Review

The Belmont Valley integrated algae pond system in retrospect

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ABSTRACT

Integrated Algae Pond Systems (IAPS) are a derivation of the Oswald-designed Algal Integrated Wastewater Pond Systems (AIWPS®) and combine the use of anaerobic and aerobic bioprocesses to effect sewage treatment. IAPS technology was introduced to South Africa in 1996 and a pilot plant designed and commissioned at the Belmont Valley WWTW in Grahamstown. The system has been in continual use since implementation, and affords secondarily treated water for reclamation according to its design specifications, which most closely resemble those of the AIWPS Advanced Secondary Process. In this paper IAPS as a municipal sewage treatment technology is re-examined in relation to design and operation, the underpinning biochemistry of nutrient removal by algae is described, and a retrospective is provided on the demonstration system at the Belmont Valley WWTW. In addition to presenting details of the process flow, several shortcomings and/or oversights are highlighted and, in particular, the need for an appropriate tertiary treatment component. However, despite the use of IAPS for sewage treatment in many countries, this technology is still viewed with some scepticism. Thus, a major purpose of this overview is to provide a synthesis of available information on IAPS and an appraisal of its use for municipal sewage treatment.

Keywords: advanced integrated wastewater pond system, integrated algae pond systems, wastewater, algae, nutrient removal, sewage

INTRODUCTION

Municipal sewage is an anthropogenically contaminated water body or stream which varies significantly depending on its origin and reaction to environmental influences, chiefly rainfall and evaporation (Adewumi et al., 2010). Rainfall dilutes the effluent and evaporation has a concentrating effect (Adewumi et al., 2010; Ahmad et al., 2011). Origins of municipal wastewater may be inclusive of, but not limited to, households, industry and agriculture (Bdour et al., 2009) and its source directly impacts its composition. However, factors such as social behaviour, economics, type and number of industries, area, climate, water consumption and the type and condition of the sewer system all contribute significantly to sewage composition (Sonune and Ghate, 2004; Su et al., 2012; Travis et al., 2012). Municipal sewage may contain contaminants such as plastics, rags, plant debris, pathogenic bacteria, fats, greases, nitrates, phosphates, heavy metals, and other potentially hazardous compounds (Sonune and Ghate, 2004; Ansa et al., 2012). Unless removed or rendered harmless in the WWT process these can adversely affect the environment. Thus, any remedial process must achieve an appropriate concentration of minerals and nutrients to avoid any acute or gradual influx into the environment of xenobiotics and toxic compounds (Lettinga, 1996; Debelius et al., 2009; Sekomo et al., 2012). The South African Government, through the Department of Water Affairs (DWA) has therefore mandated the remediation of all effluent prior to discharge to the environment to ensure that effluent streams released by municipalities (and industries) comply and will not be detrimental and/or damaging to the environment.

Innovation and advancement in the sector have proliferated wastewater treatment works (WWTW) and new process technologies are regularly made available as strategies to improve the management and remediation of wastewater (Bdour et al., 2009). Even so, management of WWT and control of final effluent quality/discharge is complex and some of the associated challenges include land, capacity, operations, maintenance and repair, technology developments, climate change, water course accessibility, and sustainability (Muga and Mihelcic, 2008; Gravelet-Blondin et al., 1997). These, coupled with available financial resources, directly impact wastewater infrastructure by influencing design, construction, operation, inspection, maintenance, and the overall efficiency of the WWTW (Korf et al., 1996). Since WWT is not a free-market enterprise in South Africa, acceptable process technologies are viewed by many as those that are either already optimised or can be immediately optimised, and without consideration of additional energy and monetary costs.

Wastewater treatment technologies currently deployed in South Africa for the treatment of municipal sewage include waste stabilisation ponds (WS) or oxidation ponds (OP), activated sludge plants (AS), bio-filtration (BF), biological nutrient removal (BNR), constructed wetlands (CW), and more (Adewumi et al., 2010; Oller et al., 2011; Tomar and Suthar, 2011). South Africa has approximately 970 municipal WWTWs which together treat an effluent stream of 7 589 000 $k\ell \cdot d^{-1}$ at an operational cost in excess of ZAR3.5 billion per year. Regional distribution of these WWTW according to size shows differences between the nine provinces:

- Gauteng Province has a relatively high number of medium (2–10 $M\ell \cdot d^{-1}$) and large (10–25 $M\ell \cdot d^{-1}$) WWTWs, with fewer micro (<0.5 $M\ell \cdot d^{-1}$) and small size (0.5–2 $M\ell \cdot d^{-1}$) plants.
- Eastern Cape, Northern Cape, Mpumalanga and Limpopo provinces mainly have micro-size and small size plants.
- North West, KwaZulu-Natal and Free State have a wider

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