Appropriate Technology Selection Tool for Decentralised Wastewater Treatment Systems

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ABSTRACT
A transition toward decentralised treatment of wastewater is currently occurring in Australia and globally, giving the opportunity for a more sustainable water cycle. Appropriate selection of decentralised treatment systems is complicated due to the number of technologies available, wide variance in capabilities of different technologies and lack of expertise of decision makers. A number of decision support tools have been developed to assist in determining appropriate technology for given situations. Previously, tools have focused on regulatory factors, however there is room for further development related to maintenance requirements, nutrient management and energy efficiency. This paper presents a recent development at the Environmental Technology Centre, Murdoch University of an electronic decision support tool for appropriate decentralised wastewater selection, focusing on the nutrient management and energy efficiency of different treatment and technologies. The tool can be applied to a large number of wastewater situations beyond the urban, including national parks, remote townships, mining camps, peri-urban areas and aboriginal communities.

INTRODUCTION

The Transition from Centralised to Decentralised Wastewater Treatment

Centralised sewage systems and treatment plants generally form the historical infrastructure arrangements that deal with wastewater in urban areas (Gikas & Tchobanoglous, 2009 van Lier & Lettinga, 1999). There are areas where decentralised technologies are the only option due to limiting factors such as isolation, energy availability or capital costs. These areas include remote locations such as small rural townships and isolated tourist locations such as national parks (Jamieson, 2005).

Decentralisation of wastewater treatment may directly improve energy efficiency and nutrient management in wastewater treatment. Centralised wastewater treatment requires significant energy expenditure due to the pumping and treatment of excessive quantities of water (van Lier & Lettinga, 1999). With the current focus on climate change, reduction in energy usage highlights the beneficial nature of distributed wastewater treatment (Gallego et al., 2008). Sandy soils in Western Australia result in poor nutrient retention and increase the possibility of nutrient leaching where the groundwater is in close proximity of the soil surface. Distributed wastewater treatment and recycling may help close the nutrients loop, preventing nutrient rich wastewater from being disposed of in sandy soils and also allows nutrient recycling (Ho, 2003).

Barriers To Implementation Of Decentralised Technologies.
Although the transition to onsite and decentralised wastewater treatment is occurring both globally and in Western Australia the process has been slow (Miller, 2006, Strang *et al.*, 2007). There are a number of barriers to distributed wastewater treatment and reuse, including policy and technical issues (Miller, 2006, Strang *et al.*, 2007).

The extensive range of commercially available wastewater treatment systems is a major barrier to implementation of small-scale technologies, as personnel responsible for their implementation often have limited knowledge regarding technology types (Green & Ho, 2005, IETC, 2002). It is imperative that technologies match their intended application in relation to environmental sensitivity, required effluent quality, maintenance requirements, available energy and various other criteria (Adenso-Diaz *et al.*, 2005, Hidalgo *et al.*, 2007, Miller, 2006). Lack of general principles that can be applied to specific situations means that such an extensive range of factors significantly complicates the decision making process (Hidalgo *et al.*, 2007).

This barrier may be overcome with the use of decision support tools (DSTs) that take into account a large number of parameters related to choosing an appropriate technology. A considerable number of these tools have been developed including MEDAWARE, MOSTWATER, SANEX, WAWTTAR and WTRNet; focussing on technical and financial constraints, effluent and water reuse standards and wastewater treatment types (Hidalgo *et al.*, 2007, IETC, 2002, Joksimovic *et al.*, 2006). Although these tools all have relatively specific application, they still effectively simplify the decision making process related to wastewater treatment technology selection. This research focuses on the adaptation of a final decision support tool, the DeWaTARS EDST (Decentralised Wastewater Treatment and Recycling Systems Electronic Decision Support Tool), for application to remote tourist areas.

DeWaTARS EDST.
The DeWaTARS EDST aims to provide sustainable wastewater treatment and reuse through an onsite and decentralised approach (Jamieson, 2006). This particular decision support tool was created to address appropriate technology choice for decentralised wastewater treatment in the Perth Metropolitan Region. The DeWaTARS EDST framework is built on two concepts: sustainable water management and source separation. Within this framework the principles of health risk and environmental consideration, scale of collection and treatment system components are addressed (Jamieson, 2006).

The tool is an algorithm presented in the form of a flow sheet asking a series of questions of the user to determine which wastewater treatment technology would be most appropriate for their given situation.

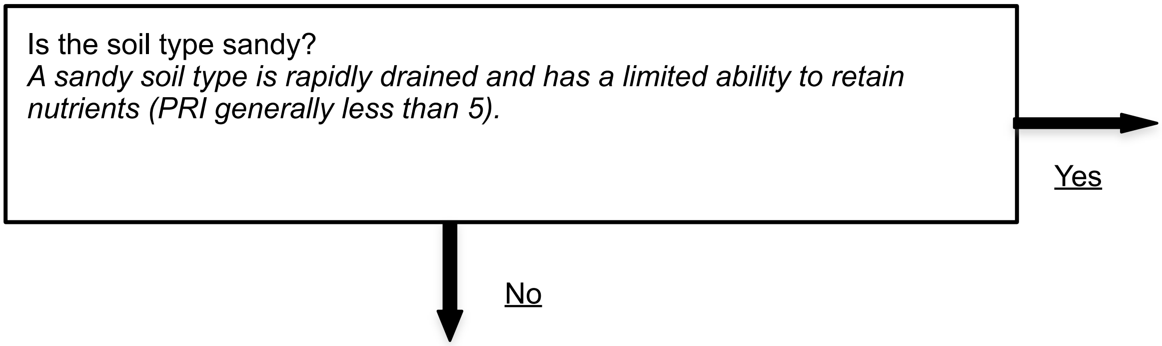

Figure 1. An example from the DeWaTARS EDST user interface (Jamieson, 2006).

There are three main steps included in the algorithm related to local geographical factors, development characteristics and specific requirements of the user. Literature review identified nutrient risk at the site of treatment and reuse and the scale of collection as primary factors to determine appropriate technology selection. The first two steps in the algorithm determine the onsite nutrient risk and whether wastewater collection is lot scale (up to 1.8kL of wastewater per day), cluster scale (<50kL of wastewater per day) or village scale (>50kL of wastewater per day) (Jamieson et al., 2006). Finally the user is asked questions relating to specific requirements of the wastewater treatment, for example whether minimisation of water use is required (Jamieson, 2006).

At the end point of the DeWaTARS algorithm the user receives options of one or more treatment types. Additional components to improve the effectiveness of the wastewater system and the potential for effluent reuse are also recommended by the DeWaTARS EDST. These technology types and additional components included:

- Aerobic treatment units,
- Soil, sand and peat filters,
- Composting systems,
- Ponds and wetlands,
- Anaerobic systems,
- Physico-chemical systems, and
- Greywater treatment systems (Jamieson et al., 2006).

The EDST is linked to a DeWaTARS database listing commercially available technologies, allowing the user to select an available technology once a treatment category has been established. Within this database, each technology type is evaluated for removal of organics, removal of nutrients, energy use, capital and management costs, footprint, required maintenance and sludge production. On the basis of this evaluation each technology is given a final score, allowing the user of the tool to decide between technology options on the basis of these factors (Jamieson, 2006).

The DeWaTARS EDST was examined by the primary author to determine areas where it could be improved for application to remote tourist areas and other non-urban wastewater situations.

METHODOLOGY

Remote Tourist Areas and Wastewater Treatment
A number of remote tourist area case studies were considered in order to assess factors for consideration for wastewater technology selection. A review of literature was also carried out focussing on remote tourist areas and specific issues related to appropriate wastewater selection. These factors were combined to compile a comprehensive list related to remote tourist areas.

DeWaTARS EDST Evaluation
The DeWaTARS EDST was applied to a range of case studies in order to identify strengths and weaknesses within the algorithm, particularly in relation to energy efficiency, nutrient management and other factors specific to remote locations. A number of the case studies used and factors that were considered through the application of the DeWaTARS EDST are listed in Table 1.

Table 1. DeWaTARS EDST case studies and their factors for consideration.

Site & Location	Local Geographical Factors	Other Factors for Consideration
Banksia Tourist Village, Hazelmere	- sandy soils - >3m to groundwater - no nearby surface waters	- no sewer connection - opportunity for wastewater reuse onsite via irrigation - collection and reuse will be by village scale
Environmental Technology Centre, Murdoch University	- sandy soils - <3m to groundwater - <1km to Murdoch Swamp	- sewer connection - facilities servicing a number of offices - opportunity for wastewater reuse onsite via irrigation - collection may be lot or cluster scale
Nambung National Park, 245km north of Perth in the Pinnacles Desert	- sandy soils - ~40m to water table - nearest surface water body ~6km away	- no sewer connection - expected wastewater flow variation from 1kL/week to 10 kL/day - energy produced onsite from photovoltaic cells and a backup diesel generator - public facility - possible toxic inputs from chemical toilet emptying - collection may be lot or cluster scale
Single Residence, Mt Nasura	- clay-rich soil - >3m to groundwater - no nearby surface waters	- no sewer connection - opportunity for wastewater reuse onsite via irrigation - high energy efficiency required as user preference - residence of textile artist therefore chemicals from fabric dyes may enter wastewater stream irregularly - collection will be lot scale

The DeWaTARS EDST algorithm was also evaluated in relation to factors identified for consideration in appropriate wastewater treatment technology selection for remote tourist areas. Through this evaluation of the algorithm, areas for redevelopment to address the distinct array of factors related to remote locations were identified.

DeWaTARS EDST Redevelopment
Once the strengths and weaknesses of the DeWaTARS EDST were identified, the EDST was modified to build upon the existing strengths and overcome the weaknesses to allow for application to remote tourist areas.

A new Decentralised Wastewater Treatment and Recycling Systems for Remote Tourist Areas Electronic Decision Support Tool (DeWaTARS:RTA EDST) was created, based on the SANEX DST and the DeWaTARS EDST approaches, following three stages:

- Determination of specific wastewater treatment technologies relevant for application in remote tourist areas,
- Development of a set of criteria to be used to evaluate the appropriateness of these technologies, and
- Incorporation of the criteria into an algorithm that could be utilised for appropriate technology selection in remote tourist areas.

Electronic Adaptation
Once the algorithm had been developed it was adapted into an electronic decision support tool (DeWaTARS:RTA EDST) to provide a more useable format for those who will use the tool. Microsoft Excel was selected as the program into which the algorithm was adapted as it has widespread use and it is likely that most users would have previous experience with it. Further, it is also the program into which the DeWaTARS EDST was formatted, allowing efficient redevelopment by following this approach.

Trialling of the DeWaTARS:RTA EDST
The new DeWaTARS:RTA EDST was tested in order to determine its effectiveness in appropriate technology selection as well as the user-friendly aspect of the tool. It was tested on a Facilities Owner/Designer, a Facilities Manager and a Facilities Operator.

RESULTS

Remote Tourist Areas and Wastewater Treatment
From the case study and literature review of remote tourist areas carried out, a number of criteria that must be considered when implementing wastewater technologies in such areas were identified. Factors identified and their significance are outlined in Table 2.

Table 2. Factors associated with wastewater treatment in remote tourist areas.

Factor	Significance
Energy availability	- case study review identified remote tourist areas with both unlimited and limited energy supply - literature review also identified that energy is not always available for wastewater treatment, with long-drop toilets being employed
Environmental Sensitivity	- close interaction with natural areas increase the need for effective wastewater management to prevent contamination of groundwater or surface water bodies - low-impact facilities are required to comply with ecotourism principals - some case studies centred around water bodies or were sites with sandy soils increasing nutrient contamination risk
Seasonal variation of wastewater flow	- there may be significant differences in wastewater flow between tourist and non-tourist seasons
Periods of no wastewater flow	- some remote tourist areas are closed for a certain amount of time throughout the year, therefore there will be periods with no wastewater flow
Land availability	- certain treatment technologies require a large footprint, national parks and other remote tourist areas may not have much land available to allow clearing for wastewater treatment - ecotourism principles require low-impact facilities, so substantial clearing of land may not be acceptable
Maintenance	- the remoteness of a tourist area may result in frequent maintenance of a wastewater treatment system being unviable
Water availability	- water supply may be limited
Appropriate use of facilities	- emptying of campervan chemical toilets into the wastewater stream may cause concerns if a biological treatment process is being utilised
Sewer connection	- case study review identified remote tourist areas such as Nambung National Park and Purnululu National Park that had no sewer connection as well as remote tourist areas that were serviced by nearby town sites, for example Longitude 131 and Paperbark Camp.

DeWaTARS EDST Evaluation
The results of application of the DeWaTARS EDST to each case study are outlined in Tables 3-6.

Table 3. Treatment options for Banksia Tourist Village, Hazelmere.

	Option 1	Option 2	Option 3
Toilet Type	Dual Flush	Dual Flush	Dual Flush
Scale of Collection	Village	Village	Village
Core Treatment	Moving Bed Bioreactor	Rotating Biological Contactor	Submerged Aerated Filter (intermittent)
Additional Components	Phosphorus Precipitation	Phosphorus Precipitation	Phosphorus Precipitation
End Application	Drip Irrigation	Drip Irrigation	Drip Irrigation

Table 4. Treatment for the Environmental Technology Centre, Murdoch University.

	Option 1 (only 1 option provided)
Greywater Type	Including Kitchen
Scale of Collection	Lot
Core Treatment	Secondary Greywater Treatment System
Additional Components	-
End Application	Drip Irrigation

Table 5. Treatment for Nambung National Park, Pinnacles Desert.

	Option 1 (only 1 option provided)
Greywater Type	Including Kitchen
Scale of Collection	Lot
Core Treatment	Amended Soil Filtration
Additional Components	-
End Application	Infiltration and Evapo-Transpiration

Table 6. Treatment options for Single Residence, Mt Nasura.

	Option 1	Option 2	Option 3
Toilet Type	Dual Flush	Dual Flush	Dual Flush
Scale of Collection	Lot	Lot	Lot
Core Treatment	Percolating Filter (humus)	Moving Bed Bioreactor	Submerged Aerated Filter (intermittent)
Additional Components	-	-	-
End Application	Drip Irrigation	Drip Irrigation	Drip Irrigation
Greywater Type	To Blackwater	To Blackwater	To Blackwater

In the original DeWaTARS EDST, scale of collection of wastewater was defined as lot scale (<1.8 kL/day), cluster scale (1.5-50 kL/day) and village scale (>50 kL/day). Nambung National Park and the Environmental Technology Centre wastewater collection both see wastewater collection from publicly shared facilities, with 'lot' scale of collection however wastewater flows were equivalent to 'cluster' scale. Therefore the current wastewater flow filter was unsuitable for communal facilities as would be found in remote tourist areas such as Nambung National Park.

At the Single Residence, Mt Nasura, there was a preference for energy efficient technologies, while at Nambung National Park there was limited energy available. However, case study application of the DeWaTARS EDST identified an underlying assumption that unlimited energy is available at each site. While this assumption is acceptable for application in the Perth Metropolitan Region, availability of energy was identified as a factor affecting technology selection in remote tourist areas through both case study and literature review.

The current configuration of the DeWaTARS EDST has a minor focus on energy efficiency through a simple energy evaluation of different technology types in the DeWaTARS database. This data is only valid once the selection process is complete and is therefore only useful where the DeWaTARS EDST provides multiple wastewater treatment options. Incorporation of an energy assessment into the algorithm would be required to allow for application in remote tourist areas, as it would take into account situations where energy is unavailable or limited.

DeWaTARS EDST Redevelopment

The diverse range of possible wastewater situations in remote tourist areas means application of all technology types listed in the original DeWaTARS database may be possible. Therefore, this database was utilised as the start point when determining appropriate technology.

Three primary filters were incorporated to eliminate technologies that were not appropriate for a given wastewater situation. The initial two filters address the environmental sensitivity to nutrients and energy available, factors that were identified to be the most limiting factors for wastewater technology selection in remote tourist areas. The final primary filter determined wastewater flow, as this factor has significant bearing on the technologies being applied.

Once filters had been applied, a refined list of technologies that could be applied was identified. These were evaluated through final flow sheets, into which other factors for consideration, such as maintenance requirements and seasonal wastewater flows, were incorporated.

Nutrient risk filter

The nutrient risk filter classified sites were of a high, medium or low nutrient risk, based on soil type, depth to the water table, and distance from the nearest surface water body. These criteria are based on Western Australian government policies and Water Quality Protection Notes (Government of Western Australia, 1981, Department of Water, 2006).

Energy filter

Application of the energy filter identified that sites either had no energy, limited energy or unlimited energy available. 'Unlimited' energy referred to situations where it was sourced from a centralised grid or from an onsite system that was oversized in relation to onsite requirements. An onsite system was deemed oversized more than 10W per person was produced daily for wastewater treatment, based on the energy needs of a standard onsite aerobic treatment unit.

Reliability of the energy supply was also important as the Department of Health legislates that retention time of untreated wastewater is a maximum of 24 hours. Therefore, available energy was considered limited if accessibility to the remote site may prevent recognition of system failure or the ability to repair the system within a 24 hours period.

Wastewater flow filter

The wastewater flow filter determines the wastewater flow from remote tourist area sites based on the number of visitors to the site. The Health (Treatment of Sewerage and Disposal of Effluent and Liquid Waste) Regulations 1974 contains estimates of wastewater flow from non-residential situations. This filter determined wastewater flow using these estimates and by categorising the facilities at each site and identifying the average visitor number. Wastewater flow was determined to be low (<2 kL/day), medium (2-50 kL/day) or high (>50 kL/day).

Final evaluation flow sheets

Application of the primary filters allowed elimination of technologies that were not appropriate for the final wastewater situation. A number of final evaluation flow sheets were employed to allow evaluation of the remaining technologies to determine the most suitable for the situation.

Electronic Adaptation

Once completed, the algorithm was integrated into Microsoft Excel as an electronic decision support tool. Automation of the questions through hyper linking answers to the appropriate following question, allows systematic, uncomplicated application for the user.

Testing of the DeWaTARS:RTA EDST

Overall, the application of the DeWaTARS:RTA EDST was found to be effective with candidates being able to navigate through the tool without significant difficulty. It was identified that the main considerations regarding implementation of wastewater treatment in remote tourist areas were identified and dealt with through the tool. One concern raised by personnel through trials of the DeWaTARS:RTA EDST was related to the fact that the database of technologies could not be updated once the tool has been released.

DISCUSSION

Significant Findings

- On-site energy availability was identified as the most significant factor affecting the treatment.
- No energy availability limited treatment types to soil and peat filters, ponds and wetlands, and anaerobic treatment systems.
- A percolating filter with a humus medium was identified as a suitable technology where limited energy was available.
- In high nutrient risk areas, intermittent aeration treatment units can operate with limited energy availability and deliver higher nutrient removal.
- Combination of technologies was found to be an option to provide a high level of treatment and still maintain a low level of energy use.
- At sites where there is unlimited energy available there are more options for wastewater reuse as effluent may be treated to a higher level.

Application of the DeWaTARS:RTA EDST.

The development of the DeWaTARS:RTA EDST, for application to remote tourist areas, factors that are shared by many remote areas were addressed. Therefore application can be to a wider range of situations including remote townships and mining villages within Australia and abroad.

Testing of the DeWaTARS:RTA EDST
Application of the tool was successful, with all candidates being able to apply the tool with minimal difficulty. Concerns were raised by all candidates in regards to the fact that the DeWaTARS database of technologies cannot be updated once it has been provided to the user. This was identified to be a significant issue as there is the possibility that improved technologies may come onto the market. Possible ways that this may be addressed would be to develop an online database to which the users of the EDST may be directed, that is regularly updated by persons responsible for the development and distribution of the tool. Alternately, the user may be provided with a database that they may update themselves if they encounter additional technologies through their research.

CONCLUSION

Conclusions
Through this research, an Electronic Decision Support Tool to allow for appropriate wastewater technology selection for remote tourist areas with a primary focus on the energy efficiency and nutrient management capabilities of wastewater treatment technologies was developed.

The DeWaTARS:RTA EDST identifies a total of 27 possible wastewater situations in remote tourist areas based on environmental nutrient risk (high, medium or low), energy availability (no energy, limited or unlimited) and wastewater flow (high, medium or low). Technologies that are applicable to each individual wastewater situation are evaluated through a series of flow sheets that incorporate significant factors for consideration.

The factors identified for consideration when selecting wastewater technology in remote tourist areas were incorporated into an algorithm to allow a systematic method of technology selection. To allow the algorithm to be applied in an uncomplicated manner it was electronically adapted into an automated form in Microsoft Excel.

Trialling of the tool was successful in that all candidates were capable of navigating through the tool and receiving a viable answer with minimal difficulty. This testing also identified a number of areas where the tool could be improved.

Recommendations
- The DeWaTARS:RTA EDST should be provided to Department of Environment and Conservation project staff for a more extensive period for detailed evaluation and assessment.
- The tool should be trialled on a wider range of candidates so that it may be developed to a higher standard.
- Identification of a greater number of technologies that require no energy input and their incorporation into the DeWaTARS database may improve the applicability of the tool.
- Alternately, a tool to accompany the DeWaTARS:RTA EDST may be developed, with a focus on recommendation of appropriate renewable energy technologies for sites that currently have no energy source.

Further Research

The DeWaTARS:RTA EDST could be improved through further research as follows:

- Further testing of the DeWaTARS:RTA EDST to refine the questions and educational information provided and therefore ensure effective application and allow commercialisation of the EDST.
- Further research into technologies that do not require energy for wastewater treatment and recycling to provide improved options for sites where no energy is available and there is a high nutrient risk to the environment.
- Inclusion of information regarding possible onsite renewable energy systems to be installed at sites where no energy is available.
- Further trialling of the tool through case study application, including implementation of recommended technologies at certain case study sites and monitoring the systems to evaluate their appropriateness.

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BIOGRAPHIES

Emma Tomren

Emma Tomren has completed a Bachelor of Science in Conservation Biology and a Bachelor of Science in Environmental Science with Honours at Murdoch University, Western Australia. She undertook her Honours project in 2008, working as part of the research group at Murdoch University's Environmental Technology Centre. The focus of the project was appropriate technology selection of decentralized wastewater treatment and recycling systems for remote tourist areas, with project sponsorship from the Department of Environment and Conservation. This project involved the development of an electronic decision support tool for decentralized wastewater treatment and recycling systems, taking into account factors such as energy efficiency, nutrient removal and maintenance requirements of the individual systems.

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Prof Goen Ho

Prof Goen Ho also lectures at Murdoch University. His areas of expertise include waste management, pollution control and environmental technologies, particularly those which achieve sustainable development. Prof Ho also supervised this research work.