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Thermodynamic analysis of an urban water system with reclaimed water as supplemental water resource

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ABSTRACT

The natural water system maintains its dynamic equilibrium through a hydrological cycle that involves a series of natural processes. Such a natural water cycle has been much disturbed by human activities in the process of water use. An urban water system was thus modeled in this paper as a series of artificial water cycles overlaid upon the natural water cycle. The system was thermodynamically analyzed by calculating the entropy budget as $\Delta S = \Delta_i S + \Delta_e S$ where $\Delta_i S$ and $\Delta_e S$ are the entropy increases due to natural and artificial contributions, respectively. The natural water cycle free from human disturbance should possess the nature of self maintenance of water and materials balance and could be assumed as a pseudo-reversible process with $\Delta_i S \to 0$. $\Delta_e S$ was then supposed as to be contributed by artificial disturbances on water quantity such as by water withdrawal, and on water quality such as by pollutant discharge. A series of models were developed for calculating $\Delta_e S$. As a result of scenario analysis of urban water system in Xi'an, a metropolitan in northwestern China, using these models, it was indicated that under the current condition of water supply and wastewater treatment, if 20% of the treated wastewater could be reused, $\Delta_e S$ would be decreased by 15.22% from the current level, while if the percent of treated wastewater reuse could be increased to 40%, $\Delta_e S$ would be decreased by 29.93%. Thermodynamic analysis thus provided a tool for quantitative evaluation of the effect of urban wastewater reclamation and reuse.

Keywords: Urban water system; Thermodynamic analysis; Entropy; Pseudo-reversible process; Water reclamation

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