Environment, Development and Sustainability (2021) 23:2243–2260
https://doi.org/10.1007/s10668-020-00672-7

Improving water pricing decisions through material flow cost accounting model: a case study of the Politsi Water Treatment Scheme in South Africa

Michael Bamidele Fakoya[1] · Emmanuel O. Imuezerua[2]

Received: 11 May 2019 / Accepted: 5 March 2020 / Published online: 12 March 2020

Abstract
The challenge of water pricing by water treatment schemes is related to the inability of the traditional cost accounting method to provide enough water purification-related cost information to assist water scheme managers in making informed water management decisions. We adopted the material flow cost accounting (MFCA) model to capture water purification-related costs in highlighting inefficiencies in the water purification process and to adequately align other systems' cost to the cost of water loss for effective water management decisions. We conducted a case study of the Politsi Water Treatment Scheme (PWTS) in South Africa to assist the management in making informed water management decisions by revealing inefficient processes, water loss volume and corresponding costs. Findings reveal that the water scheme is operating at a loss because of high water purification overhead costs. Furthermore, we found that the current input–output measurement approach used at PWTS is substantially inefficient in capturing water loss and water-related costs during purification. We recommend that the adoption of the MFCA model by Politsi should not be intended as a one-off project but should be gradually integrated into the existing system to realise consistent improvement in determining the volume of water loss and its related costs information for effective decision-making.

Keywords Water treatment · MFCA model · Water management accounting · Water loss · Contingency theory

1 Introduction

The United Nations Sustainable Development Goal (UNSDG) goal number 6 seeks to achieve a universal and equitable target of safe and affordable water for all people by 2030. The UNSDG targets significantly increased efficiency in water use through sustainable withdrawals and supply of freshwater. Moreover, the UNSDG in addressing water scarcity

✉ Michael Bamidele Fakoya
michael.fakoya@ul.ac.za

[1] ACSAM, School of Accountancy, University of Limpopo, Mankweng, South Africa

[2] Department of Accounting, Vaal University of Technology, Vanderbijlpark, South Africa

seeks to reduce the number of households suffering from water scarcity substantially. Indeed, water scarcity is increasingly a critical issue around the world (Challenges Program on Water and Food, 2005:52; Sulser et al. 2010:276). However, achieving sustainable and affordable water for all people requires considerable investment. Added to which, the burgeoning population, economic growth and climate change issues are all putting pressure on water supply and water resources, forcing different countries to revisit and assess how water resources are managed (Singh et al. 2009:3655). The pressure on countries to provide affordable water to poor households is a burden borne by publicly funded water utilities. These utilities require investments to improve and expand the existing facilities (Nagpal et al. 2019). However, most water utilities are unable to recover both operational and maintenance costs. The inability to cover these costs is exacerbated by the limited capacity of these water utilities to increase water tariffs. While water pricing and tariff mechanisms are crucial to improving water provision and supply (Pinto et al. 2018), there is a need to adopt a more integrated water management system that promotes process efficiency seeing that water utilities have limited capacity to increase water tariff. Compounding the challenge to safe and affordable drinking water other than process inefficiency is cost-recovery, availability and affordability.

Hence, we used the MFCA model to capture and analyse water-related costs in the Politsi Water Treatment Scheme (PWTS) in the Limpopo Province of South Africa to examine the existing approach in determining water pricing decisions. Whereas attempts by water utilities in South Africa to improve the water supply system have been technologically driven (Morrison and Schulte 2010:9), we, nonetheless, believe that adopting a management accounting tool to capture water-related processing costs will adequately assist in improving inefficiencies in water processing and promote appropriate pricing decisions. This study seeks to highlight the inadequacies of relying on the conventional input–output approach in determining water processing costs and pricing decisions. Hence, the significance of this study is the demonstration of an integrated approach of adopting the MFCA model with existing input–output water accounting techniques in capturing water cost-related costs to enable appropriate water pricing decisions in water utilities.

2 Theoretical framework

We acknowledged that there is no universal approach to solving organisational challenges; and so, we adopted the contingency approach to management as the appropriate framework in this study. In the process of organising and controlling activities in an organisation, there is no single way of doing it, but instead performance is dependent on the situations within the organisation and its external environment (Waterhouse and Tiessen 1978:66; Fakoya 2014:20). Likewise, the contingency approach to management proposes that an accounting information system should be planned flexibly to consider environmental issues as part of an organisation's strategy (Riahi-Belkaoui 2002:140). Intrinsically, we believe that the adoption of a management accounting information system needs to adjust precisely to assist an organisation in improving its decision-making process. By relying on the contingency approach to management, we seek to identify specific water-related processing costs not captured by an existing management accounting system that could be linked with a specifically designed costing framework. This is to make areas of inefficiency visible and transparent to appropriately match an organisation's environmental impact and resource utilisation of physical and monetary data for improved decisions.

3 Traditional water accounting

The traditional water accounting approach tracks water inflows and outflows over a period (Vardon et al. 2006:651). As such, water accounting is the identification, quantification and reporting of information of water flow within a system and is the first step in formulating productive and sustainable water management strategies in any nation (Godfrey and Chalmers 2012). In countries like Australia, China and India, there have been studies on water accounting (Chalmers et al. 2012:1002; Meng et al. 2014:7). Nonetheless, a White Paper was issued and promulgated into the South African National Water Act in 1998 to signal the shift in the country's water resource management (Republic of South Africa 1998). Water scarcity is prevalent in South Africa, and this situation makes it expedient for an improved water management framework and policy formulation (National Water Resource Strategy 2011:90). Moreover, Van der Zaag et al. (2010) reasoned that the capturing and management of water-related cost needs to be improved through the application of an appropriate water management costing system for better per capita water accessibility. As such, the South African government recognises effective and efficient water resources management as part of government's function through reforms and regulations (Schreiner and Hassan 2011:87).

Developing an accounting framework to measure the use and production of water resources (Molden and Sakthivadivel 1999) will help in determining appropriate water pricing. Consequently, the adoption of an internal information system aimed at capturing all cost elements associated with the water purification process, and water losses will likely ensure adequate water measurement and improve water management efficiency for valid pricing. Accordingly, the identification and capturing of water processing-related cost data and information are critical aspects of water management (Karimi and Bastiaanssen 2015).

4 Water management accounting

Water provisioning challenges around the world are increasing (IWMI 2010) because of population growth and limited water sources, and there is a need to manage water sources efficiently (Molden 1997). Despite these challenges, useful information for water pricing decisions is declining. Subsequently, resolving water challenges requires information from multidisciplinary perspectives (Molden 1997). Owing to the inability of the current water input–output approach to adequately capture water-related costs and losses, we reasoned that the integration of the MFCA model with the existing accounting information system in water utilities is required to assist water utility managers in arriving at appropriate water pricing decisions. Hence, we reasoned that the provisioning of water purification process information must be coherent to provide an integrated representation useful for assessing and resolving water-related challenges. Therefore, water management accounting (WMA) is more than just an environmental management approach (Christ and Burritt 2014); instead, it is also good management. WMA is the classifying, measuring and recording of water flow information in a system to increase or maximise an existing supply (Burritt and Christ 2015).

In this study, WMA is the use of management accounting principles to improve water purification processing decisions. Over the years, there has been an increased call for information linked to water-related cost activities to be integrated into the existing management approach (Ridoutt et al. 2009). In South Africa, the existing cost accounting system used by the water utilities has been ineffective in capturing water loss and all other water-related costs in the water purification process (DWAF 2011). Hence, from a management accounting perspective, adequate capturing of water purification process costs could result in appropriate water pricing decisions. The inadequacy of existing cost accounting systems in organisations meant to support sound decision-making was alluded to by Kotzee (2016).

In water utilities, the water purification processes' end-product and subsequent pricing is an activity requiring every single material or chemical component used in its purification to be priced adequately. Therefore, to completely capture all water-related costs and leakages during the purification process, which the current accounting system overlooks, it is vital for an appropriate management accounting system (MAS) to be adopted (Kotzee 2016). The significance of capturing and matching all water-related costs during water purification processes cannot be overemphasised. This is essential since it will assist water scheme managers in determining the actual cost of water processing, thereby resulting in efficient water pricing.

5 Management accounting information systems

Prior ways of resolving organisational challenges may become ineffective for the current business environment, which is continuously evolving (Neizvestnaya and Antonova 2015). Thus, management accounting continually seeks new information to impact and improve decision-making to turn challenges and opportunities into profit (Chapman and Kihn 2009). The management accounting function provides a system for interpreting accounting data for improved decision-making. Management accounting assists management in decision-making by providing accurate information about an organisation's activity. According to Ramagopal (2009), the management accounting function provides cost information for planning, decision-making, performance evaluation, control, management of costs and cost determination. Intrinsically, an appropriate MAS capable of providing accurate information is required in assisting managers in making an informed decision on the efficient utilisation of resources for profitability (CIMA 2015; CFMS 2014). Given this, it is plausible that adopting an appropriate MAS will enhance effective capturing of water processing costs for appropriate water pricing decision among South Africa's water utilities.

6 Environmental management accounting (EMA)

EMA helps to identify, collect, estimate, analyse physical and environmental cost and related monetary information to make environmentally related decision-making in organisations (UNDSD 2001; Qian et al. 2011). Schaltegger et al. (2010) state that EMA is a concept of accounting that uses accounting tools and practices to assist organisations in internal management decision-making on environmental issues. Furthermore, EMA is a corporate environmental management approach involving the application of accounting tools to assist managers in decision-making (Schaltegger et al. 2011). EMA is a tool for adapting physical and economic measures of environmental data into information for decision-making to improve environmental performance (Bennett et al. 2013). EMA tools include life cycle costing, full cost accounting, benefits assessment, strategic planning and MFCA for environmental management (Savage and Jasch 2005).

Additionally, EMA is measured both in physical and monetary terms (UNDSD 2001). However, Jasch (2003) speculates that when the organisation fails to identify and account for the environmental impacts of their activities, they risk losing opportunities for improved economic (through cost-saving opportunities) and environmental performance. Therefore, the adoption of an appropriate EMA tool such as the MFCA model in an organisation makes the generation of high-quality information (monetary and non-monetary data) possible to aid decision-making.

7 Material flow cost accounting (MFCA)

MFCA continues to attract attention as an EMA support tool for identifying the environmental impact of corporate waste generation (Nakajima 2003). As a decision-making tool, MFCA provides executives and managers with information on impact and cost-reduction opportunities for the environmental impact from operations (METI 2007). MFCA focuses on tracking and capturing waste and nonsalable products during production for cost-savings opportunities to be identified. The identification of cost-saving opportunities through MFCA assists in improving organisations' productivity by classifying production output into good (saleable) and negative (nonsalable) products (Schaltegger et al. 2008). It is imperative to note that MFCA indicates the limit of waste an organisation can reduce by making material losses visible (Nakajima 2010). Information on material loss (in the case of this study, water loss) is useful for waste (water loss) reduction decisions. The availability of process waste information will assist managers in the waste reduction for appropriate pricing decisions.

8 Applying MFCA for process improvement

Organisations often seek ways to reduce their environmental impact and improve waste discharge during production through capturing of waste information. Waste management is a measure that supports the effective use of resources (Geng et al. 2007:146; Fakoya 2014). Recycling of used materials as input for new products often includes the amount spent on the material resource to waste generation (Smith and Ball 2012). However, in promoting waste management through recycling, organisations will incur a higher energy and other systems cost. As such, waste reduction may seem a reasonable option since it avoids such expenses when recycling. Over the years, production process improvements focus on lead time reduction, waste and whatever may increase productivity without conscious analysis of the monetary component, thereby making it difficult for managers to understand any constructive improvement to the status quo (Kasemset et al. 2013). Essentially, the adoption of MFCA in an organisation will assist in capturing material and energy flows, thereby revealing an area of inefficiency in the production processes both in physical and monetary terms (Jasch 2003). This is because MFCA ascertains the quantities and costs of materials, processing and waste treatment so that decision-makers can have a look at the source of waste generated with a visible view of impending challenges, which then leads to the reduction in waste generation itself (METI 2007). Consequently, the adoption of the MFCA framework in a water utility would assist water scheme managers to capture water purification costs accurately so that areas of inefficiency can be reduced allowing scheme managers to determine appropriate water pricing decisions.

9 Method

The methodological approach of this study was the mixed method. We applied the action research approach because we intended to assist in improving the existing approach in capturing water processing information at the Politsi Water Treatment Scheme (PWTS). Hence, we adopted the case study research design to generate an in-depth and multifaceted understanding of the complex real-life issues associated with water purification and pricing decisions. The case study of the Politsi Water Treatment Scheme (PWTS) aided us in understanding the challenges of the existing accounting system and in recommending any improvement plan for appropriate water pricing decisions. We approached the water utility company—the Lepelle Northern Water (LNW) that manages the PWTS for permission to use its facility for the study. Written approval was given to the researchers by LNW through its legal office. We conducted in-depth interviews with relevant officers of the water utility. These officers included the Chief Executive Officer (CEO) of the LNW, scheme manager of PWTS, supervisor of PWTS and the Chief Financial Officer (CFO) of LNW. The respondents were selected because of their influence directly and indirectly on the PWTS's water purification decision-making process.

Subsequently, we were granted access to the PWTS, where we gathered existing data from its daily water purification records. Existing data for PWTS records were generated through daily records by the water scheme supervisor who supervises and ensures the purification of daily water processing. We visited the PWTS to observe the water purification with the permission of the LNW, where the scheme supervisor took us around the facility. We were privileged to ask questions about the different materials (chemicals) used and related costs at each purification stage. We also documented the inputs as observed and cross-checked with the daily records provided to resolve any unclear issues by asking the scheme supervisor relevant questions. We ensured clarification of any figure recorded or provided onsite before using it in our computations. Interviews and application of MFCA were done between February 2018 and February 2019.

Data collected onsite and from the daily records were analysed through the Umberto Efficiency^{+} software. *Ifu Hamburg GmbH* developed the Umberto Efficiency + software in Hamburg, Germany, to capture and analyse production processes information both in quantity and costs. This enabled areas of inefficiency in a process to become visible and thus support managers' waste reduction and pricing decisions. Results from the Umberto Efficiency^{+} are presented in the MFCA result section. The responses from the in-depth interview were explained to give credence to the result obtained from the Umberto Efficiency^{+} analysis.

We presented the Umberto Efficiency^{+} analysis to the management of the LNW at their head office, with the results elaborately discussed. The discussion was tabled to give feedback to management and to indicate areas of concern in the PWTS.

10 MFCA result-PWTS

The Umberto Efficiency^{+} software was used to capture actual water processing volume and costs at the PWTS. To better understand the production processes of the PWTS, we developed a graphical representation of the purification processes. Visibility is enhanced by using the Umberto Efficiency^{+} referred to as the *Sankey* diagram in Fig. 1. This diagram

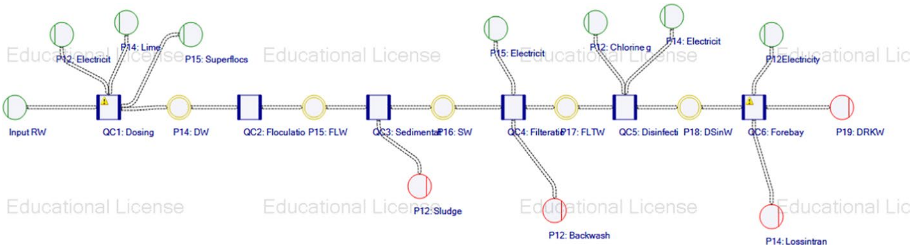

Fig. 1 Sankey diagram of the Politsi Water Treatment Scheme flow process *Source*: Authors' portrayal of the Politsi Water Treatment Scheme purification process

was used to visualise energy and material flows in the water purification process. The *Sankey* diagram portrays all processing costs that the traditional input–output approach does not capture.

Furthermore, the *Sankey* diagram shows all process costs captured at each quantity centre (process costs) making visible any water purification process where water loss occurs so that corrective action can be taken to save, reduce or eliminate such incidences and the related costs. This assists in determining the overall production costs of a batch of drinkable water for appropriate water pricing decisions. The following is the *Sankey* diagram and ledger accounts (Tables 1, 2, 3, 4, 5 and 6) of the various water purification processes at PWTS. Table 7 represents other overhead costs associated with water processing.

Figure 1 represents the total flow at the PWTS water purification process. The green circle represents the input, the blue cookies represent the quantity centre, and the yellow circle represents the intermediate goods, while the red circle represents output (good or negative). Data were collected and measured using the Umberto Efficiency^{+} software, and the results are represented in the cost tables as follows.

Table 1 represents QC1 which is the dosing process in the conventional plant. In this centre, 6408 kilolitres (*kl*) of raw water were extracted from the dam as input. Other materials used at this centre include lime, superfloccs and energy. The PWTS does not use the calcium hypochlorite (HTH) at the dosing stage because the extracted raw water does not contain many impurities and sediments. The lime used at the dosing stage is meant to disrupt the cellular processes of micro-organisms through oxidation. The electricity used in QC1 relates to the machine, which grinds lime and blends the chemical with the raw water during dosing. The monetary value attached to each material is shown in Table 1, and there was no water loss at this QC during water purification and the application of MFCA. The total output from this QC is 6408kl at ZAR1.20/kl. This output is then transported to QC2 (flocculation) by gravity.

Table 2 is QC2, also known as flocculation, and it is the QC where flocs start to form. This QC2 receives an input of 6408kl of dosed water from QC1, and the formed flocs start to settle at the top of the water. No additional material is used at this stage of water purification, and no water loss is captured; hence, the same 6408kl of water is the output transported to QC3 by gravitational force as input.

Table 3 presents the data for QC3, also known as sedimentation or the settling tank. The input for this process is the 6408kl from the flocculation process. The settling tank is where the flocs are separated during water processing through dedicated channels to the next process in the water purification. There is no added material at this stage of water purification, but a water loss of 192.24kl at ZAR1.20/kl is captured. The water loss recorded during this process is because of sludge formation where the heavier flocs can settle to enable good

Table 1 Process QC1—dosing

Input							Output						
Place	Material Type	Material	Coefficient	Unit	Price	Value	Material	Place	Material Type	Coefficient	Unit	Price	Value
P12: Electricity	Good	Electricity	36.25	kWh	15.658 ZAR/kWh	567.6025 ZAR	DoW: Dosed Water	P14: DW	Good	6408.00	kl	1.267 ZAR/kl	8116.6325 ZAR
Input RW	Good	Input RW	6408.00	Kl	1.04 ZAR/kl	6664.32 ZAR							
P14: Lime	Good	Lime	67.86	Kg	5.50 ZAR/kg	373.23 ZAR							
P15: Superflocs	Good	Superflocs	38.17	Kg	13.40 ZAR/kg	511.48 ZAR							

*QC, quantity centre

Table 2 Process QC2—flocculation

Input							Output						
Place	Material type	Material	Coefficient	Unit	Price	Value	Material	Place	Material type	Coefficient	Unit	Price	Value
P14: DW	Good	DoW: dosed water	6408.00	kl	1.267 ZAR/kl	8116.6325 ZAR	FlocW: flocculated water	P15: FLW	Good	6408.00	kl	1.267 ZAR/kl	8116.6325 ZAR

*QC, quantity centre

Table 3 Process QC3—sedimentation

Input							Output						
Place	Material type	Material	Coefficient	Unit	Price	Value	Material	Place	Material type	Coefficient	Unit	Price	Value
P15: FLW	Good	FlocW: flocculated water	6408.00	Kl	1.267 ZAR/kl	8116.6325 ZAR	Sludge: Sedimentation	P12: Sludge	Material loss	192.24	kl	–	–
							SedW: sedimented water	P16: SW	Good	6215.76	kl	1.306 ZAR/kl	8116.6325 ZAR

*QC, quantity centre

Table 4 Process QC4—sedimentation

Input							Output						
Place	Material type	Material	Coefficient	Unit	Price	Value	Material	Place	Material type	Coefficient	Unit	Price	Value
P15: Electricity	Good	Electricity	90.64	MJ	15.658 ZAR/kWh	1419.241 ZAR	Backwash	P12: Backwash	Material Loss	320.40	kl	–	–
P16: SW	Good	SedW: sedimented water	6215.76	kg	1.306 ZAR/kl	8116.6325 ZAR	FiltW: filtered water	P17: FLTW	Good	5895.36	kl	1.618 ZAR/kl	9535.8735 ZAR

*QC, quantity centre

Table 5 Process QC5—disinfection

Input							Output						
Place	Material type	Material	Coefficient	Unit	Price	Value	Material	Place	Material type	Coefficient	Unit	Price	Value
P12: Chlorine g	Good	Chlorine gas	9.53	Kg	31.20 ZAR/kg	297.34 ZAR	DisW: disinfected water	P18: DSinW	Good	5895.36	kl	1.764ZAR/kl	10,400.816 ZAR
P14: Electricity	Good	Electricity	36.25	kWh	15.658 ZAR/kWh	567.6025 ZAR							
P17: FLTW	Good	FiltW: filtered water	5895.36	Kl	1.618 ZAR/kl	9535.8735 ZAR							

*QC, quantity centre

Table 6 Process QC6—forebay

Input							Output						
Place	Material type	Material	Coefficient	Unit	Price	Value	Material	Place	Material type	Coefficient	Unit	Price	Value
P18: DSinW	Good	DisW: disinfected water	5895.36	Kl	1.764 ZAR/kl	10,400.816 ZAR	Loss in transit	P14: Lossintran	Material Loss	284.54	kl	–	–
P12Electricity	Good	Electricity	1812.71	kWh	15.658 ZAR/kWh	28,383.413 ZAR	**PumW: Pump Station**	**P19: DRKW**	**Reference Flow (Good)**	**5 610.82**	**kl**	**6.912 ZAR/kl**	**38,784.229 ZAR**

The bold indicates the cost per kilolitre of the purified water before the inclusion of overhead costs

*QC, quantity Centre

product flow to the next process of the water purification. However, it should be noted that in a costing process, the good product bears the cost of the negative product in order not to lose the vital aspect of cost. The output from this QC3 was 6215.76kl at ZAR1.20/kl, and it is transported to the next QC4 as input by gravitational force.

Table 4 shows the data for QC4, also known as filtration. The filtration process is where clear water passes through the sand filter and the filter nozzles for impurities such as leaves to be trapped in the sand for backwashing when it is due. The electricity consumption at this QC occurs because of the machine capacity and the backwashing is done for two hours during water purification. During filtration, a water loss of 320.40kl was recorded. This water loss resulted from the backwashing, which flushes trapped impurities from the processed water. The total output for this QC is 5895.36kl, and it is transported to the next QC5 by gravitational force as input.

Table 5 shows the data for QC5 as the input of 5895.36 *kl* at R1.27 of water, 9.53 kg at ZAR31.20/kg of chlorine and 36.25kWh at ZAR4.75 of electricity. The addition of chlorine at this QC5 kills all the harmful micro-organisms still contained in the water. The processed water then settles in a contact tank for the chlorine and water to properly mix for human consumption. The electricity consumed at this quantity centre resulted from the machines used for the disinfection process of the water purification. A total of 5895.36kl of water at ZAR1.35/kl is transported by gravity to QC6.

Table 6 shows the data of QC6 called the forebay or pump station. An input of 5895.36kl at ZAR1.764/kl of disinfected water and 1812.71kWh at ZAR15.658/kWh of electricity resulted in an output of good water or drinkable water. The high cost of electricity at this QC6 is because of the machine used for pumping water to the municipal reservoir. The water loss captured at this QC6 is because of old and obsolete pipes used for transporting purified water to the municipal reservoir. The overhead expenses incurred by the PWTS are shown in Table 7.

Table 7 Overhead expenses Politsi Water Treatment Scheme*

Particulars	Six months	Monthly	Amount daily
Civil engineering staff	125,493	20,915.50	746.98
Mechanical engineering staff	492,972	82,162.00	2934.36
Electrical engineering staff	156,684	26,114.00	932.64
Cleaning staff	198,114	33,019.00	1179.25
Diesel expenses	200,950	33,491.67	1196.13
Other salaries (supervisor and scheme manager)	1878,372	313,062.00	11,180.79
Staff overtime payments	175,717	29,286.17	1045.93
Total	3228,302	538,050.34	19,216.08**

$= ZAR19216.08/5895.36kl = ZAR3.2595/kl$

The total daily cost of water produced $= ZAR6.912/kl + ZAR3.2595/kl = ZAR10.507/kl$.

*PWTS's overhead expenses were extracted from LNW finance records for 6 months

The PWTS sells to the municipality at a tariff of ***ZAR8.12/*kl*

The PWTS is running at a loss because it is processing its water at an approximate loss of ZAR2.387/kl. This amounts to a total loss of $6408kl \times ZAR2.387 = ZAR15295.896 daily$.

**Daily rate is divided by 28 days because Politsi Water Treatment Scheme operates on a 28-day monthly circle

***ZAR = South African Rand

Table 7 presents the total overhead costs associated with water processing at the PWTS. The MFCA model incorporates all overhead costs associated with production such as personnel costs, despite proportionately isolating material and energy costs. Overhead costs calculation is necessary to arrive at the ‘true’ cost of products; hence, it is necessary to include all personnel costs involved in the operation of the PWTS. Effectively, the total daily cost of ZAR10.507/kl encompasses all costs associated with water purification at the PWTS. However, excluding the overhead cost calculation of ZAR3.2595/kl per day, the final daily cost calculation translates to inaccurate water purification costs and the inability of management to take advantage of any potential cost-saving opportunity. The inability of the existing costing system in the PWTS to capture all related water purification costs has resulted in the inability of the management to redress the apparent daily loss incurred.

Moreover, by incurring excessive overhead (personnel) costs in the water purification process coupled with the inability of the PWTS to determine its water pricing because of subjection to the water pricing policy by the supervising government department—the Department of Water and Sanitation (DWS), is the reason the water scheme is operating at a loss. Therefore, we argue that the overreliance on the DWS to offset its personnel costs through grants and subventions and the fixing of water pricing by the DWS have made the PWTS ignore the apparent losses incurred in the water purification processes.

11 Background—Politsi Water Treatment Scheme (PWTS)

The PWTS is one of the water treatment schemes managed by the LNW. PWTS is located in a village 13 km north-west of Tzaneen in the municipal district of Letaba in the Limpopo Province, South Africa. The PWTS is currently responsible for the production and purification of between 5.8 ML and 6.2 ML day^{-1} because of over-abstraction. Currently, water purification at the PWTS uses the conventional plant system. The scheme manager is aided in the plant by the production officer (supervisor) who oversees the production process. The production officer is assisted in the water purification process by process controllers who work shifts. The plant also has maintenance officers who oversee the maintenance of the scheme’s equipment. Furthermore, there are instrumentation technicians as well as artisans who make up the complete workforce at the PWTS. However, the PWTS has been running at a loss for over a decade.

12 Summary of findings—PWTS

One significant finding from the PWTS is that it is running at a loss by about *R2.387/kl*. PWTS extracts raw water from the Vergelegen Dam by means of gravity through pipes. Moreover, water treatment processes require the adding of chemicals and expertise. During purification, there is water loss which needs to be monitored because of its effect on overall pricing decisions. It is expedient, therefore, to determine the cost of water loss. The first research objective examines the extent to which the current approach to capturing the water processing-related cost supports water pricing decisions. The second research objective assesses whether current cost accounting systems in LNW captures enough water-related information to influence appropriate water pricing decisions. The third objective demonstrates the adoption of the MFCA model in capturing water-related costs for improved water pricing decisions.

We found that PWTS does not currently use a MAS in capturing the quantity of water loss and related costs in the water purification process. Inherently, inadequate cost information is used in determining water pricing. The absence of an appropriate MAS in capturing water loss is an indication that information used in determining water pricing is defective. Findings revealed that the PWTS is running at a loss due to excessive overhead costs emanating from its use of ageing infrastructure.

13 Discussions

The critical elements in applying the MFCA model are to gain an understanding of material flow and energy use, to link physical and monetary data, to ensure accuracy, completeness and compatibility of physical data and to estimate and attribute costs to material losses. PWTS adopts the input–output measurements approach, which does not make inefficiency visible and transparent (Nakkiew and Poolperm 2016) because it does not capture all water purification-related costs. This restricts the ability of PWTS to arrive at an appropriate water pricing decision since the correct water processing costs are not captured. Hence, the PWTS will be unable to identify inefficient processes that contribute to the overall production costs.

Consequently, opportunities to implement cost-saving measures are lost. Figure 1 shows a material flow model and each process description of input and output materials (quantity and costs) in Tables 1, 2, 3, 4, 5 and 6. Material flows (raw water input, energy consumption, chemicals and other additives) are shown in Quantity Centres (QC1 to QC6) with their material inputs and outputs. Each QC accumulates the cost incurred in the specific process and indicates the water loss. MFCA is a management information system which captures all input material that flows in a production process and measures the output in the final product and its waste (Christ and Burritt 2014; Wan et al. 2015). The distribution of material costs is done in each QC, and this is distributed between the good product (saleable) and negative product (water loss in this instance) by the flow quantities (Hyršlová et al. 2011). This is then transferred to the next QC (this approach follows the conventional process costing method as depicted in ledgers QC1–QC6). Figure 1 depicts this process appropriately. However, with the PWTS adopting the traditional input–output measurement approach, it means that corresponding costs of chemicals, energy consumption and other systems cost were not included in determining the total output costs of the batch.

The MFCA model was used to check the mass balance in each process (QC). This was done to determine material and energy flow at each process and subsequent output. Identifying the real losses in each process is vital. It is challenging to determine the volume of the closing raw water inventory to aid in calculating the water volume at the beginning of the water purification process because of the type of material input (raw water) having a consistent flow. As such, we recognised the metered volume of raw water input measured at the dosing stage as the volume of raw water that was processed in each batch. Accordingly, the MFCA model provides a sound basis for capturing a full mass balance of each process (APO 2014). The weights of input materials, outputs and material losses, as well as energy consumption, were measured and determined for each process (Nakkiew and Poolperm 2016) through observation and information provided by the scheme supervisor. This was done for each QC during water purification processes.

In addressing the objective of this study, findings revealed that there is no management accounting system in place at the PWTS to capture water loss and water-related costs during water purification. This lack of a management accounting system is an indication that water loss and water-related costs were not adequately captured; hence, such information was not available to managers for effective water pricing decisions. The benefit of the management accounting system requires organisations to have adequate information about the production processes. The availability of such adequate information will assist scheme managers in identifying inefficient activities in order to overcome the challenge of incurring avoidable processing costs to arrive at appropriate water decisions (Chapman and Kihn 2009). The reliance on the input–output measurement approach to determine the percentage of water loss during water purification has been found ineffective at the PWTS. The scheme manager depends on the information given by the production officer (scheme supervisor) at the end of the water purification process to determine actual water loss daily.

From the results of PWTS, we noted that the existing approach of capturing water loss and the calculation of its associated costs have been deficient. The use of non-accounting personnel in cost data gathering was noted at PWTS as inappropriate in determining accurate water purification cost. In response to a question on how water loss is calculated at the PWTS, the manager responded:

> We only consider water loss at the end of purification when the water output is measured and compared to the raw water input. However, the water input tariff is different from the water output tariff.

This is detrimental to the effective capturing of water loss and water-related costs and hence, the challenge of inappropriate water pricing decisions. Having an accurate record of the volume of water loss and related costs during water purification would lead to an improved water pricing decision. When asked about the cost of water lost at every stage of the purification process, the scheme manager asserts:

> We multiply the input raw water from the dam by the capacity of the plant and the tariff given by regulations. The total output purified is then subtracted from the total raw material input multiplied by the dam capacity and the selling price. We do not calculate the volume or cost of water loss at every stage of the purification process.

While water loss cannot be avoided during water purification processes; it can be controlled because a litre of water lost is directly attributable to a corresponding loss of material and energy costs. Existing input–output measurement approach used at PWTS is grossly inefficient in capturing water loss and water-related costs during purification as indicated in QC3, QC4 and QC6, respectively. The cause of this inadequacy in the capturing of water loss and related costs is because the staff of PWTS lack proper understanding of calculating material (water-related inputs both in volume and costs) balance, which is an essential aspect of MFCA. When asked about the existing accounting system that provides enough waste data to support management decisions, the chief financial officer (CFO) responded:

> There is no detailed cost accounting system to capture the water purification related costs. What we do is to input all the data we receive from the production unit into the software (Systems Applications and Products (SAP) systems) we use in the organisation. The scheme manager substantiated this assertion. Furthermore, he explained that: What we do is, to sum up, the total output of water and subtract it from the total input of raw water.

In capturing water volume and related costs at each stage of the water purification system, it becomes less challenging to identify water mass flows which may have been difficult to measure. Authors, such as Molden (2007:40) and Van der Zaag et al. (2010:16), have supported this assertion in their report. The use of an appropriate MAS in an organisation is vital because the information derived from such a system may plausibly assist in effective decision-making (CIMA 2015:5; CFMS 2014:2), especially pricing decisions.

Relying on the contingency theory that there is no exact once-size-fits-all approach to management in organisations (Emmanuel et al. 1990:57; Ismail et al. 2010:22; Islam and Hu 2012:5159), the adoption of the MFCA model in PWTS has provided adequate water loss-related costs thereby exposing the inadequacies of the existing input–output approach. On how the 'true' cost of material loss is calculated from the current accounting system, the scheme manager responded:

> We capture the difference between input and output water at the end of water purification, and the figures are recorded and forwarded to the finance department.

The results derived through the MFCA analysis reveals the inability of the existing costing system at PWTS to make visible costs previously hidden in overhead cost accounts (APO 2014; Kasemset et al. 2013) thereby limiting the scheme manager's ability to identify areas of improvement and cost-savings. The use of the MFCA model to analyse the water purification process at the PWTS enabled the scheme manager to see the necessity to capture water data adequately to support appropriate water pricing decisions. We found that the PWTS' physical (water volume) and monetary (related costs) data have not been appropriately and adequately linked during water purification. This significant linkage is made visible through the application of the MFCA model, which links every kilolitre of input raw water processed at each process to its related costs before transferring such accumulated cost to the next process of the water purification process. This non-linkage of physical and monetary value may have resulted in the actual cost of water loss not having been fully accounted for by the scheme manager of the PWTS, resulting in inappropriate water pricing decisions.

14 Conclusions

The study examined the significance of applying MFCA in a water treatment scheme to support appropriate water pricing decisions. From the analysis of the PWTS, we concluded that the existing water accounting system is inappropriate for the improvement of water pricing decisions. By fully adopting the MFCA approach, the PWTS manager will be provided with adequate water-related information that will improve its water pricing decisions and provide opportunities for cost-saving to enable it to breakeven and even make a profit rather than relying on government grants for survival. Applying an efficient MAS like the MFCA will likely assist in the allocation of cost at every QC. This is consistent with USEPA (2000), which opines that the allocation of both direct and indirect cost to a production process is beneficial for inventory evaluation, profitability analysis and pricing decisions.

References

APO (Asian Productivity Organisation). (2014). *Manual on material flow cost accounting: ISO 14051*. Tokyo: Hirokawa Kogyosha Co., Ltd.

Bennett, M., Schaltegger, S., & Zvezdov, D. (2013). Exploring corporate practices in management accounting for sustainability. http://www.icaew.com/academic. Retrieved November 10, 2016.
Burritt, R., & Christ, K. L. (2015). Water crisis and management: implications for accountants in business. https://www.ifac.org/knowledge-gateway/sustainability/discussion/water-crisis-and-management-implications-accountants. Retrieved November 7, 2016.
CFMS (Centre for Financial and Management Studies). (2014). *Management accounting*. London: University of London.
Challenges Program on Water and Food (CPWF). (2005). *CGIAR Challenges program on water and food: research strategy 2005–2008*. Colombo: Sri Lanka.
Chalmers, K., Godfrey, J. M., & Lynch, B. (2012). Regulatory theory insights into the past, present and future of general-purpose water accounting standard setting. *Journal of Accounting, Auditing & Accountability, 25*(6), 1001–1024.
Chapman, C. S., & Kihn, L. A. (2009). Information system integration, enabling control and performance. *Accounting, Organisations and Society, 34*(2), 151–169.
Christ, K. L., & Burritt, R. L. (2014). Material flow cost accounting: a review and agenda for future research. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2014.09.005.
CIMA (Chartered Institute of Management Accountants). (2015). *Global management accounting principles: improving decisions and building successful organisations*. London: One South Place.
DWAF (Department of Water Affairs and Forestry). (2011). *Water for growth and development in South Africa*. Pretoria: Government Press.
Emmanuel, C. R., Otley, D. T., & Merchant, K. A. (1990). *Accounting for management control* (2nd ed.). London: Thomson Learning.
Fakoya, M. B. (2014). An adjusted material flow cost accounting framework for process waste reduction decisions in the South African brewery industry. DCom (Accounting) thesis. University of South Africa.
Geng, Y., Zhu, Q., & Haight, M. (2007). Planning for integrated solid waste management at the industrial Park level: A case of Tianjin, China. *Waste Management, 27*(1), 141–150.
Godfrey, J. M., & Chalmers, K. (2012). *Water accounting: international approaches to policy and decision making*. Cheltenham: Edwards Elgar Publishing Ltd.
Hyršlová, J., Palásek, J., & Vágner, M. (2011). Material flow cost accounting (Mfca) tool for the optimization of corporate production processes. *Business, Management and Education, 1,* 5–18.
Islam, J., & Hu, H. (2012). A review of literature on contingency theory in management accounting. *African Journal of Business Management, 6*(15), 5159–5164.
Ismail, K., Zainuddin, S., & Sapiei, N. S. (2010). The use of contingency theory in management and accounting research. *Journal of Accounting Perspectives, 3,* 22–37.
IWMI (International Water Management Institute). (2010). Research program on water, land and ecosystems. http://www.wateraccounting.org/index.html. Retrieved October 21, 2016.
Jasch, C. (2003). The use of environmental management accounting for identifying environmental costs. *Journal of Cleaner Production, 11,* 667–676.
Karimi, P., & Bastiaanssen, W. G. M. (2015). Spatial evaporation, rainfall and land use data in water accounting-Part 1. *Journal of Hydrology and Earth Sciences, 19,* 507–532.
Kasemset, C., Sasiopars, S., & Suwiphat, S. (2013). The application of MFCA analysis in process improvement: a case study of plastics packaging factory in Thailand. In *Proceedings of the institute of industrial engineers Asian conference 2013*.
Kotzee, E. (2016). *Management accounting for decision makers* (6th ed.). Upper Saddle River: Prentice Hall.
Meng, J., Cheng, G. Q., Shao, L., Li, J. S., Tang, H. S., Hayat, T., et al. (2014). Virtual water accounting for building: case study of E—Town, Beijing. *Journal of Cleaner Production, 68,* 7–15.
METI (Ministry of Economy, Trade and Industry). (2007). *Guide for material flow cost accounting*. Tokyo: Environmental Industries Office.
Molden, D. (1997). *A comprehensive assessment of water management in agriculture*. London: Earthscan.
Molden, D. (2007). *Water and food, water for life: a comprehensive assessment of water management in agriculture*. London: Earthscan.
Molden, D., & Sakthivadivel, R. (1999). Water accounting to assess use and productivity of water. *Journal of water resources development, 15*(1/2), 55–71.
Morrison, J., & Schulte, P. (2010). *Corporate water accounting: an analysis of methods and tools for measuring water use and its impacts*. Oakland: Pacific Institute.

Nagpal, T., Eldridge, M., & Malik, A. A. (2019). Global water access fund: a new idea to bridge operations and maintenance shortfalls for the poorest water utilities. *Journal of Water, Sanitation and Hygiene for Development*. https://doi.org/10.2166/washdev.2019.248.

Nakajima, M. (2003). Introducing material flow cost accounting for environmental management accounting systems. In *International symposium on environmental accounting* (pp. 48–51).

Nakajima, M. (2010). The development of MFCA: MFCA management in supply chain. *A Journal of Japan Industrial Management Association, 20*(1), 8–12.

Nakkiew, W., & Poolperm, P. (2016). Application of Material Flow Cost Accounting (MFCA) and quality tools in wooden toys product. In *Proceedings of the 2016 international conference on industrial engineering and operations management Kuala Lumpur*, Malaysia, March 8-10.

National Water Resource Strategy. (2011). Managing water for an equitable and sustainable future. From: http://www.gov.za/sites/www.gov.za/files/FinalWater.Pdf. Retrieved March 31, 2016.

Neizvestnaya, D. V., & Antonova, N. V. (2015). Organization of management accounting in water transport companies. *Asian Social Sciences, 11*(11), 330–335.

Pinto, F. S., Tchadie, A. M., Neto, S., & Khan, S. (2018). Contributing to water security through water tariffs: some guidelines for implementation mechanisms. *Journal of Water, Sanitation and Hygiene for Development, 8*(4), 730–739.

Qian, W., Burritt, R., & Monroe, G. (2011). Environmental management accounting in local government. *Journal of Accounting, Auditing and Accountability, 24*(1), 93–128.

Ramagopal, C. A. C. (2009). *Accounting for managers: Strategy from basics*. Bengaluru: New Age International (P) Ltd.

Republic of South Africa. (1998). National Water Act. Government Gazette 398. 26 August 1998. Cape Town: Office of the President.

Riahi-Belkaoui, A. (2002). *Behavioural management accounting* (1st ed.). Westport: Greenwood Publishing Group.

Ridoutt, B. G., Eady, S. J., Sellahewa, J., Simons, L., & Bektash, R. (2009). Water footprint at the product brand level: Case study and future challenges. *Journal of Cleaner Production, 17*(13), 1228–1235.

Savage, D., & Jasch, C. (2005). *International guidance document on environmental management accounting*. New York: International Federation of Accountants (IFAC).

Schaltegger, S., Bennett, M., Burritt, R. L., & Jasch, C. (Eds.). (2008). Environmental management accounting (EMA) as a support for cleaner production. In *Environmental management accounting for cleaner production. Eco-Efficiency in Industry and Science* (vol. 24, pp. 3–26). Dordrecht: Springer.

Schaltegger, S., Bennett, M., Burritt, R. L., & Jasch, C. (2010). *Eco-efficiency in industry and science. Environmental management accounting for cleaner production* (5th ed.). Berlin: Springer.

Schaltegger, S., Gibassier, D., & Zvezdov, D. (2011). *Environmental management accounting. A bibliometric literature review*. Lüneburg: Centre for Sustainability Management.

Schreiner, B., & Hassan, R. (2011). *Transforming water management in South Africa: designing and implementing a new policy framework*. New York: Springer.

Singh, R., Maheshwari, B., & Malano, H. M. (2009). Developing a conceptual model for water accounting in Peru-urban catchments. 18th World IMACS/MODSIM Congress, Australia 13-17 July 2009. From: http://www.mssanz.org.au/modsim09. Retrieved March 28, 2016.

Smith, L., & Ball, P. (2012). Steps towards sustainable manufacturing through modelling material, energy and waste flows. *International Journal of Production Economics, 140*(1), 227–238.

Sulser, T. B., Ringler, C., Zhu, T., Msangi, S., Bryan, E., & Rosegrant, M. W. (2010). Green and blue water accounting in the Ganges and Nile basins; implications for food and agricultural policy. *Journal of Hydrology, 384*(3–4), 276–291.

UNDSD (United Nations Division of Sustainable Development). (2001). *Environmental management accounting, procedures and principles*. Geneva: UNSDS.

USEPA (United States Environmental Protection Agency). (2000). An introduction to environmental accounting as a business management tool: Key concepts and terms. In M. Bennett & P. James (Eds.), *The green bottom line: Environmental accounting for management: Current practice and future trends* (pp. 61–85). Sheffield: Greenleaf Publishing.

Van der Zaag, P., Juizo, D., Vilanculos, A., Bolding, A., & Uiterweer, N. P. (2010). Does the Limpopo river basin have sufficient water for massive irrigation development in the plains of Mozambique? *Journal of Physics and Chemistry of the Earth, Parts A/B/C, 35*(13–14), 832–883.

Vardon, M., Lenzen, M., Peevor, S., & Creaser, M. (2006). Water accounting in Australia. *Journal of Ecological Economics, 61*(6), 650–659.

Wan, Y. K., Ng, R. T. L., Ng, D. K. S., & Tan, R. R. (2015). Material flow cost accounting (MFCA) based approach for prioritisation of waste recovery. *Journal for Cleaner Production, 107,* 602–614.
Waterhouse, J. H., & Tiessen, P. (1978). A contingency framework for management accounting systems research. *Accounting Organisations Society, 3*(1), 65–76.