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Exploring the potential for wastewater reuse in agriculture as a climate change adaptation measure for Can Tho City, Vietnam

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ABSTRACT

Climate change is impacting water resources in the Mekong Delta of Vietnam. Drought is becoming more severe and water scarcer. Thus, action on adaptation to climate impacts is urgently needed. We assess the potential for wastewater reuse as an adaptation measure to cope with water scarcity in Can Tho City, within the heart of the Mekong Delta. We show that wastewater effluent can be used to irrigate at least to 22,719 ha of paddy rice (16% of the rice-cultivated area in the city) at 3 crops per year. The fertilizing properties of the water would eliminate part of the demand for synthetic fertilizers, providing a maximum of 22% of the nitrogen (N) and 14% of the phosphorus (P) requirement for the winter–spring crop. On a yearly basis, recovery of wastewater could reduce the discharge of N by 15–27% and the discharge of P by 8–17%. Such a program would contribute to a decrease in the level of pollution in the local rivers and canal systems, while also reducing the need for expensive tertiary treatment

1. Introduction

Adverse impacts of climate change have already been observed with respect to natural, food security, human health, the environment, economic activity and physical infrastructure (IISD – International Institute for Sustainable Development, 2007). If a global temperature increase of 3–4 °C is reached, changes in runoff patterns and glacial melt could force an additional 1.8 billion people to live in a water-scarce environment by 2080 (UNDP – United Nations Development Programme, 2007). The United Nations estimate that globally a third of the world's population has a serious water shortage problem and this number could grow to two-thirds by 2025 if no corrective measures are taken (McCarthy, 2003). The Food and Agriculture Organization (2000) notes that millions of people are seriously affected by drought in several countries in the near East and South Asia. There is increasing demand for freshwater resources which is creating a situation that is unsustainable, with projections that 90% of all available freshwater could be allocated by the year 2025 (Salem, 2003). The world's poor are more seriously impacted by a higher frequency and intensity of droughts (Meehl et al., 2007). Analyses indicate that the degree of change and the extent of observed impacts are at the extreme upper limits of earlier Intergovernmental Panel on Climate Change (IPCC) predictions, and in some cases exceed them (IPCC, 2007a): "More extensive adaptation than is currently occurring is required to reduce the vulnerability to future climate change" and "a portfolio of adaptation and mitigation measures can diminish the risks associated with climate change" (IPCC, 2007a).

The potentially adverse impacts of climate change on water resources are particularly worrisome for Vietnam, where water is considered the most important factor for development. According to a recent World Bank study (Dasgupta et al., 2007), Vietnam ranks among the top five developing countries most impacted by climate change, especially due to sea level rise. Anticipating a sea level rise of 1 m (which could occur by 2100), it is estimated that the economic losses would amount to 10% of the GDP. Approximately 12,300 km^2 or 31% of the total land area of the Mekong Delta, including 9800 km^2 of land used for agriculture and aquaculture could be affected; and 4.8 million people could be impacted, including more than 1.5 million poor individuals. Such impacts would substantially deter Vietnam's strategy of sustained economic growth as the main mechanism for poverty alleviation. The IPCC (2007b) also noted that Vietnam is one of the countries that has suffered from global warming. During the past 50 years, the sea level in Vietnam has risen by approximately 20 cm, and it is projected that compared to the period of 1980–1999 the sea level could increase 75 cm by the end of the 21st century (MONRE – Ministry of Natural Resources and Environment, 2009). Saline water has

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invaded inland areas and pollutes freshwater resources. In addition, researchers in Vietnam forecast that the total volume of surface water in 2025, 2070 and 2100 will be about 96%, 91% and 86%, respectively, of today's quantity (DWRM – Department of Water Resources Management, 2008). Based on the volume of surface water generated within the country (i.e. not including upstream Mekong River flow), Vietnam already is a water deficient country and will face many challenges with water resources in the near future (DWRM, 2008).

Despite the recent economic growth in Vietnam, climate change is a concern as the livelihoods of a large proportion of the population depend on climate influenced sectors such as agriculture, animal husbandry and forestry (APN – Asia-Pacific Network for Global Change Research, 2007; Chaudhry and Ruysschaert, 2007).

Within Vietnam, the Mekong Delta has been identified as being particularly susceptible to the impacts of extreme climate events and climate variability. The Mekong Delta region is home to one-fifth of Vietnam's population and has a population density that is amongst the highest in the country. Agriculture and fisheries are the major sources of income for a majority of the people. The area, known as the 'rice bowl' of Vietnam, with approximately 10,000 km^2 of land under rice cultivation, contributes 46% of the total national food production. Climate change has impacted water resources in the Mekong Delta as droughts have become more severe and water scarcer. Moreover, climate change will affect water quality in water scarce regions, with rivers losing assimilative capacity and salinity increasing (Sadoff and Muller, 2009).

Faced with these challenges, there is an urgent need to improve the efficiency of water consumption and to augment the existing sources of water with more sustainable alternatives. Wastewater reuse has become increasingly important in water resource management for both environmental and economic reasons. It has a long history of application, primarily in agriculture, but increasingly, industrial, household, and urban applications are being developed (Stander and Van Vuuren, 1969; Angelakis et al., 1999; UNEP – United Nations Environment Programme, 2002; Chu et al., 2004; Bixio et al., 2006; Miller, 2006; Jimenez et al., 2010; Wichelns et al., 2011; Chew et al., 2011). With the rapid increase in water demand from all sectors, the increasing interest in water reuse is understandable. On average, for cities with a population of 1 million inhabitants, with typical wastewater generation rates of 30–70 m^3 per resident per year, the total amount of wastewater is enough to irrigate an area of 1500–3500 ha and provide a savings of about \$5 million US (SIDA – Swedish International Development cooperation Agency, 2000).

Wastewater reuse, when appropriately applied, is considered an example of Environmental Sound Technology (EST) (UNEP, 2000) and has various benefits. First, recycled wastewater can serve as a more dependable water source, containing useful substances such as organic carbon and nutrients for some applications. The use of nutrient-rich water for agriculture and landscaping may lead to a reduction or elimination of fertilizer application. Second, wastewater reuse leads to reduced treatment needs, which results in a cost savings. Finally, by reusing treated wastewater, more freshwater can be allocated for uses that require higher quality, thereby contributing to more sustainable resource utilization (UNEP, 2005).

Two-thirds of urban wastewater generated in the world receives no treatment before discharge to a receiving water body and this can be a particular problem in developing countries (Raschid-Sally et al., 2001; Qadir et al., 2010). The costs of providing conventional (up to tertiary) wastewater treatment cannot be supported by many cities, particularly in the developing world. An alternative to the disposal of untreated wastewater in surface water is to reuse the treated wastewater for agriculture. In this way, wastewater may be seen as a resource, which provides an opportunity for increasing food security in rapidly growing urban areas. Furthermore, Wichelns et al. (2011) note that in developing countries reuse of untreated wastewater by small farmers is frequently done informally (and even unintentionally), which increases health risks to both the farmer and the consumer. An organized and regulated system of water treatment and reuse could result in economic and environmental benefits and concurrently reduced health risks. Clearly, then, treated wastewater may be considered – a 'new' water resource, which can add to the general water balance of a region. This 'new' source can be an effective substitute for freshwater used in irrigation and should be considered an integral component of local water resources (Scheierling et al., 2011). The economic appraisal of case studies in Spain and Mexico shows that there is potential for "win–win" arrangements – among cities, farmers and the environment – involving the use of reclaimed water (Heinz et al., 2011).

Formal and regulated wastewater reuse has not received much attention in Vietnam, even though wastewater has been used locally in agriculture because it is cost-effective for the farmer and contains many nutrients (e.g. Nguyen, 2001; Vu, 2001; Raschid-Sally et al., 2001; Khai et al., 2007). Wastewater from livestock breeding and some agro-industries is also reused for biogas production at a small and medium scale (Trinh, 2001). Wastewater-fed aquaculture is a well established practice developed mainly through farmer experience accumulated over the past 30 years in Vietnam. But techniques and skills developed are still far from sustainable and optimal in achieving the dual objectives of aquaculture production and treatment of the wastewater (Vo, 2001). Furthermore, experiments at the Cuu Long Rice Research Institute (Cao et al., 2010) found that irrigation with wastewater from catfish farming increased rice yield by 1 t ha^{-1} and large amounts of nitrogen and phosphorus fertilizer were saved.

Although the potential health and environmental risks related to wastewater reuse are well known in general terms (WHO/FAO/UNEP, 2006; Asano et al., 2007; Jiménez and Asano, 2008; IWMI-IDRC – International Water Management Institute – International Development Research Center, 2009; Asano, 2010; Murray et al., 2011), and the economic costs and benefits analyzed and acknowledged in various studies (IWMI, 2001; Hussain et al., 2001, 2002; IWMI, 2002; Danso et al., 2002; Buechler et al., 2002; Drechsel et al., 2006; Obuobie et al., 2006; Asano et al., 2007; Aquarec, 2006; Heinz et al., 2011; Drechsel and Seidu, 2011; Weldesilassie et al., 2008, 2009, 2011), no effort has been made to integrate these key aspects into an analytical framework which provides useful information to policy makers in countries like Vietnam, faced with the challenge of developing climate change adaptation strategies. Given this background, the objective of this study is to explore the potential of wastewater reuse in agriculture as a climate change adaptation measure for Can Tho City in particular, and the Mekong Delta, in general. The primary focus of the paper is a planning level determination of the treated wastewater volume and nutrient load that could be made available to rice farmers. The environmental benefits from the reduction of untreated wastewater loads discharging to local water bodies also are noted, but a full environmental assessment, which would address environmental and health risks, while considering also socio-cultural issues, remains to be done.

2. Materials and methods

2.1. Study area – Can Tho City in the Mekong Delta

Can Tho City (hereinafter also called the City, referring to the urban area including the peri-urban area around it) has an area of 1401 km^2 (3.46% of the whole Mekong Delta) and a population of 1.171 million, making it the largest city in the Mekong Delta (Fig. 1)