ✓	▨
WWTP Energy Consumption per Unit Ammonium Removed	*kWh/kg A*	🟩 ✓	🟥 ✓	🟧 ✓	
WWTP Energy Consumption per Unit Phosphorus Removed	*kWh/kg P*	🟩 ✓	🟥 ✓	🟧 ✓	▨
Pump House Energy Consumption per Unit Flow	*kWh/m^3*	🟩 ✓	🟥 ✓	🟧 ✓	🟧 ✓

DISCUSSION

The available KPIs shown above in Table 2, vary substantially between WWTPs. From these variances, a number of deductions can be made.

Wastewater Treatment Plant A, which during testing was noted to operate a highly effective data acquisition system, displayed the greatest level of KPI availability, with 24 of the 25 identified KPIs capable of being implemented into a benchmarking strategy. This result was not surprising due to the high level data acquisition in this permanently staffed WWTP. In terms of energy consumption KPIs, each KPI in the outline benchmarking system was available for benchmarking and was considered highly reliable. This is in contrast to WWTPs B, C and D due to the high level of energy data available from the WWTP's supervisory control and data acquisition system (SCADA). The remaining test WWTPs do not offer the same data availability and must rely on retrieving energy consumption data from their energy provider. In the case of WWTPs C and D, the reliance on retrieving energy consumption from an external source leaves the reliability of the data as 'moderately accurate' as indicated by the orange markers in Table 2.

A key finding from this study, although partially removed from the concept of benchmarking, is the poor flow data accuracy which is the case in many Irish WWTPs. Preliminary investigations coupled with the additional comments given by stakeholders in this study, have identified one significant contributing factor for these inaccuracies. Every Irish WWTP with a PE of greater than 500 persons is legally obliged to adhere to a discharge licence set out by the EPA. These licences often state that flow monitoring must be conducted continuously/daily in any WWTP. However, the data acquired from this monitoring regime is generally only required in order to report on an annual basis, the remaining organic and hydraulic treatment capacities within the WWTP. A limited annual assessment, displayed in units of PE/day and m^3 of influent/year may only be required for regulatory purposes, thus more frequent monitoring is not carried out.

Due to the high dependency that many KPIs have on the availability of accurate flow data, the overall KPI list can quickly be diminished when flow data is identified as an inaccurate data source. This can be clearly seen in WWTP B, where additional comments from the testing stage identified that influent flow monitoring data was completely unreliable due to the flowmeters incorrect position on the incoming wastewater stream, a fact also stated in the Annual Environmental Report (AER) for 2014 for WWTP B. Thus 13 of the 25 identified KPIs could not be reliably utilised in this WWTP without corrective action on influent monitoring.

In decentralised and unmanned WWTPs with a PE of less than 500, as is the case for WWTP D, it can be difficult to obtain any data sets such as effluent quality and energy consumption due to (i) the lack of a legal requirement for this data to be collected and (ii) the unmanned nature of the treatment plant. As a result, many decentralised WWTPs may be incapable of implementing a benchmarking system. This inadequacy in a decentralised WWTP may be resolved by conducting a brief but intensive monitoring period where data is collected on a weekly, daily or even hourly basis for the purpose of benchmarking.

In all four of the WWTPs which took part in this study, achieving accurate chemical consumption data can also be complicated. Many WWTPs record their chemical consumption by keeping a record of the amount of chemicals delivered to the WWTP and the associated date. However, these deliveries may be on a monthly or even quarterly basis depending on the chemical holding capacity present on-site, which leaves the data both sporadic and unworkable when aiming to identify periods of large chemical consumption, as is often the goal in resource benchmarking.

CONCLUSIONS

There is a need for best management practices for WWTP benchmarking to focus on the identification of WWTPs capable of conducting accurate and detailed KPI analysis. The survey toolkit, developed in this research as part of benchmarking system development, offers a viable solution to this problem in a concise and effective manner. Assessing available data, along with its validity, is key to effective benchmarking as nothing can be gained from benchmarking with, or against, incorrect data.

Accurate flow data along with regular compliance monitoring is a key requirement for any benchmarking scheme which aims to detail either operational performance or resource consumption in WWTPs. To accompany these data sets, high resolution energy and chemical consumption data further increases the ability for a WWTP to achieve successful benchmarking.

The novel KPI identification toolkit, KPIAdvisor, as part of the overall resource benchmarking system (KPIAdvisor and KPICalc) developed in this research is:

1. Easily accessible, highly automated, and suitable for implementation in WWTPs of varying treatment processes, population equivalent, staffing numbers and resource consumption;

2. Adept at assisting stakeholders in the identification of faults in data acquisition methods in WWTPs prior to the initiation of WWTP resource consumption benchmarking. This feature can save WWTP managers and operators from spending time implementing a benchmarking system which is destined to fail due to poor data reliability;

3. Designed to offer toolkit users an incentive for improving data acquisition methods by displaying any additional KPIs to the user which could be adopted in their WWTP, provided that the respective data source inaccuracies were corrected.

Future work on KPIAdvisor aims to create a more robust and easily accessible tool. Proposed works include:

- Wider testing of both KPIAdvisor and KPICalc in various WWTPs in order to isolate any discrepancies in both the methodology and outputs of resource benchmarking and to correct these issues in future toolkit versions;

- Redesigning the excel-based toolkit into a software version using Python as the preferred programming language in conjunction with PostgreSQL. This software version, which will include both KPIAdvisor and KPICalc, will offer online access to benchmarking results from both the WWTP in question and similar/nearby WWTPS. These benchmarking results will be displayed in both a numerical and graphical format using Geographical Information Systems.

KPIAdvisor, when used in tandem with KPICalc, offers WWTPs a large incentive to opt into benchmarking schemes, which will assist in reducing currently excessive global energy and water demand. KPIAdvisor offers a key development in terms of identifying best practices in resource consumption benchmarking in WWTPs through the user-friendly features and developments which it offers in any wastewater treatment plant configuration.

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APPENDIX A: KEY PERFORMANCE INDICATORS UTILISED IN KPIAdvisor AND KPICalc

GROUP	KEY PERFORMANCE INDICATOR	UNITS	CALCULATION
FLOW	**Design Capacity Utilised**	%	*(Volume of influent wastewater / (Design Capacity of WWTP x 0.15))x100*
	Treated Wastewater in WWTP	%	*(Volume of wastewater treated / volume of influent wastewater) x 100*
	Volume of Storm Overflow	%	*(Volume of storm overflow / volume of influent wastewater) x 100*
	Sludge Production in WWTP	*Kg/m³*	*Volume of sludge produced on-site / volume of wastewater treated*
REGULATORY COMPLIANCE	**Overall Compliance with Discharge Requirements**	%	*(Total number of tests meeting discharge requirements / Total number of tests carried out) x 100*
	COD Discharge Compliance Requirements	%	*(Number of COD tests meeting discharge requirements / Number of COD tests carried out) x 100*
	BOD Discharge Compliance Requirements	%	*(Number of BOD tests meeting discharge requirements / Number of BOD tests carried out) x 100*
	Ammonium Discharge Compliance Requirements	%	*(Number of Ammonium tests meeting discharge requirements / Number of Ammonium tests carried out) x 100*

GROUP	KEY PERFORMANCE INDICATOR	UNITS	CALCULATION
REGULATORY COMPLIANCE	**Orthophosphate Discharge Compliance Requirements**	%	*(Number of Orthophosphate tests meeting discharge requirements / Number of Orthophosphate tests carried out) x 100*
	Total Phosphorus Discharge Compliance Requirements	%	*(Number of Total Phosphorus tests meeting discharge requirements / Number of Total Phosphorus tests carried out) x 100*
	Total Suspended Solids Discharge Compliance Requirements	%	*(Number of Total Suspended Solids tests meeting discharge requirements / Number of Total Suspended Solids tests carried out) x 100*
	Oil, Fats and Grease Discharge Compliance Requirements	%	*(Number of Oil, Fats and Grease tests meeting discharge requirements / Number of Oil, Fats and Grease tests carried out) x 100*
	Detergents Discharge Compliance Requirements	%	*(Number of Detergents tests meeting discharge requirements / Number of Detergents tests carried out) x 100*
	Sulphates Discharge Compliance Requirements	%	*(Number of Sulphates tests meeting discharge requirements / Number of Sulphates tests carried out) x 100*
	Chlorides Discharge Compliance Requirements	%	*(Number of Chlorides tests meeting discharge requirements / Number of Chlorides tests carried out) x 100*
	Metals Discharge Compliance Requirements	%	*(Number of Metals tests meeting discharge requirements / Number of Metals tests carried out) x 100*

GROUP	KEY PERFORMANCE INDICATOR	UNITS	CALCULATION
REMOVAL CAPACITY	**BOD Removal Capacity**	*%*	*((Weight of BOD present per unit of influent wastewater x volume of influent wastewater) / (weight of BOD present per unit of effluent wastewater x volume of effluent wastewater)) x 100*
	Nitrogen Removal Capacity	*%*	*((Weight of Total Nitrogen present per unit of influent wastewater x volume of influent wastewater) / (weight of Total Nitrogen present per unit of effluent wastewater x volume of effluent wastewater)) x 100*
	Ammonium Removal Capacity	*%*	*((Weight of Ammonium present per unit of influent wastewater x volume of influent wastewater) / (weight of Ammonium present per unit of effluent wastewater x volume of effluent wastewater)) x 100*
	Phosphorus Removal Capacity	*%*	*((Weight of Total Phosphorus present per unit of influent wastewater x volume of influent wastewater) / (weight of Total Phosphorus present per unit of effluent wastewater x volume of effluent wastewater)) x 100*
WATER CONSUMPTION	**Mains Water Volume Consumed**	*Litres/m³*	*Volume of mains water consumed on-site / volume of wastewater treated*
	Mains Water Cost	*€/ m³*	*Cost of mains water consumed on-site / volume of wastewater treated*
	Wastewater Reuse	*%*	*(Volume of mains water consumed / volume of wastewater treated) x 100*

GROUP	KEY PERFORMANCE INDICATOR	UNITS	CALCULATION
CHEMICAL CONSUMPTION	**Calcium Carbonate Utilised**	*Kg/m³*	*Weight calcium carbonate of utilised / volume of wastewater treated*
	Calcium Hydroxide Utilised	*Kg/m³*	*Weight of calcium hydroxide utilised / volume of wastewater treated*
	Calcium Oxide Utilised	*Kg/m³*	*Weight of calcium oxide utilised / volume of wastewater treated*
	Sodium Bicarbonate Utilised	*Kg/m³*	*Weight of sodium bicarbonate utilised / volume of wastewater treated*
	Sodium Carbonate (Soda Ash) Utilised	*Kg/m³*	*Weight of sodium carbonate (soda ash) utilised / volume of wastewater treated*
	Sodium Hydroxide (Caustic Soda) Utilised	*Kg/m³*	*Weight of sodium hydroxide (caustic soda) utilised / volume of wastewater treated*
	Alum Al(III) Utilised	*Kg/m³*	*Weight of alum Al(III) utilised / volume of wastewater treated*
	Iron Fe(III) Utilised	*Kg/m³*	*Weight of iron Fe(III) utilised / volume of wastewater treated*
	Ferric Chloride Utilised	*Kg/m³*	*Weight of ferric chloride utilised / volume of wastewater treated*
	Aluminium Chloride Utilised	*Kg/m³*	*Weight of aluminium chloride utilised / volume of wastewater treated*
	Polyaluminium Chloride Utilised	*Kg/m³*	*Weight of polyaluminium chloride utilised / volume of wastewater treated*
	Polyiron Chloride Utilised	*Kg/m³*	*Weight of polyiron chloride utilised / volume of wastewater treated*
	Alum Sulfate Utilised	*Kg/m³*	*Weight of alum sulfate utilised / volume of wastewater treated*
	Ferric Sulfate Utilised	*Kg/m³*	*Weight of ferric sulfate utilised / volume of wastewater treated*

GROUP	KEY PERFORMANCE INDICATOR	UNITS	CALCULATION
ENERGY CONSUMPTION	**WWTP Energy Consumption per PE**	*kWh/PE/ year*	*(Energy consumed in both WWTP and pump house / (Volume of effluent wastewater / 0.15))*365*
	WWTP Energy Consumption per Unit Flow	*kWh/m³*	*(Energy consumed in both WWTP and pump house / volume of effluent wastewater)*
	WWTP Energy Consumption per Unit BOD Removed	*kWh/kg BOD*	*(Energy consumed in both WWTP and pump house /*
	WWTP Energy Consumption per Unit Nitrogen Removed	*kWh/kg N*	*(Energy consumed in both WWTP and pump house /*
	WWTP Energy Consumption per Unit Ammonium Removed	*kWh/kg A*	*(Energy consumed in both WWTP and pump house /*
	WWTP Energy Consumption per Unit Phosphorus Removed	*kWh/kg P*	*(Energy consumed in both WWTP and pump house /*
	Pump House Energy Consumption per Unit Flow	*kWh/m³*	*(Energy consumed in pump house / volume of influent wastewater)*