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Unlocking water efficiency improvements in manufacturing — From approach to tool support

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ABSTRACT

Water represents an irreplaceable resource for manufacturing companies and yet many fail to exploit hidden potentials in optimizing their water system and its operations. This issue is often indicated by ad-hoc water efficiency efforts leading to only sub-optimal results. A prevailing lack of transparency and unattractive amortization times further complicate a continuous improvement process. This paper presents a structured approach with prototypical tools for systematically unlocking water efficiency improvements in manufacturing companies exemplified by a consistent case from the automotive industry. Seven consecutive work steps demonstrate the identification and visualization of water related hot-spots, the derivation of basic water improvement principles, the consideration of water reuse options as well as the assessment of resource interdependencies before closing with a holistic evaluation.

Introduction

Population growth and rising living standards require a higher demand of new products and an increased use of resources. Considering the world's current situation in regards of resource consumption per capita, today's population already exceeds the planets natural bio-capacity [1,2]. This trend is expected to continue moving upwards causing an increased demand for material resources in general and an increase in direct and material resource embodied energy in particular by 40% over the next twenty years, provided that no major policy changes are realized [3,4]. Especially, material and energy intensive industries are confronted with rising gas, coal and oil prices entailing strong cost pressure as well as stringent regulatory concerns for emissions on their business. Therefore, industry started tackling and structuring their material and energy demand patterns, not only from an environmental but also from an economical perspective. In that context, industry has lately put a strong emphasis on increasing their energy efficiency because it not only favors their economical situation but also their reputation and image toward the environment [5,6]. Thus, many efforts have focused on reducing energy demand and resulting greenhouse gas emissions by increasing energy efficiency through different approaches [7–11].

However, industry requires more resources than solely material resources and energy which are also intrinsically linked to other resources [12]. One vital resource that has often been neglected in that context and only recently gained momentum is water. International surveys, e.g. of the OECD (Organization for Economic Co-operation and Development), further predict an increased global water demand by 55% in 2050, including an increase in manufacturing's share by 400%, which is strongly influenced by leading emerging nations and water's close linkage to energy [13].

Saving water also entails further benefits such as reduced pollution discharges, more resilient ecosystems and lower energy demands [14].

Although, global industry already uses around 22% of the available freshwater, the environmental assessment of freshwater use in industry has only played a subordinate role so far since freshwater is mostly assessed as a neutral, renewable resource. In that regard it is important to further consider local availability and associated water stress as well as water quality constraints including effort for distribution and treatment. Based on these characteristics, freshwater use may exhibit different impacts from industrial processes that need to be considered [15,16]. This aspect particularly exacerbates the environmental impact of freshwater use in many leading emerging and developing countries. With respect to industrial countries, their water demand currently exceeds the global average due to more water-intense industrial

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production processes [17]. Yet, many of these countries, and in particular European Countries, waste 20–40% of its available freshwater by failing to deploy technological improvements which alone can account for up to 40% improvement by enhancing the water productivity per volume [18].

In addition to that, it has been acknowledged by the United Nations that there exists a gap of knowledge, particularly in manufacturing, concerning the amount of water withdrawal and consumption used for manufacturing transformation processes and production needs [19]. This issue is of high of relevance for both small and medium sized companies as well as large sized manufacturing enterprises since this gap of knowledge results in missing starting points for water minimization efforts [20]. Information regarding water withdrawal and consumption is usually only monitored on a factory level and assigned to the respective process chains via allocation rules.

Considering the situation of having insufficient information and decision support about possible starting points for water efficiency improvements available, there is a need for an user-supported and systematic approach. As known from other disciplines (e.g. lean and energy management), the objective of the approach is to establish a continuous improvement process (CIP) for water efficiency in manufacturing. This objective is also addressed by recent standardization principles and guidelines like DIN EN ISO 14001 (environmental management system [21]). The proposed approach fosters water efficiency improvements by following three major phases that are all supported by user-friendly tools:

- Water data acquisition to provide transparency about the current situation
- Analysis of the current situation and derivation of measure for improvement
- Holistic assessment of the derived measures for improvement.

The following section of this paper introduces different sources of water supply and respective water types in manufacturing before different uses cases of water as well as potential wastewater treatment stages are explained. After that, present modeling approaches with regard to water are stated and distinguished. The subsequent section presents the proposed approach exemplified by an automotive case including a detailed description of the separate work steps as well as selected remarks on a few supportive tools.

Water in manufacturing

Process water supply and water types

Water as a resource has different quality and quantity related characteristics. From a quality perspective, water has e.g. different temperatures, pH levels and varying purities whereas the quantity perspective is mainly described by volume flows and water stocks.

Based on that, also the supply and use of water in industrial processes is quite heterogeneous due to manifold requirements concerning the water quality and quantity of each process. To gain a better understanding of a typical industrial water system Fig. 1 provides a schematic overview of such a system including different water states, functions as well as selected forms and processes thereof. The exemplary forms and processes of the three functions source, usage and treatment also represent major parts in an industrial water system.

The supply of process water for industrial purposes can be allocated in different ways. Usually, raw water as a source is withdrawn from ground water feeding aquifers and wells, from surface water or the public water supply network. In addition to that, there are further possible supply alternatives such as rain

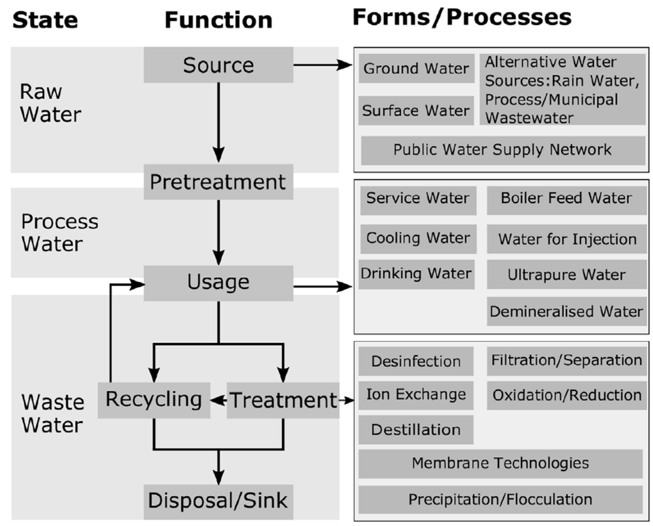

Fig. 1. Broad overview of an industrial water system.

water basins or process and municipal wastewater as long as it meets respective process water requirements for the operations and processes at hand. Based on the quality requirements of the processes it may be necessary to carry out a pretreatment of the raw water to acquire the proper form and related quality of the process water. Generally, it can be distinguished between forms of water with comparably low requirements such as service, cooling and boiler feed water and water types with very strict and high quality standards due to technical and hygienically reasons such as drinking, demineralised, ultrapure water and water for injection, as depicted in Fig. 1 [22].

To ensure such water quality either prior to using the process water or to subsequently discharging the wastewater, different pretreatment and treatment technologies are installed. These technologies can be further subdivided into different stages. Instead of directly discharging the wastewater another option that is used in industry is either a direct reuse of wastewater in different processes and process tanks or the use of recycled wastewater after it has been treated by the wastewater treatment technologies [23], as shown in Fig. 1.

Water usage in industrial processes

Industry often considers water as a utility and uses it for different purposes with different functions. Table 1 shows an exemplary overview of various functions of process water from varying manufacturing and process areas as well as involved materials and contaminants that may be relevant for recovering from the respective operations [24].

Table 1 indicates that water can either be used as a raw material or an irreplaceable utility due to its chemical properties. The manufacturing industry uses in that sense large amounts of water particularly for cooling or cleaning and rinsing purposes, respectively. For example during the transformation process in manufacturing, water becomes polluted by conditioning and cleaning activities as well as through direct contact with water-soluble components. After that, the water's quality is deteriorated in such a way that it requires treatment prior to re-using it in the production or disposing it as wastewater [24].

Stages of (waste) water treatment in manufacturing

Typical water and wastewater treatment comprises water softening (e.g. by removing Ca, Mg), removal of suspended solids,