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Industrial water mass balance as a tool for water management in industrial parks

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ABSTRACT

Industry is demanding ever-greater volumes of water, while at the same time producing wastes and effluents, which in many places taint and damage the quality of this precious resource on which all life depends. This article formalizes a systematic water mass balance framework to quantify all anthropogenic and natural water flows into, water flows inside and effluents out of the industrial parks. Quantitative performance indicators are derived, including management and operation indicators. The approach makes visible large flows of water that have previously been unaccounted and ignored. In 2012–2014, the water consumption, which made up 59.5–90.2% of industrial water withdrawal, was 8.5–51.2% higher than wastewater generation. The approach demonstrates how the principles of water balance can help robust water accounting, monitoring, optimum operating and management in industrial parks. Furthermore, performance indicators could evolve to a useful tool for leading to more systematic analysis of the impact of industrial design and management.

1. Introduction

The attention paid to industrial water management varies considerably industrial scale from region-to-region and ecological health concerns [1]. The industrial activities, however, can lead to severe pollution and resource depletion, especially water pollution and water depletion, because many industrial parks are located along the rivers for convenient water supply and transport [2]. Large amounts of water are consumed and wastewater is treated through the integrated wastewater treatment plants, which have been adopted by most industrial parks [3]. The increasing demands for water supply and deteriorated water quality have been important constraints to the sustainable development of industrial parks. Industrial-scale wastewater reuse, wastewater treatment and decentralized supplies are a reliable and practical way to cope with these problems. This trend creates an enhanced need to understand water flows through and within the industrial park boundary [4].

A mass-balance approach is useful in examining the water management that an approach requires comparison of inputs and outputs. Transformation refers to alteration of mass water (the state in which the mass water is transported) from inflow to outflow waters, without changing the total mass water that entered the system. The water mass balance analysis has been used for urban water [5,6], biodiesel production [7], water basin [8], lake [9], base metals [10], etc. However, this approach has not yet been applied in industrial park because of poor data availability and quality. In developing countries like Vietnam, the number of industries that manage water in a systemic and holistic way is limited. Water management in the majority of industries is limited to ensuring the provision of water, and some efforts to control or treat effluents [3].

Hence, the paper describes the industrial water mass balance analysis in contribution method and material to enable quantitative benchmarking of the water performance of industrial parks and give better understanding of water metabolism in these areas.

2. Methodologies

2.1. Case study

Industrial parks in Vietnam have developed rapidly since 1986 and there are 289 industrial parks throughout the country. Dong Nai province located in the South of Vietnam and is leading the country in the number of industrial parks. Dong Nai province currently has 31 industrial parks with total area of 9573 ha including various industrial sectors. This rapid industrialization

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appears to be associated with a rapid environmental degradation and a great pressure on the natural resources. The water management in the industrial parks in Dong Nai meets number of problems such as: (i) inaccurate forecasting of water quantity, and (ii) un-control the quantity and quality of effluent. Hence, in this case study, the water metabolism in industrial parks will be examined by water mass balance analysis methods, as the basis to explore this tool in industrial water management.

2.2. Data acquisition

A questionnaire survey on water use, water contribution and effluent generation was conducted through 31 industrial parks in Dong Nai province; and limited to the industrial parks had fully yearly environmental monitoring report. The acquisition of data for the case study was done through a questionnaire-survey, expressly developed for the study. The inquiries contained 14 questions, grouped into four blocks: (i) characterization of enterprises: industrial sector, products, number of labors, etc.; (ii) water consumption, wastewater reuse: sources and flows; (iii) water service: water supply, connection of drainage system; and (iv) wastewater production: generation, composition, flows and treatments.

Questionnaires were hand-delivered and later gathered from each enterprise in industrial parks in Dong Nai province. In some cases, the information was completed with face-to-face or telephone interviews. Matric for water balance analysis was constructed using inquiry data. Each row of the matric represented an enterprise, while each column represented a component of water balance analysis (ie., water consumption, wastewater generation, wastewater treated, water losses, etc.). Several problems arose while revising the inquiries data: some enterprises, industrial parks had not fully completed the questionnaires, so there were many unknown flows; much erroneous data were also found. Water balance was applied to each enterprise in order to verify the data (find the erroneous values) and to quantify unknown water flows. After applying this methodology, 19 industrial parks were discarded because of the incongruity in the data given, and the final analysis was done for 12 industrial parks with 664 enterprises (Fig. 1).

2.3. Mass balance analysis

The industrial water use survey was carried resulting in creation of water flow balances. In order to systematize, the method of mass balance analysis was applied. A system is defined by a system border, processes, goods and fluxes of goods between the different processes. This approach was deemed to be necessary in this analysis to enable the identification of areas where water could be recycled, use of raw materials and other inputs optimized and where closed loop systems could be implemented [11].

The application of the method consists in five steps [12], flow diagram of mass balance analysis was given in Fig. 2, as following:

- First *the system has to be analysed*: the system border has to be defined, the most important processes have to be characterized and the indicator elements have to be chosen.
- In a second step, *system description*. The system is defined by boundaries in space and time. The mass fluxes of input and output through the different processes and the concentration of the indicator elements are measured. With the results of step two, the element fluxes can be calculated.
- The third step, *data acquisition* consists in the interpretation and validation of the determined material and element fluxes.
- The forth step *water balances, modeling and scenario building* consists in the development of scenarios and the determination of monitoring points. For this step the mathematical description is very important.
- The last step is *interpretation*. The results of water balance analysis study are interpreted taking into consideration loading quantities, sustainable indicators or other assessment approaches.

2.4. Significant issues in the adaptation of water balance analysis to industrial parks

When water balance is adapted to industrial parks, some aspects should be pointed out:

- Depending on the industrial park's location, water balance analysis can suppose important environmental impacts.
- Whereas at national and provincial level most of the data are statistical, in industrial parks data are given by the enterprises,

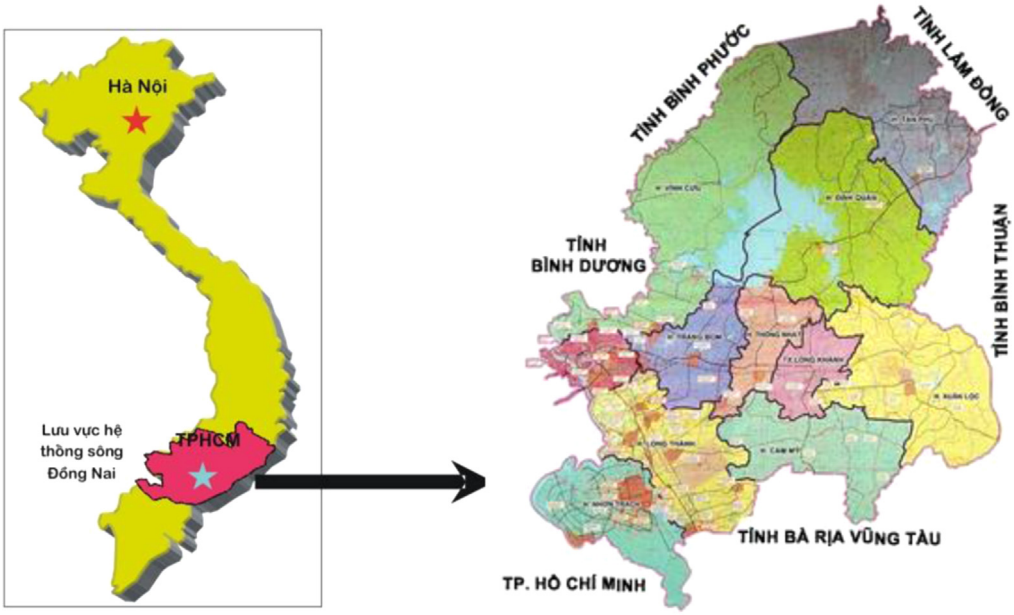

Fig. 1. Map of Dong Nai province.