SUSTAINABLE PRODUCTION AND CONSUMPTION 5 (2016) 82–93

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

An industrial water management value system framework development

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ABSTRACT

Whilst it is generally accepted that improvements in water management are required worldwide, the relatively low apparent financial cost of water is inhibiting the essential changes. Motivating factors are necessary to enable the transformation and whilst standards such as ISO14046 Water Footprint and even ISO50001 Energy Management provide a framework to allow companies fulfil their corporate and social responsibilities, the cost savings associated with the necessary modifications do not alone provide adequate justification. The reason for this is that the true cost or true value of the water being used is not known.

The background to the water predicament along with an outline of the water–energy nexus is articulated in this paper. Details of significant, predominantly industrial, water management studies undertaken in different parts of the world are outlined. A common trend is identified, whereby the true cost of the water is rarely determined and hence unappreciated.

In order to remedy this situation within industry, a novel framework for establishing the true cost of water by analysing the value added has been developed and its application to a typical manufacturing factory is described in this paper. The framework may also be similarly applied to other water life-cycle stages.

The true cost provides a valuable insight into the operation of the facility, a means for internal and external benchmarking and internal cost control, and also the data necessary to financially justify any modifications required. The data may also be used to assist with the calculation of a water footprint or a life-cycle cost.

If the proposed methodology is implemented, changes will be possible which will result in water, energy and cost savings along with environmental benefits. Employment of this methodology, involving a Value System (VS) and a simulation model, would facilitate the application of Information and communications technology (ICT) to resource efficiency and thus may be used to assist in confronting necessary sustainability challenges.

Keywords: Value system; Water–energy nexus; Water management; Water footprint; Intelligent efficiency; Smart manufacturing

Abbreviations: AHU, Air handling unit; DIW, Deionised water; IChemE, Institution of Chemical Engineers; ICT, Information and communications technology; ISO, International Organization for Standardization; LCA, Life cycle assessment; m3, Cubic metre; OECD, Organisation for Economic Co-operation and Development; PFD, Plant flow diagram; UNESCO, United Nations Educational, Scientific and Cultural Organization; UNFAO, United Nations Food and Agriculture Organization; WWAP, United Nations World Water Assessment Programme; VS, Value system; VA, Value added; WWTP, Wastewater treatment plant; ZLD, Zero liquid discharge; $/m3, US Dollar per cubic metre.

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Received 25 June 2015; Received in revised form 17 November 2015; Accepted 29 November 2015; Published online 23 December 2015.

http://dx.doi.org/10.1016/j.spc.2015.11.004

1. Introduction

1.1. *Water background worldwide*

The status of the world's current water situation is the subject of many major studies and reports. When combined with demographic predictions, the conclusions are relatively consistent in identifying the impending crisis. Global water demand (in terms of water withdrawals), is projected to increase by 55% by 2050, mainly because of the growing demands from manufacturing (400%), thermal electricity generation (140%) and domestic use (130%) (OECD, 2012). As a result, freshwater availability will be increasingly strained over this time period, and more than 40% of the global population is projected to be living in areas of severe water stress by 2050. There is also clear evidence that groundwater supplies are diminishing, with an estimated 20% of the world's aquifers being over-exploited, some critically so (United Nations World Water Assessment Programme, WWAP 2014).

1.2. *Water supply cost*

Analysis of the supply cost of water provides some interesting observations. This cost in several countries around the world, as outlined in Table 1, varies considerably and also varies depending on the use, however in industrial expenditure terms, it is consistently low.

The supply cost is not dependent on the value of the item, but on the amount permitted, as with other commodities. This cost does not however incorporate any non-monetary consideration, such as drought, famine and loss of life and therefore is not a value. Also, it is a basic supply or invoiced cost and does not include any subsequent treatment or processing expenditure necessary to facilitate the utilisation of the water for its ultimate intention. The objective of this research is to identify and provide a mechanism for the determination of the true cost of the water utilised within industry, thus providing a mechanism by which water, along with the associated energy, may be managed more effectively with consequential benefits financially and environmentally. The value that water customers are willing to pay and the value that suppliers are willing to accept are a separate analysis, not included in this research.

2. Water usage and management

2.1. *Water in agriculture and food*

It is predicted that population growth will necessitate 60% more food by 2050 and thus a 19% increase in agricultural water use (UNFAO, 2012). Allied to this, the foods eaten by the people have a significant impact on water consumption. The increasing population in the middle class worldwide leads to more people choosing western-style diets, which are high in protein, sugar and fat, all of which are expensive in terms of water for food production.

The water consumed in the production of an agricultural or industrial product is termed 'virtual water' (Renault, 2002). Every day a person drinks 2–4 litres of water, but they will also consume 2000–5000 litres of virtual water embedded in their daily food. There is a hidden cost of water in the food we eat.

Beyond agriculture, the biggest water use in the food industry is the cleaning of processing equipment/plants and food products. This can account for up to 70% of a factory's water usage (WRAP UK, 2013). A study examining the use of recycled water in Australia (Martin-Nagel et al., 2011) indicates that recycling water during food production is acceptable to the public if the water has been collected, treated and processed to drinking water quality.

2.2. *Water consumption industrially*

In industry, water performs many functions. These range from being used as a raw material in the beverage industry, to cleaning in manufacturing facilities and cooling in power generation stations. Typically, in a manufacturing facility, mains water is taken in and although it is true that the supply cost is low, the additional value-added costs involving labour, materials, energy and equipment required for the operations such as purification, chemical treatment and ultimate disposal, increase the financial value of the water considerably.

In the commercial and retail sectors, the penalty for excessive utilisation is of significance; however in the industrial situation it is not as onerous as the relative cost of the water compared to other utilities is low. Industrial facilities purchase their raw water supply and also contribute towards its treatment on discharge. However, due to the relatively low cost, the impact on water conservation is very small. Consequentially, water conservation investments provide a relatively low payback, which leads to difficulty with their justification. In certain industries, such as those in the food and beverage sector, the investments are justified and there have been considerable improvements made in many installations by a combination of strategic investments along with focused low-cost operational and maintenance improvements. However, in other large industries the justification is solely based on the commitment to improvement of the corporate and social responsibility. The primary focus of any industry is on its fundamental business and not on energy or water efficiency. However these may be incorporated into its larger objectives in order to achieve cost control and satisfy corporate and social responsibilities. Undeniably several large corporations successfully spearhead the debate relating to resource efficiencies and actively promote discussion relating to the changes required to facilitate the effective management of water and energy.

In order to assist and encourage attention in these areas, the requirement for a system of assigning real or added value to water is required and has been identified (Walsh et al., 2015).

2.3. *Water management strategies*

Aside from ISO14001, ISO14046 and ISO50001 there are also other water management strategies which are presently yielding results. Globally the impetus for Zero Liquid Discharge (ZLD) has resulted from an increase in scarcity of freshwater and also a tightening of regulations and restrictions relating to discharges. The capital cost associated with the technology investment can be significant; however the savings over time can be substantial. Once the true cost is determinable, the savings can be estimated accurately and the investment justified.

In common with most industrial practice, there is a concerted drive to increase production with less or even with Zero Water. This concept does not mean that no water is used. Rather, water-neutral process operations are achieved