Feasibility analysis of wastewater and solid waste systems for application in Indonesia

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HIGHLIGHTS

- Technical & financial evaluation of wastewater & solid waste systems was performed.
- The resource recovery potential from wastewater and solid waste was assessed.
- Effect of land and resource price variations on the total life cycle was analyzed.
- The analysis helps countries to select feasible wastewater and solid waste systems.

ARTICLE INFO

ABSTRACT

Indonesia is one of many developing countries with a backlog in achieving targets for the implementation of wastewater and solid waste collection, treatment and recovery systems. Therefore a technical and financial feasibility analysis of these systems was performed using Indonesia as an example. COD, BOD, nitrogen, phosphorus and pathogen removal efficiencies, energy requirements, sludge production, land use and resource recovery potential (phosphorus, energy, duckweed, compost, water) for on-site, community based and off-site wastewater systems were determined. Solid waste systems (conventional, centralized and decentralized resource recovery) were analyzed according to land requirement, compost and energy production and recovery of plastic and paper. In the financial analysis, investments, operational costs & benefits and Total Lifecycle Costs (TLC) of all investigated options were compared. Technical performance and TLC were used to guide system selection for implementation in different residential settings. An analysis was undertaken to determine the effect of price variations of recoverable resources and land prices on TLC. A 10-fold increase in land prices for land intensive wastewater systems resulted in a 5 times higher TLC, whereas a 4-fold increase in the recovered resource selling price resulted in maximum 1.3 times higher TLC. For solid waste, these impacts were reversed — land price and resource selling price variations resulted in a maximum difference in TLC of 1.8 and 4 respectively. Technical and financial performance analysis can support decision makers in system selection and anticipate the impact of price variations on long-term operation. The technical analysis was based on published results of international research and the approach can be applied for other tropical, developing countries. All costs were converted to per capita unit costs and can be updated to assess other countries' estimated costs and benefits. Consequently, the approach can be used to guide wastewater and solid waste system planning in developing countries.

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1. Introduction

The Millennium Development Goals (MDG) state that the proportion of people without access to sanitation facilities should be halved by 2015 compared to 1990. Nevertheless, a large fraction of the population in developing Asia currently lacks access to improved sanitation (ADB, 2012). In 2010, access to improved wastewater facilities in Indonesia was 56% (Ministry of Health, 2010) while progress reports suggest that Indonesia is not on track reaching the MDG's (WHO and UNICEF, 2014). National Health Surveys (Ministry of Health, 2013) show that less than 25% of households is served by a solid waste management system.

The vast majority of households in Indonesia with access to wastewater facilities rely on septic tanks (WSP, 2013a). A septic tank is the minimum treatment requirement in Indonesia (BPS, 2014) and minimum design standards for septic tanks are available (MoPW, 2000), yet rarely enforced. Consequently, 95% of septic tanks leak and result in the pollution of groundwater (WSP, 2013a). Community based systems or SANIMAS (Indonesian: *Sanitasi oleh Masyarakat*) comprising a community sanitation center or a simplified sewer system of small diameter pipes connected to an anaerobic baffled reactor have been gaining grounds (Ulrich et al., 2009; Roma and Jeffrey, 2010; Reynaud et al., 2012a). By 2010, nearly 600 of such systems were implemented with 5000 additional systems planned for the near future (Eales et al., 2013; Kearton et al., 2013). Evaluation of these systems (Reynaud et al., 2012b; Eales et al., 2013; Kerstens et al., 2012) confirmed the technical capabilities of the anaerobic systems to meet applicable effluent standards (MoE, 2003). However, challenges were identified such as the division of roles and responsibilities in technical and financial management, and the removal and safe disposal of sludge (Eales et al., 2013; Kerstens et al., 2012).

By 2012, only 12 centralized municipal wastewater treatment plants (WWTP) were in operation in Indonesia serving less than 1% of the population (Kearton et al., 2013; USAID, 2006). The systems utilized were (aerated) lagoons, UASB (Upflow Anaerobic Sludge Blanket), Rotating Bio-Contactors (RBC's) and activated sludge systems (Kearton et al., 2013). Poor sewer network quality causes seepage of groundwater into the network, which dilutes the sewage and increases the flow to the treatment works (USAID, 2006). Connecting households to the sewer systems is a major problem (Whittington et al., 2000; Kearton et al., 2013) and requires institutional strengthening and advocacy (Winters et al., 2014). Several medium centralized WWT systems (serving 500 to 5000 households), typically RBC's or Anaerobic Filters, were established in the past years (PDPAL-Banjarmasin, 2012) or are planned (Kearton et al., 2013).

Existing Municipal Solid Waste (MSW) systems include the collection of waste from households by motorized or hand carts to a transfer station, followed by transportation to a landfill (Aprilia et al., 2012; TTPS, 2009). Between 2010 and 2014, 207 municipal landfills were constructed but only 132 have sufficient capacity until 2019 (MoPW, 2014b). The government is aiming for a 20% reduction of (urban) waste landfilled through the promotion of the "3R concept (Reduce, Reuse, Recycle)" (Bappenas, 2011), which has resulted in the construction of approximately 300 communal 3R stations by 2014 (MoPW, 2013e).

The lack of adequate wastewater systems combined with inadequate solid waste management is causing the contamination of both surface and ground waters (ADB, 2013) and thereby posing public health and environmental risks (Baum et al., 2013; Wright et al., 2013) and economic losses (Hutton, 2013). Furthermore, the value of resources in wastewater and solid waste, such as energy, water, organics, nutrients and other recoverable products like plastic and paper, is being ignored. Resource recovery can benefit long-term operational and financial sustainability, while offering access to hygienic sanitation (Murray and Ray, 2010; Sasaki and Araki, 2013). Energy usage for conventional aerobic technologies contributes significantly to operational costs (Chernicharo, 2006) and in the absence of a stable power supply, sustainable service provision may be compromised (Lettinga, 2006). The predicted population growth and urbanization (Proyeksi Penduduk Indonesia, 2013) will add pressure on space availability (related to population density), especially in urban areas (Aprilia et al., 2012). Consequently, the area footprint of facilities becomes an important parameter in system selection. In this paper, system selection covers collection, transport, treatment, disposal and resource recovery (Tilley et al., 2014).

This study provides a combined feasibility analysis of wastewater and solid waste technologies and combinations thereof. Both of these sanitation sub-sectors (wastewater and solid waste) aim to improve public health and the environment, and should therefore be addressed and solved simultaneously to achieve the desired quality of life (ADB, 2013; Ersoy et al., 2008). For that reason wastewater and solid waste management are often managed by one public authority e.g. a single ministry, as is the case in Indonesia and China (ADB, 2013; Yan et al., 2006). Moreover, both waste streams (water and solids) concern anthropogenic sources and are intrinsically related to human settlement development. Linking the feasibility of wastewater and solid waste technologies to (1) data on the population that has access to wastewater and solid waste facilities and (2) key residential features (urban/rural, land availability or population density) would therefore result in a sanitation decision support system and planning framework, showing the number of required systems and the associated costs. Data on access to sanitation, residential features and population development and prognoses for a wide variety of development countries are freely available (WHO and UNICEF, 2014; BPS, 2014; NBSC, 2014; Ministry of Health, 2013; UNpopulation, 2012; DSM, 2014). However, despite the availability of general guidelines on system selection (TTPS, 2009) and a range of comparisons and evaluations on wastewater and solid waste systems (Kearton et al., 2013; Eales et al., 2013; Aprilia et al., 2012; USAID, 2006; WSP, 2011), a combined feasibility analysis of wastewater and solid waste systems under different residential conditions is lacking in scientific literature.

A second reason for an integrated wastewater and solid waste analysis is that the organic fraction of solid waste and wastewater can be treated using similar technologies such as digestion and composting (Zeeman and Kujawa-Roeleveld, 2011). In addition, energy consuming wastewater processes (e.g. aerobic technologies) may be combined with energy producing (anaerobic) solid waste or wastewater treatment processes resulting in net energy producing systems (Meinzinger et al., 2009; Kujawa-Roeleveld and Zeeman, 2006; Kerstens et al., 2009b). Insights into potential synergy for the treatment of wastewater and solid waste flows may thus result in more favorable financial feasibility and consequently accelerate sanitation development.

This paper aims to provide an analysis of selected wastewater treatment and municipal solid waste systems, including the financial and environmental performance of these systems under Indonesian conditions. It is hypothesized that a wastewater and solid waste system selection can be based on a small number of readily available parameters (residential density, urban/rural features). By including both investment and operational costs and benefits, the proposed system selection framework can be combined directly with life cycle costs, thereby allowing for the development of a principle framework for wastewater and solid waste planning and costing in developing countries.

The analysis was based on international literature and includes a comparison of different technological systems according to: (1) removal efficiency of COD, BOD, nitrogen, phosphorus and pathogens, (2) sludge production, (3) energy consumption, (4) area requirement and (5) resource recovery potential (phosphorus, energy, duckweed, compost and water). Secondly a financial analysis was performed focusing on a comparison of investment and operational costs as well as the potential benefits accrued from resource recovery. Subsequently the Total Lifecycle Costs (TLC), comprising investment and operational costs minus potential benefits over a 20 years operation time, were evaluated.