Development of a Knowledge Management System for Operation of the

Algal Integrated Ponding System (AIPS)

- A Training and Operations Tool for Small Wastewater Treatment Plants

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TT 372/08

Water Research Commission

DEVELOPMENT OF A KNOWLEDGE MANAGEMENT SYSTEM FOR OPERATION OF THE ALGAL INTEGRATED PONDING SYSTEM (AIPS)

A TRAINING AND OPERATIONS TOOL FOR SMALL WWTPs

Report to the

Water Research Commission

by

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WRC Report No. TT 372/08

FEBRUARY 2009

Obtainable from:

Water Research Commission
Private Bag X03
Gezina
0031

The publication of this report emanates from a report entitled ***The Development of a diagnostics based knowledge management system for the efficient operation and training of staff associated with municipal sewage treatment facilities****”*
(WRC Project No K5/1337).

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ISBN 978-1-77005-791-3

Printed in the Republic of South Africa

EXECUTIVE SUMMARY

DEVELOPMENT OF A KNOWLEDGE MANAGEMENT SYSTEM FOR OPERATION OF THE INTEGRATED ALGAL PONDING SYSTEM (AIPS)

OVERVIEW

TSI had been approached by the Environmental Biotechnology Research Unit (Rhodes University) in 2001 with respect to providing a solution to the loss of valuable tacit knowledge at Sewage Processing Plants around the country due to high staff turnover. A knowledge management technique, developed by Gerrit Lok, was proposed as a possible solution and a demonstration site was recommended by the Water Research Commission and Rhodes University to evaluate the applicability of this tool.

The Integrated Algal Ponding System (IAPS) project, co-ordinated by the University at the Grahamstown Sewage Works, had thus been targeted for the demonstration of this tool.

BACKGROUND

As part of its contribution towards the country's RDP, in terms of provision of low-cost sanitation for low-income consumers, the Water Research Commission (WRC) had embarked upon the IAPS project in Grahamstown. The IAPS plant constructed at the Grahamstown Disposal Works is a joint project involving the Water Research Commission, Grahamstown Municipality and Rhodes University's Environmental Biotechnology Research Unit (EBRU). It had been designed as both a demonstration plant and a research facility with the objective of promoting acceptance and advancing knowledge in the operation of low-cost photosynthetic water treatment systems.

OBJECTIVES

The primary objective of this initiative was to capture the expertise, skills and knowledge developed by an individual or a team of individuals who have performed demanding tasks at the IAPS. A secondary objective was to develop the decision support system to allow for the simulation of fault conditions with appropriate remedial actions and reference to background support material. One of the main requirements of the diagnostic system was that it should not be another so-called "expert system" but would be a "non-robotic" system. In other words, when used for problem solving, it would actually enhance the learning of the user.

APPROACH

A "hands-on" approach was used in this study to develop a totally comprehensive tool for the layman-operator. Information (both tacit and explicit) was captured via site visits, liasons with plant engineers and operators as well as various sources of literature to provide the input to the decision support engine that would ultimately serve to assist easy assimilation of plant protocol under varying conditions, by the end user.

RESULTS

A Decision Support System was developed on an MS-Access database using web page support for the decision tree and reasoning path. The final product was presented in the form of a CD to the client with installation and operational instructions.

CONCLUSIONS

It is believed that the power and simplicity of such a dynamic tool enhances not only the user's explicit understanding of the process, but also its own value to the business at the end of the day.

RECOMMENDATIONS

It is recommended that the applicability of this tool in other such systems wherein the success of its operation depends upon intangible facets inherent in the human experience, that is explicit knowledge, be investigated further.

ACKNOWLEDGEMENTS

The authors wish to thank the Water Research Commission for the funding of this project and Dr Oliver Hart for his contribution with respect to technical aspects of plant operation.

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1. INTRODUCTION

1.1 THE SANITATION CHALLENGE

In 2000 it was estimated that 2.4 billion people did not have access to basic sanitation, and that a lack of access to sanitation and clean water lead to 1.7 million deaths in that year (WHO, 2002). Furthermore, according to the Global Water Supply and Sanitation Assessment (WHO, 2000), approximately 4 billion cases of diarrhoea each year cause 2.2 million deaths, mostly in children under the age of 5. In 2000 a meeting of world leaders aimed at addressing key global problems resulted in the formulation of eight Millennium Development Goals (UN, 2004). One of the goals aimed at ensuring environmental sustainability included a target to reduce by half the proportion of people without access to hygienic sanitation facilities by 2015. A report released in 2004 (UN, 2004) indicated that progress towards this particular goal in Sub-Saharan was negligible. In Africa as a whole, the number of people with access suitable sanitation increased from 373 million to 471 million between 1990 and 2000. However, "a total of 400 million additional people will need to be provided with access to improved water supply to meet the 2015 target" (WHO, 2000).

Two important roles of sanitation services are, firstly, to break the cycle of faecal-oral transmitted disease (Kitawaki, 2002) and secondly, to reduce the negative impacts of sewage on the environment. Diseases associated with faecally-contaminated water include diarrhoea, dysentery, salmanellosis, cholera and a range of protozoal infections (Cliver and Fayer, 2004). Environmental consequences of poor sanitation include contamination of surface and groundwater sources and may result in eutrophication (Cugier *et al*., 2005). Since the 1950s, the global water utilisation has tripled and it is predicted that by 2025, up to 3.4 billion people will be living in water-stressed countries (UNFPA, 2004). Thus, the need to prevent contamination of both surface and ground water sources through the provision of adequate sanitation for all must remain a priority.

In the past, disposal of sewage in urban areas has relied largely on waterborne reticulation and the subsequent treatment of the wastewater at centralised sewage treatment works (STWs) (Wilderer, 2001 cited in Langergraber and Muellegger, 2005). The effluent requiring treatment is often a combination of domestic and industrial effluent, as well as storm water (Horan, 1990). Treatment technologies themselves range from large stabilization ponds, which are relatively simple to operate, to more technically sophisticated activated sludge systems requiring skilled and experienced operators. The choice of technology will depend on factors such as effluent volumes, climate, discharge standards, land availability and the availability of finances for both construction and operation (Mann & Williamson, 1982; Kitawaki, 2002; Naidoo *et al*., 2002). However, although a range of technologies are available that, under ideal operating conditions, are capable of producing effluent that poses minimal risk to human health or the environment, in light of a recent study by Fatoki *et al*. (2003) the actual performance of such centralised systems must questioned.

The study by Fatoki *et al*. (2003) indicated that a STW in the Eastern Cape Province of South Africa produced an effluent of a quality that failed to meet many of the national effluent discharge guidelines, and therefore posed a threat to the Keiskamma River which is used for drinking, washing and recreation. This finding was supported by earlier research by Antrobus (2002). According to the State of South Africa Population Report (2000), approximately 30% of households in the Eastern Cape Province did not have access to any form of formal sanitation, while 35% and 6% relied on pit and bucket systems, respectively. More recently, advances towards eradication of the bucket system have been achieved in part through provision of waterborne sanitation, which has placed further burden on existing sewage treatment infrastructure. Anecdotal evidence suggests that retention of experienced individuals and their tacit knowledge within the sanitation sector has contributed to the poor record of effluent treatment within South Africa and needs to be addressed as a matter of urgency.

1.2 KNOWLEDGE MANAGEMENT

Skills, heuristics, experience and natural talent, are human elements that play a key role in the natural selection of companies within today's corporate jungle. Capturing this intangible or tacit knowledge for security or well being of a corporate culture has been the focus of industry for some time now. The complexity of such a task is best described by Snowden (1999) in his article on ‘Knowledge Management in Practice’ where he comments that "In seeking to manage knowledge, it is important to understand that we are dealing with a complex, unpredictable and interrelated ecology of individuals, communities, markets and stakeholders, all of whom have their own histories and agendas". The concept of knowledge management is finding application in a wide variety of organizations and could well contribute to improved operation of sewage treatment facilities through the capture of the tacit knowledge of experienced plant operators.

1.3 THE INTEGRATED ALGAL PONDING SYSTEM

Considering the above limitations of conventional domestic wastewater treatment services in the context of a rapidly developing country, it is perhaps appropriate to consider alternative technology types.

Integrated Algal Ponding System (IAPS) technology often comprising a facultative pond followed by one or more High Rate Algal Ponds (HRAP) has received much attention (Oswald, 1988a; Rose *et al*., 1998; Rose *et al*., 2002) and is considered appropriate technology for the treatment of domestic and industrial wastewaters (van Hille & Duncan, 1996; Rose *et al*., 1998). The facultative pond is largely responsible for the removal of organic material (BOD), helminth ova and nitrates while the HRAP, supporting a culture of microalgae, can be extremely effective for the removal of pathogenic microorganisms and ammonia (El Hamouri *et al*., 1994; Rose *et al*., 2002; Brune *et al*., 2003; Rose *et al*., 2006). Apart from the ability of this technology to achieve and maintain the desired standard of treatment, it offers other advantages that should make it particularly applicable to users in developing countries. Algal ponding technology is relatively inexpensive in terms of both capital and operational costs (Brune *et al*., 2003). In gravity-fed systems, the only moving part would be a motor to turn the paddle wheel of the HRAP, and thus the degree of mechanical maintenance and energy requirements of the system are extremely low. Furthermore, due to the robust nature of the system, a full-time highly skilled on-site operator is not required and a single expert could monitor numerous sites without risking the quality of the final product.

As discussed above, one of the most likely causes of the poor treatment of municipal effluent in the Eastern Cape is that volume of wastewater received by many of the existing STWs exceeds their design capacity. The IAPS technology is modular by design and would thus lend itself to construction of additional units as required, provided that the necessary land area was available. As the HRAP is highly effective for the removal of pathogens, and ammonium from wastewater, the addition of one or more of these units to existing STWs should be considered to address the high levels of these contaminants in treated STW effluent in the Eastern Cape.

1.4 OBJECTIVE OF THE STUDY

Various techniques of knowledge management have been developed but the purpose of this report was to demonstrate the applicability of the concept within the effluent treatment sector. More specifically, the purpose was to apply a technique developed by Eskom Enterprises (TSI), under the guidance of G.W. Lok, to capture the tacit knowledge of experts at a demonstration IAPS that has been operated by Rhodes University's Environmental Biotechnology Research Unit (EBRU) in Grahamstown (South Africa) for over a decade.

2. DEFINITIONS

The following definitions for tacit knowledge were derived from the Electrical Power Research Institute (EPRI) (2002):

- Tacit knowledge consists of expertise, skills and knowledge developed, or known, based on previous experience by an individual or a team of individuals, who have performed a demanding task. This knowledge is unique, known only to one or a very few individuals or teams and not available to others in procedures, or through normal training.

- Tacit knowledge is in the minds of team members, and it enables individuals and teams to act, adapt and evolve. It more specifically arises from experience and can be comprised of an advanced mental model or sharp perceptual skills that enable individuals or teams to detect, diagnose and solve problems more quickly than their counterparts. According to EPRI (2002), three types of tacit knowledge exist:

- One type consists of problem detection, decision-making and problem solving skills. This includes people who have expertise in detecting, troubleshooting or diagnosing certain types of problems. Indicators and human senses are being strongly used here.

- The second type of tacit knowledge has to do with seeing relationships and interactions not obvious to others. Experienced people develop more robust and complete mental models of how plants, processes, etc. works, how companies interact, and how an organisation works. Specific experience related to the company.

- The third type relates to corporate history and location of valuable knowledge. People who have worked in an organisation for many years have been exposed to key events, informal notes, documents and records and other people, these workers have assimilated this knowledge as part of their experience base. These people are aware of the rationale behind specific procedures, designs, processes, etc.

3. METHODOLOGY

3.1 INTRODUCTION

The methodology used to capture the tacit knowledge of the experts working on the IAPS was based on analysis of the treatment processes involved and ranking of questions that would enable the collection of conclusions and remedial actions to solve operational problems. It should be noted that this methodology has been developed by Eskom and remains the intellectual property of Eskom. The questions and relevant answers, together with images documenting specific operational conditions or components of the plant were then incorporated into a software-based system that now forms part of the current report. It was envisioned that this software-based tool could then be used during training of operators by helping the trainee to decide on an appropriate course of remedial action in response to a simulated fault condition with which they had not had any prior experience. In this way, they knowledge of the system experts could be transferred rapidly to relatively inexperienced operators.

To assist anyone in using the techniques and tools properly, a methodology was needed to assist the analyst in asking the right questions and leading the process to the correct conclusions. Experts know when something is wrong in a process because of their experience on the plant processes and it is this experience-based ability to detect process faults through early-warning signs that needs to be passed on the inexperienced operators. The challenge with the development of a knowledge management systems, such as that documented in this report, is the identification and formulation of the correct questions.

3.2 DEVELOPMENT OF THE KNOWLEDGE MANAGEMENT SYSTEM

Preliminary discussions with experts on the IAPS technology revealed that the best-suited approach to developing a system for rapid problem-solving and training for future operators of a small sewage treatment works, such as the IAPS, would be to develop a knowledge repository and decision support system that would allow the capturing of experience by simulation of plant and process fault conditions.

The starting point in the development of the decision support system was the identification of critical operational or performance parameters, including those detectable by human senses, that could be measured against plant specifications. The critical parameters could then be evaluated to identify increasing trends towards an ‘out of specification’ condition or could be highlighted when a particular parameter exceeded specified limits. A critical parameter could be any of the human senses or process parameters e.g. smell and visual detection, flow, or analysis conducted and are vital to the control of the plant.

The decision support system was designed by starting with a decision tree, which is a flow chart of all the questions, answers, conclusions and remedies ordered in a logical manner. The design was based on the collection of all possible causes of problems related to plant and processes by discussions with experienced plant personnel. A clear differentiation was made between the possible causes, followed by a prioritisation of the causes according to the experienced probability of occurrence. The questions were then formulated to select the correct priority cause for the plant malfunction.

The Decision Support System (DSS) also took into account the level of job authority required to initiate specific remedies. This is an important aspect as every job entails a specific level of operating authority and consequent safety measures that have to be taken into account when implementing the remedial actions specified by the DSS. For example, in the event that a junior plant operator detects a process fault that require shut-down of the plant, permission for this drastic remedial action would need to be sought from the Plant Supervisor.

The DSS ‘engine’ uses a Microsoft Access Database that controls all the permutations of the problem events, questions, conclusions and remedies for the existing problem being experienced. The interaction between the application and the database is controlled using the Internet Explorer that displays the conclusion and remedial action pages. Executable scripts allow the web to enable interaction between the server and the browser sited on the user’s computer.

4. DECISION TREE

Computer-based systems are by their nature difficult to describe and it was therefore considered appropriate to demonstrate how the system functions using a specific example of a decision tree methodology. Generally, the development of the decision tree involved four main steps:

1. *Identify the processes*: Usually these are only the main or critical processes. The process, that has little impact on the behaviour or the system of processes together, is not feasible to evaluate. Processes are usually described by verbs.

2. *For each process identified in step 1, list the inputs*: The inputs can have an effect on the process and can lead to undesirable output or behaviours. An input should be a noun.

3. *List the undesired outputs or behaviours*: Most processes have outputs. Either it can be a definite output or it can determine behaviour of a system. Defining the main outputs or behaviours that are undesirable forms the starting point of solving process-related problems.

4. *Development of the decision tree*: Once steps 1-3 have been completed then it is possible to design the main decision tree. An example of the process, as applied to the IAPS, is illustrated below.

EXAMPLE 1

Step 1: Identification of processes in the IAPS:

- Grit removal
- Inlet weir control
- Primary digestion and fermentation
- High Rate Algal Ponding
- Algal settling
- Drying of algal sludge

Step 2: Establish inputs and outputs

- Raw sewage is pumped from the Grahamstown municipality sewage plant to the IAPS inlet grit removal process.

Step 3: Indicators (identification of undesirable conditions)

The next step in constructing the decision support system is to determine the behaviours that are undesirable to each individual plant process. Two main indicators describe the output behaviour of the IAPS processes. They are:

- The human senses used to detect undesirable behaviour of the plant processes, e.g. rotten egg smell.
- More sophisticated indicators like flow, microbiological and chemical parameters being measured.

The indicators describing the behaviour of the processes can be summarised as shown in Table 1. It should be noted that the process condition descriptors are a combination of those that are easily detected using the senses and those that require more sophisticated analytical data. These process behaviour indicators are then used to develop the questions used to populate the decision tree.

Step 4: Development of questions and the decision tree

Usually the first question is the most important question, which can lead to diagnoses of all other possible plant processes.

The first question to start the process can thus be:

1. <u>Is there a problem detected with the plant?</u>

The phrasing of this question is important, as are all other questions in this tool. It must not provide a solution before prompting the user for an input. In phrasing the question in this way, the user will need to make use of his senses (sight, smell, etc.) to initiate a search path one would need to take. This will lead the user of the system to a "Yes or No" selection. If "no" is selected then the daily tasks can be started. The "Yes" selection initiates the start of the rest of the decision support system.

The second question will help to guide the user to select the process-related problem. It should be noted that the possible answers to the various questions incorporate the tacit knowledge of the expert.

Table 1: Performance indicators for the IAPS

Process Description	Process output behaviour indicator
Grit removal	• High grit concentration to weir
Inlet weir control process	• No/Low flow • High flow to PFP
Primary digestion and the fermentation process.	• Fermentation pH <7 • Helminth eggs>0 • Odor – Rotten eggs • Leaves and scum on surface. • pH<7 at pond effluent. • Settable solids > 0 mgl water level in pond too high. • Methane gas appears intensively across pond surface. • Ammonia >27 mgl^{-1}
High Rate Algal Ponds	• pH<7 • V-Notch level between PFP and HROP, high • V-Notch level between PFP and HROP, low • Algae colour is brown to yellow. • Paddle wheel not turn properly. • Ammonia level >0 • Coliform>0 (filtered)
Algal settling	• Persistent odour • Scum on settling pond surface.
Drying of algal sludge	• Persistent odour

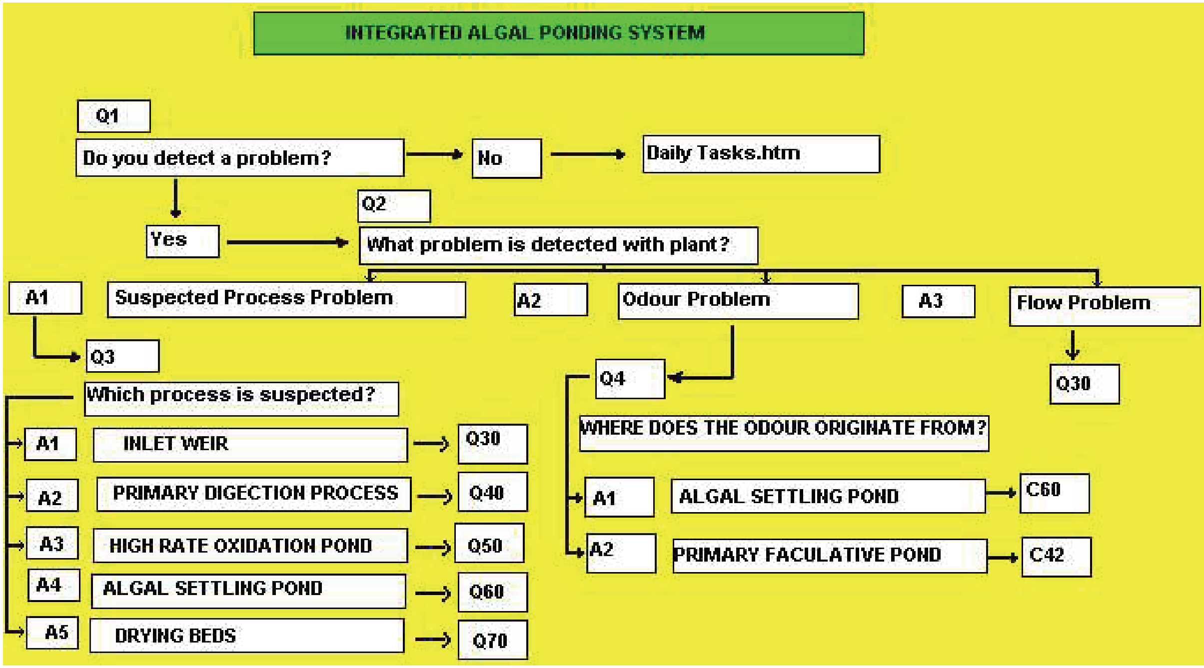
2. What problem is detected?

For the IAPS, the answers or options given to the user to select were:

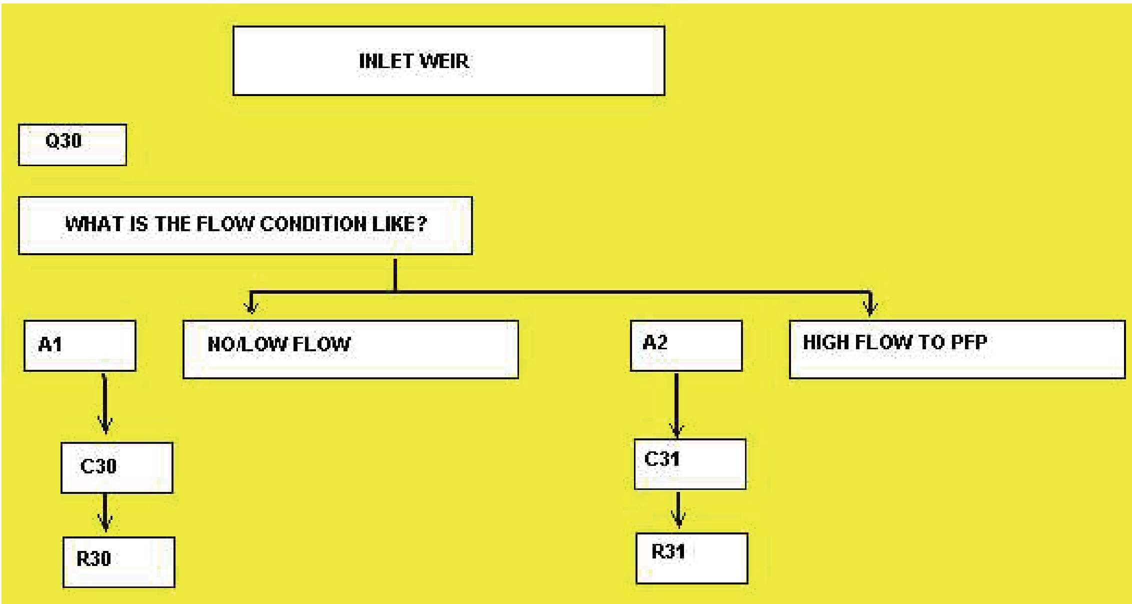
1. There is an odor (smell)
2. There is a flow problem
3. There is a suspected problem with one of the processes.

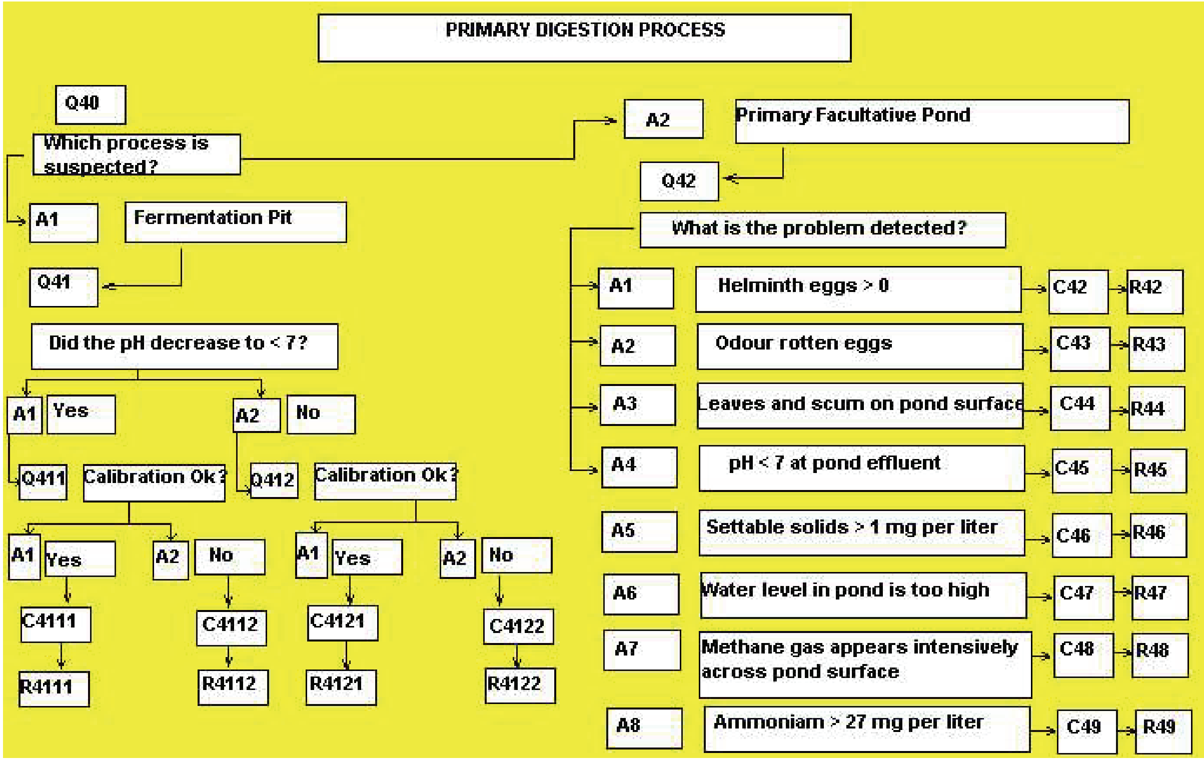
These options are determined from the outputs or behaviours defined as ‘undesirable’ using human senses.

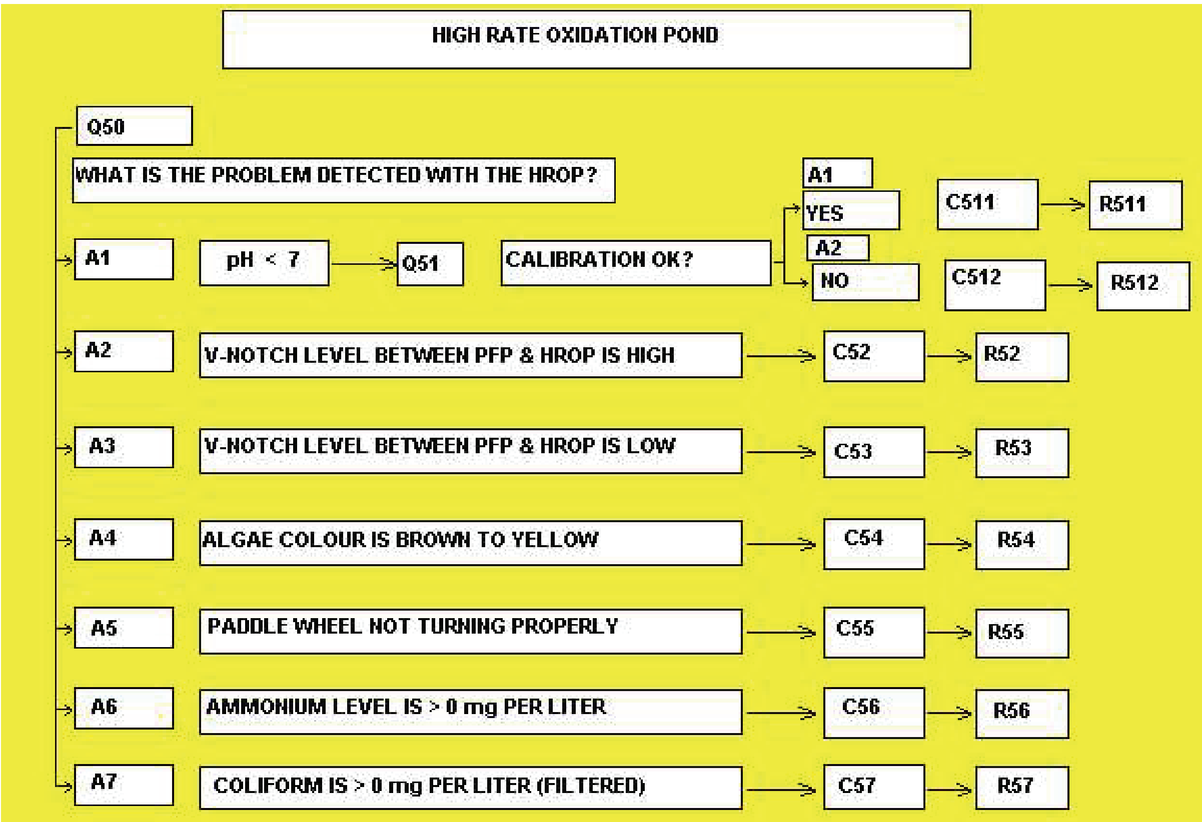
Each option or answer from the first question must be expanded with further questions, answers, conclusions and remedial actions. To illustrate the expansion, decision trees relevant to the IAPS are illustrated below.

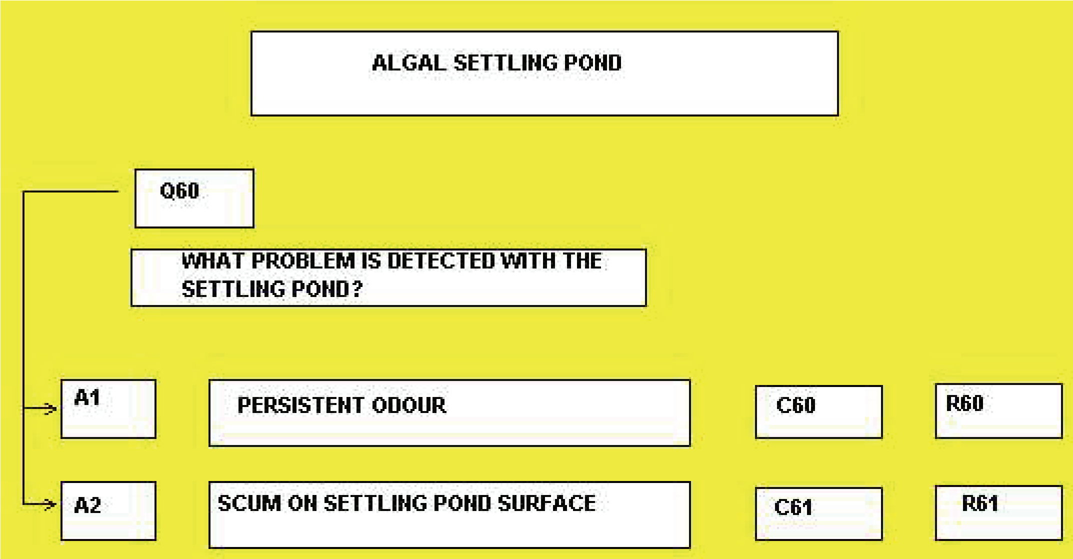


The four questions (Q1-Q4) in the slide above depict how the decision support system can lead the user to any part of a process through the selection of available answers (A). The following slides illustrate how initial questions and answers lead to further questions until a point is reached where the correct course of remedial action has been identified.




PRIMARY DIGESTION PROCESS
Q40
Which process is suspected?
A1
Fermentation Pit
A2
Primary Facultative Pond
Q41
Did the pH decrease to < 7?
A1
Yes
A2
No
Q411
Calibration Ok?
Q412
Calibration Ok?
A1
Yes
A2
No
A1
Yes
A2
No
C4111
C4112
C4121
C4122
R4111
R4112
R4121
R4122
Q42
What is the problem detected?
A1
Helminth eggs > 0
C42
R42
A2
Odour rotten eggs
C43
R43
A3
Leaves and scum on pond surface
C44
R44
A4
pH < 7 at pond effluent
C45
R45
A5
Settable solids > 1 mg per liter
C46
R46
A6
Water level in pond is too high
C47
R47
A7
Methane gas appears intensively across pond surface
C48
R48
A8
Ammoniam > 27 mg per liter
C49
R49


HIGH RATE OXIDATION POND
Q50
WHAT IS THE PROBLEM DETECTED WITH THE HROP?
A1
pH < 7
Q51
CALIBRATION OK?
A1
YES
C511
R511
A2
NO
C512
R512
A2
V-NOTCH LEVEL BETWEEN PFP & HROP IS HIGH
C52
R52
A3
V-NOTCH LEVEL BETWEEN PFP & HROP IS LOW
C53
R53
A4
ALGAE COLOUR IS BROWN TO YELLOW
C54
R54
A5
PADDLE WHEEL NOT TURNING PROPERLY
C55
R55
A6
AMMONIUM LEVEL IS > 0 mg PER LITER
C56
R56
A7
COLIFORM IS > 0 mg PER LITER (FILTERED)
C57
R57



Following the finalisation of the layout of the decision tree, the questions, answers and conclusions are then used to populate a database. The function of the database is to control the possibilities shown in the decision support layout. Developing the DSS for the IAPS (as illustrated above) is no different from any other system to which this tool might be applied, including larger sewage treatment plants or another organisation. The objectives could be different, e.g. identify and capture reasons for success and scope of knowledge of a senior corporate manager or even a plant engineer, but the reasoning behind the development of the decision tree is the same.

Populating the DSS engine is the most time-consuming part of the project. It involves creating reasoning paths within the DSS engine (MS Access database) derived from the decision tree and creating hyperlinks with web pages inside the process sub-directory, which will reside in the reasoning path. The web pages will contain the conclusions, remedies and support information. The support documentation includes both generic and specific information on all aspects of the plant that in turn includes graphical/pictorial detail of process and process problems as well as video clips in MPEG format. The entire tool serves to provide a complete layman's guide to understanding the system processes in an efficient manner, without burdening the user with irrelevant information that is not pertinent to the query. Thus, a user may use the system to identify a cause to a particular problem via hyperlinks to specific points on the support material, without having to browse through the entire documentation.

The user makes use of the DSS by running the visual basic software application on a computer with the following specifications:

5. SYSTEM REQUIREMENTS

5.1 SOFTWARE REQUIREMENTS

The application was developed and tested for the following operating systems:

Operating Systems	• Windows 95 (Service Pack 1) • Windows 98 • Windows 2000 (Service Pack 2)
Internet Explorer	Version 5.X or later

5.2 HARDWARE REQUIREMENTS

The total disk space needed for the installation is approximately 4MB. A Pentium I will be sufficient for this application to run properly.
NOTE: Keep in mind that the database can grow as the user populates it and can require extra hard disk space.

6. INSTALLATION

6.1 INSTALLATION REQUIREMENTS

It is required that all programs are closed to ensure a proper installation. Make sure that no programs are running.

6.2 INSTALLATION INSTRUCTIONS

The installation is supplied on a CD. Please follow the following installation instructions:

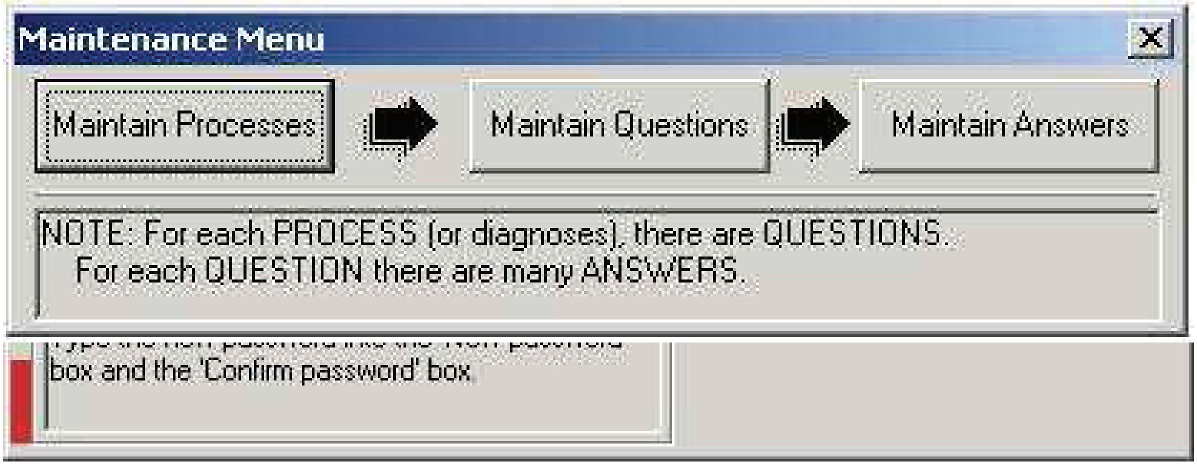
1. Insert the CD-ROM into your CD-ROM Drive.
2. Click on the start button on your Windows main menu.
3. Select RUN.
4. Click on BROWSE.
5. Select the CD ROM Drive (e.g. D)
6. Inside the CD-ROM, open the Set-up directory.
7. Select the Setup.EXE file and click OPEN
8. Back at the RUN menu, click OK.
9. The Setup will now continue as normal. Follow the on-screen instructions to complete the setup.

7. MAINTENANCE INSTRUCTIONS

7.1 LOGGING ON

- Click on the Edit menu, and select the Maintenance item. Alternatively, you can select icon on the toolbar
- A logon dialog box, like the one below, will appear
- Inside this box you can type in the administrator's password. By default this password will be 'password'. You can click on 'Change Password' to change the password. However, you must type in a valid password before you can enter the 'Change Password' dialog box. In the change password dialog box, type in the new password into the '"New password' and 'Confirm Password' boxes. Click OK.
    - To logon, type in the correct password, and click OK inside the Logon dialog box.

- The maintenance navigator will open, from where you can maintain the process, question and answer information.



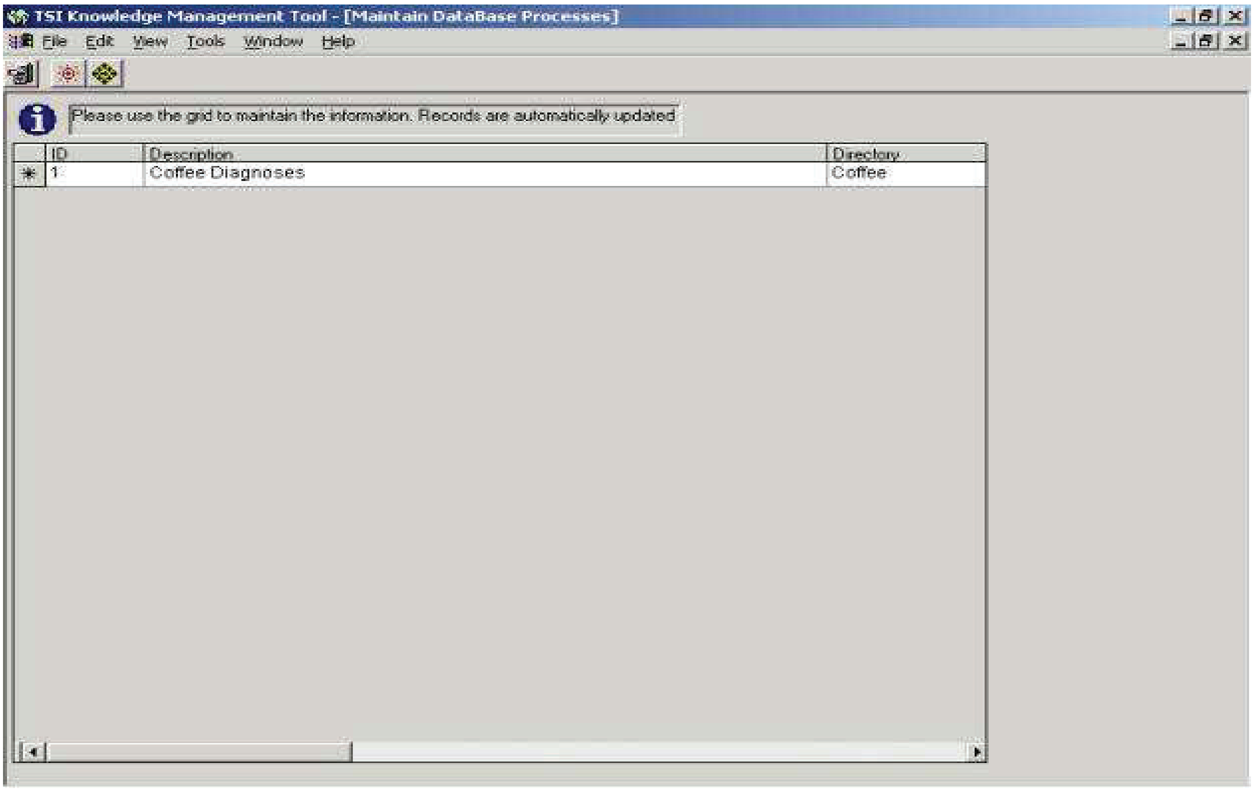
7.2 CAPTURING THE PROCESS INFORMATION

The first step is to capture the process information including conclusions and remedies. In the current system, the conclusions and remedies were HTML files that could not be stored within the database. Therefore, the information path was specified as the main path, and each process specified only the sub path where its information could be found.

For example, the information path was set to 'C:\Data\Knowledge Management Tool\Processes'.

7.3 OPENING THE PROCESS SCREEN

- From the Maintenance Menu, click on Maintain Process
- A process maintenance screen will appear as below



7.4 MAINTAINING THE PROCESS DATA

- Type in the next number in the list. If list is empty, start at 1. If the last number is 1 as in the above screen, type in 2.
- Type in the description of the process or diagnoses.
- Type in the sub directory name that will reside in the information path for this process.

NOTE:

- The information will be saved, as it is typed into the grid. No save button is necessary. However, it is necessary to exit the current cell on the grid to activate the change
- Also note the ID of the process added. This will be the reference inside other maintenance tables.

7.5 CAPTURING THE QUESTIONS FOR THE PROCESS

From the decision trees, one can determine all the questions to be typed into this screen.

7.5.1 *Opening the questions maintenance screen*

- From the Maintenance Menu, click on Maintain Questions.
- A process maintenance screen will appear.

7.5.2 *Updating the questions*

- Select the process to add the questions for.
- Select the next question number. Type in 1 if this is the first question. If the highest question number is 2, type in 3 for that process. Type this number into the 'Question No.' field.
- Type in the question into the 'Question Text' field.
- Type in the name of the question support page, which needs to be stored in the selected process' directory as specified on the process maintenance page. The question support page is important, because it helps the user of the system to understand which answer to choose for the question.

7.6 CAPTURING THE ANSWERS TO EACH QUESTION

7.6.1 *Opening the answers maintenance screen*

- From the Maintenance Menu, click on Maintain Answers.
- A process maintenance screen will appear.

7.6.2 *Updating the answers*

- Select the process and question for which an answer is required.
- Select the next answer number. Type in 1 if this is the first question. If the highest question number is 2, type in 3 for that process. Type this number into the 'Answer ' field.
- Type the answer into the 'Answer Text' field.
- Type in either a C or a Q for ‘Conclusion’ or ‘Question’, respectively, and press TAB. This will automatically enter the word ‘conclusion’ or ‘question’ for you.
- If there is a follow-up question number, type in the follow up question. This will only be enforced if the follow on type is a question.
- If the follow on type is a conclusion, type in the name of the conclusion page.
- Type in the name of the question support page, which needs to be stored in the selected process' directory as specified on the process maintenance page. The

question support page is important, because it helps the user of the system to understand which answer to choose for the question.

7.7 BACKUP OF THE DATABASE INFORMATION

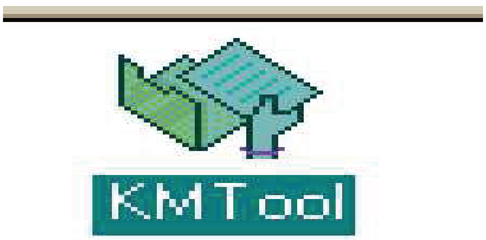
The administrator of the tool is responsible for backup of the database and the process information pages. However, there is functionality inside the system that copies the database to a different path. It is important to note that backups should not be placed on the same physical drive as the database. To backup (copy) the database to another path, do the following:

- On the Tools menu, select the Options menu item.
- On the dialog, select the Backup Database button.
- Select the path to copy the database to.
- Click OK.

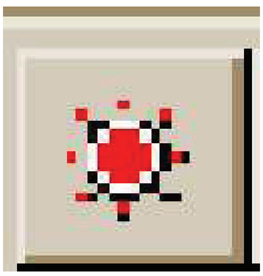
If you select Cancel when selecting the backup path, the database will not be copied.

8. USER INSTRUCTIONS

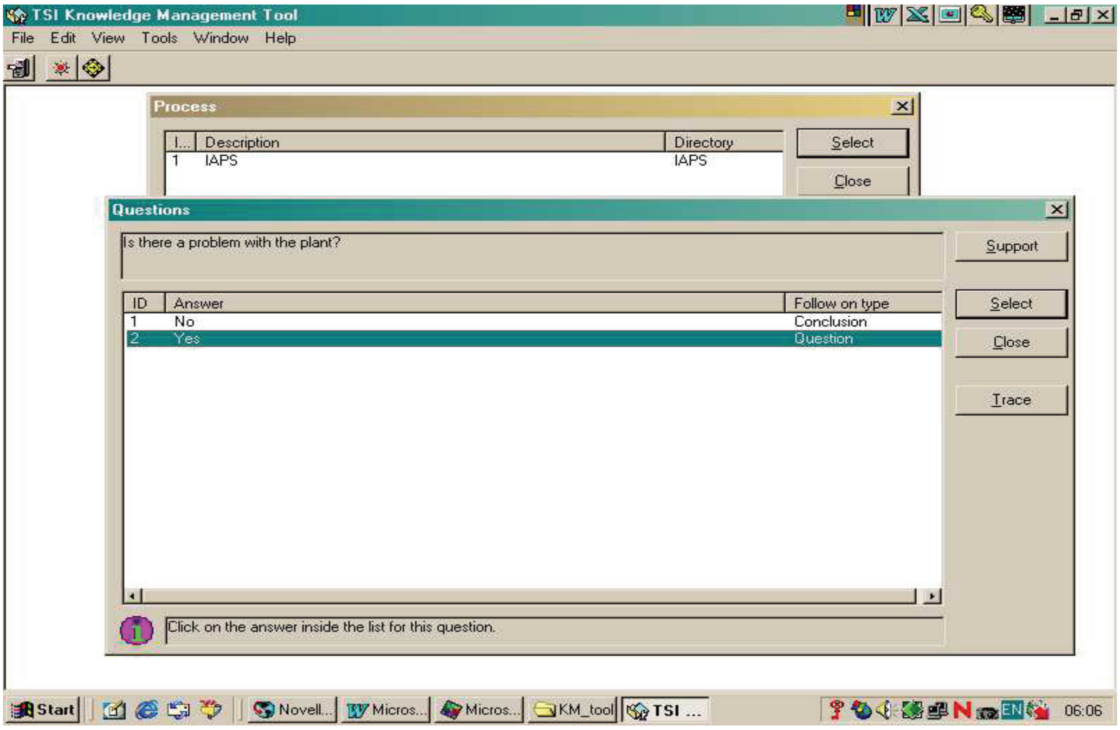
Open the ‘KM Tool’ directory and click on the ‘KM Tool’ icon:



Click on the process icon:



The query path may then be followed by highlighting the applicable answers in the cascade of questions along the decision path until a conclusion and remedy is reached.



9. CONCLUSIONS AND RECOMMENDATIONS

The current technical report describes the development of a software-based decision-support tool and its applicability to the capture and dissemination of tacit knowledge within the sewage treatment sector. More specifically, the tool was applied to the IAPS – a low cost, robust algal-based effluent treatment system.

Although the current decision support tool has not yet been used formally to train operators of IAPS, initial tests confirmed that the system could assist non-experts to correctly identify process problems and then decide on appropriate remedial measures. It is recommended that further tests be conducted on the software, specifically to confirm its applicability to accelerated training of plant operators. In addition, the tool could be applied to conventional sewage treatment plants such as activated sludge systems that are used in many cities and towns around South Africa.

10. REFERENCES

Antrobus, S.J. (2002). The Feasibility of the Independent High Rate Algal Pond as a Technology for the Improvement of Sewage Treatment in the Eastern Cape. MSc Thesis, Rhodes University.

Brune, D.E., Schwartz, G., Eversole, A.G., Collier, J.A. and Schwedler, T.E. 2003. Intensification of pond aquaculture and high rate photosynthetic systems. *Aquacultural Engineering*, 28: 65–86.

Cliver, D.O. and Fayer, R., (2004). Section V: Categories of waterborne disease organisms, in Cotruvo, J.A., Dufour, A., Rees, G., Bartram, J., Carr, R., Cliver, D.O., Craun, G.F., Fayer, R. and Gannon, V.P.J. (eds), *Waterborne Zoonoses: Identification, causes and control.* IWA Publishing, London: 209 – 333.

Cugier, P., Billen, G., Guillaud, J.F., Garnier, J. and Ménesguen, A. 2005. Modelling the eutrophication of the Seine Bight (France) under historical, present and future riverine nutrient loading. *Journal of Hydrology*, 304: 391-396.

Electrical Power Research Institute. 2002. 'Guideline for capturing valuable undocumented knowledge from Energy Industry personnel.' - Report no. 1004663, March 2002. (restricted use within Eskom and Eskom contractors/co-workers).

El Hamouri, B., Khallayoune, K., Rhallabi, N. and Chalabi, M. 1994. High-Rate Algal Pond performances in faecal coliforms and helminth egg removals. *Water Research*, 28: 171–174.

Fatoki, O.S., Gogwana, P. and Ogunfowokan, A.O. 2003. Pollution assessment in the Keiskamma River and in the impoundment downstream. *Water SA*, 29 (2): 183-187.

Horan, NJ. 1990. *Biological Wastewater Treatment Systems: theory and operation*. John Wiley & Sons Ltd, Chichester, UK.

Kitawaki, H. 2002. Common problems in water supply and sanitation in developing countries. *International Review for Environmental Strategies*, 3: 264-273.

Langergraber, G. and Muellegger, E. 2005. Ecological Sanitation – a way to solve global problems? *Environment International*, 31: 433–444.

Mann, H.T. and Williamson, D. 1982. *Water Treatment and Sanitation: simple methods for rural areas*. The Intermediate Technology Publications, Russell Press Ltd, Nottingham, UK.

Naidoo, K., Ndlovu, V., Mjadu, L., Goatley, K.T. and Kerdachi, D.A. 2002. The exceptional simultaneous removal of carbon, nitrogen and phosphorus in a simple activated sludge treatment system at Kingsburgh wastewater treatment works. *Water SA Special Edition*: WISA Proceedings.

Oswald, W.J. 1988a. Micro-algae and waste-water treatment, in Borowitzka, M.A. & Borowitzka, L.J. (Eds). *Micro-algal Biotechnology*. Cambridge University Press, Cambridge, UK.

Rose, P.D., Boshoff, G.A., van Hille, R.P., Wallace, L.C.M., Dunn, K.M. & Duncan, J.R. 1998. An integrated algal sulphate reducing high rate ponding process for the treatment of acid mine drainage wastewaters. *Biodegradation*, 9: 247-257.

Rose, P.D., Boshoff, G.A. & Molipane, N.P. 2002. Integrated algal ponding systems and the treatment of domestic and industrial wastewaters. Water Research Commission Report TT 192/02, Water Research Commission, Pretoria, South Africa.

Rose, P.D., Wells, C., Dekker, L., Clarke, S., Neba, A., Shipin, O. & Hart, O.O. 2006. Integrated algal ponding systems and the treatment of domestic and industrial wastewaters. Part 4: system performance and tertiary treatment options. Water Research Commission Report TT 193/06, Water Research Commission, Pretoria, South Africa.

Snowden, D. (1999). The principles and practice of knowledge disclosure. *Knowledge Management*, 1(3): 40-45

State of South Africa's Population Report. 2000. Department of Social Services and Poverty Alleviation. Available at http://www.capegateway.gov.za/eng/publications/reports_research/S/17883 (accessed 27 March 2005).

United Nations (UN), 2004. Millennium Development Goals: Progress report. www.un.org/milleniumgoals/mdg2004chart.pdf (accessed 27 March 2005)

United Nations Population Fund (UNFPA), 2004. State of the world population 2004. The Cairo Consensus at ten: population, reproductive health and global effort to end poverty. Available at www.unfpa.org (accessed 27 March 2004)

Van Hille, R. & Duncan, J. 1996. Bioremediation of heavy metal polluted acidic mine drainage effluent by *Spirulina sp*. *Journal of Applied Phycology*, 8 (4-5): 461

WHO / UNICEF 2000. Global water supply and sanitation assessment report. World Health Organisation and United Nations Children's Fund Joint Monitoring Programme (JMP). Available at www.who.int/docstore/water_sanitation_health/Globassessment/GlobalTOC.htm (accessed 27 March 2005).

WHO, 2002. World Health Report 2002: Reducing risks, promoting healthy life. Geneva: WHO. Available at www.who.int/whr/2002/en/ (accessed 27 March 2005).