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WATER POLLUTION VII

Modelling, Measuring and Prediction

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PREFACE

Water Pollution is essentially an interdisciplinary field involving scientists and professionals with a wide variety of expertise ranging from chemists to engineers and from experimentalist to computational scientists. It is also an international field of research as the contamination of our precious water resources goes beyond national borders and is a problem of global concern.

The International Conference on Modelling, Monitoring and Prevention of Water Pollution, held regularly in different locations around the world, provides a forum for the presentation of the latest developments in the field and for their discussion. This book contains most of the papers presented at the 7th Meeting held in Cádiz and organised by the Wessex Institute of Technology of the UK and the University of Cádiz with the collaboration of many distinguished scientists and practitioners.

The papers in this volume present some of the latest results in this important field; work which is essential to understanding the nature of the problem and for proposing appropriate solutions, which may eventually provide the guidelines required to take steps towards the remediation or recovery of water resources.

The sections in the book cover topics such as Groundwater and aquifer contamination; Wastewater treatment and re-use of water; Lakes, rivers and wetlands; Coastal areas and seas; Biological effects; Organic contaminants and agricultural pollution; Oil spills; Mathematical and physical modelling; Experimental and laboratory work; Surveying techniques, monitoring and remote sensing; Remediation studies; and Health, social and economic problems.

The Editors are grateful to all authors for their contributions and to the members of the International Scientific Advisory Committee for having helped to review the papers, thus ensuring the quality of the book.

C.A. Brebbia
D. Almorza
D. Sales
Cádiz, 2003

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Expert system in activated sludge process operation

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Abstract

During the two last decades, the different methods of Artificial Intelligence, especially expert systems, have increasingly been in use. Expert system as a branch of artificial intelligence having high capabilities is used in wastewater treatment plant operation. A knowledge-base expert system called ASPOEX (Activated Sludge Process Operation Expert System) is developed to assist operation in diagnostic and remedy in wastewater treatment using the activated sludge operation.

Created by expert system shell called XIP+, it can diagnose the problems and recommend solutions to handle them in various phases of activated sludge process – aeration tank, secondary clarifier and aeration system.

ASPOEX captures the domain's knowledge in a set of rules and process them using a Backward-chaining technique. This system has explaining capability and uses graphics images to explain recommendation.

1 Introduction

Knowledge and experience are very important in wastewater treatment plant operation, thus expert system has high potential capabilities in this field. Many researchers have been working to distinguish the application of expert system in wastewater treatment plant operation. One of the first research has been carried

out by Johnston [1]. He developed an expert system for recognition problems in activated sludge process.
Other research in this field include:
To develop an expert system for the control of biological phosphorus removal plant by Kirchten and Wilson [2].
To develop an expert system for anaerobic digestion process operation by Barnett and Andrews [3].
To develop an expert system for process control of nitrification in activated sludge process by Ozgur and Stenstrom [4].
For operator training, traditional methods such as classroom training and operating manuals are available; however in experience, these methods are of limited effectiveness. To be effective, classroom training requires much more time than most operation staff available during the first few critical months of operation in a new plant. Since pragmatic operators may not see immediate application of the theoretical knowledge presented, lessons are quickly forgotten. Operating manuals, even if well written, often require careful study to fined practical solution to the existing problems and therefore tend to lay unused. Such problems have led to calls for better training. Problems with activated sludge process operation may be addressed by the development of knowledge base or expert system to support process operation.

2 Expert system

Expert system is a computer program designed to model the problem-solving ability of a human expert. There are two major traits of an expert system we attempt to model in our system: the expert's knowledge and reasoning. To accomplish this, the system must have two principal modules: a knowledge base and inference engine. This simple view of an expert system is illustrated in Figure1.
The knowledge base contains highly specialized knowledge on the problem area as provided by the expert. It includes problem facts, rules, concepts and relationships. The inference engine is the knowledge processor, which is modeled after the expert reasoning. The engine works with the knowledge stored in the knowledge base, to draw conclusions or recommendations.

2.1 Expert system characteristics [5]

-An expert system embodies expertise on some well-focused problem.
-Expert system uses heuristic reasoning to efficiently solve problems.
-Expert system can work under the constraints of uncertain or unknown information using inexact reasoning techniques.
-An expert system can explain how it arrives at a solution and why it asks a question.
-Developing an expert system is an iterative process.
-A trademark of all expert systems is separation of the system's knowledge from its control.

2.2 Major steps of development an expert system [5]

Expert system designers have termed the process of building the system knowledge engineering.
Thus knowledge engineering is the process of building an expert system. Un like conventional programming, developing an expert system is a highly iterative process. The designers partially builds the system, test it, them modifies the system knowledge. This process is repeated throughout the project where the system's knowledge and designers under standing grow with each test.

2.2.1 Assessment

During the assessment phase, studies are conducted to determine the feasibility and justification of the candidate problem. Following this study, the problem is further examined to define the overall goal of the project. This effort specifies the important features and scope of the project and also establishers the needed resources including project personal. Sources of needed knowledge, including experts and various reports, are also identified. After this initial phase of the project, the principal project requirements are defined.

2.2.2 Knowledge acquisition

The objective of the knowledge acquisition phase is to acquire the knowledge on the problem that is used to provide both insight into the problem and the material for the design of the expert system. The process of acquiring organizing studying knowledge is formally known as knowledge acquisition.

2.2.3 Design

Following the knowledge acquisition phase, insight is gained on the best approach for representing the expert's knowledge and problem-solving strategies in the expert system. During the design phase, the overall structure and organization of the system' knowledge are define. Methods are also defined for processing the knowledge. A software tool is chosen that can represent and reason with the system's knowledge in a manner that is similar to the approach taken by the human expert.
During the design phase, an initial prototype system is built. The purpose of the prototype is to provide a vehicle for obtaining a better understanding of the problem. By first building a small system, and reviewing the test result with the domain expert, insight is gained in to additional system requirement. The prototype also serves as the focal point further interview with the expert.
System design is inherently an iterative process where finding from system testing are used to refine the system's knowledge and structure.

2.2.4 Testing

The testing phase is not a separate task, but rather a continual process throughout the project. Following each interview with the domain expert, new knowledge is added to the system.

2.2.5 Documentation
The documentation phase addresses the need to compile all of the project's information into a document that can meet the requirements of both the user and developer of the expert system. The documentation must contain a knowledge dictionary that provides a well-organized presentation of the system's knowledge and problem-solving procedures. It is augmented throughout the project as new knowledge is obtained.

2.2.6 Maintenance
After the system is deployed in the work in environment, it will need to be periodically maintained. An expert system continues to grow and learn. Knowledge isn't static; it grows, evolves, and matures. The system's knowledge may need to be refined or update to meet current needs. Major system requirement changes may also occur that would require a reformation of system specification. Therefore, it is important that an effective maintenance program be established for an expert system project.

3 Activated sludge process operation [6]

The activated sludge process is an aerobic, suspended growth, biological treatment method. It uses the metabolic reaction of microorganisms to produce a high quality effluent by converting and removing substances that have an oxygen demand. This treatment method, witch is usually a secondary treatment process can also be an advanced treatment process. It generally follows a primary clarifier. In activated sludge process (Figure 2) the wastewater enters an aerated tank where previously developed biological floc particles are brought into contact with the organic matter of the wastewater. The organic matter, a carbon and energy source of cell growth, is converted into cell tissue and oxidized and Products. The contents of aeration tank are called mixed liquor.
The aeration tank is a heart of the activated sludge process. Here, air or oxygen is introduced into the system to satisfy the requirements of the microorganism and to keep the activated sludge properly mixed in the aeration tank oxygen is introduced in to the aeration tank by aeration system. Two most common types of aeration systems are subsurface diffusion and mechanical aeration. After the mixed liquor is discharged from an aeration tank, a clarifier separates the suspended solid from the treated wastewater. The concentrated biological solids are then recycle back to the aeration tank to maintain a concentrated population of microorganism to treat wastewater.
The basic activated sludge process has several interrelated components:
-Single or multiple aeration tanks where the biological reactions occur;
-An aeration source to provide adequate oxygen and mixing sources can be compressed air, mechanical aeration.
- A clarifier to separate the biological solids from the treated wastewater.
- A mean of collecting the biological solids in the clarifier and recycling most of them to the aeration tank.

- A mean of removing or wasting excess biological solids from the system.
Knowledge and experience are very important in wastewater treatment plant operation, especially activated sludge process. Operational problems arise from the complexity of process and inability to control inputs. Most process problems can be traced to either an overload of operator's information-processing capabilities or the existence of a knowledge limitation, i.e. insufficient knowledge of the process and its operation. The expert system is identified as an appropriate mean for solving of these problems.

4 Activated Sludge Process Expert System (ASPOEX)

The many units in activated sludge process for example aeration tanks, aeration systems and secondary clarifiers depends on the optimization of involved effective parameters such a biological oxygen demands, dissolved oxygen and sludge retention time. Therefore a successful activated sludge process operation depends on the management and control of these parameters by specialists and skilled staffs. In developing countries such as Iran the application of ASPOEX for management and control of wastewater treatment plants can be assist to solve the human expert deficit problems.

4.1 Knowledge acquisition
First the acquisition of existed information and knowledge are required. Next the organization of this knowledge is used for development of a knowledge base.
Any information and knowledge have been used during this study have achieved from Environmental Protection Agency (EPA) and Water Pollution Control Federation (WPCF). This information was completed and organized by using of the results, which had obtained from the experiments in wastewater treatment plants. Figure 3 shows the organization of the ASPOEX knowledge base.

4.2 Knowledge classification
Knowledge was divided to limited knowledge base because their rules and facts were various. For example the problems that is occurred during of activated sludge process are shown in Fig.4.

4.3 Selection of an expert system shell
Considered necessary software is development easily by using of expert system shells. Through out this study XIP+ was used as an expert system shell. The characteristics of this shell are as following:

- Representation of knowledge as rules
-Forward and backward chaining
-Graphic imaging
-Link to other software
-Why and How mechanisms

4.4 Designs and development

Following the knowledge Acquisition phase, most excellent approach for representing the ASPOEX 's knowledge was rule base and best method for problem solving was identified backward chaining technique.

Development of expert system program is iterative process. Therefore for design of this software, first a prototype of obtained knowledge concerning to identification of activated sludge process problems was developed. The iterative process finalized the system. This software can be update by new knowledge. With regards the characteristics of shell, this software have why and how mechanism too.

4.5 Testing procedure

Testing for assurance of software was carried out by introduce of actual data. For example introducing of some data ran this procedure for a municipal wastewater treatment with bulking sludge problem. More description is illustrated in Table1.

5 Conclusions

Created by APSOEX, It can diagnose the problems and recommended solutions to handle them in various phases of activated sludge process. The assurance of system is increased by the addition of the results that will obtain from new experiments. By using of expert system the knowledge and experience of human domains can be transfer to the wastewater treatment plants operators.

Table 1: Case study on operation of wastewater treatment plants [7].

Plants located	Wastewater type	Problem type	Remedial	Result
Plant A	Municipal	Bulking sludge Caused by Filamentous type M.parvicella	Anaerobic selector	Remedy bulking sludge
Plant B	Municipal	Bulking sludge Caused by Filamentous type 803	Increase aeration Increase waste sludge	Remedy bulking sludge

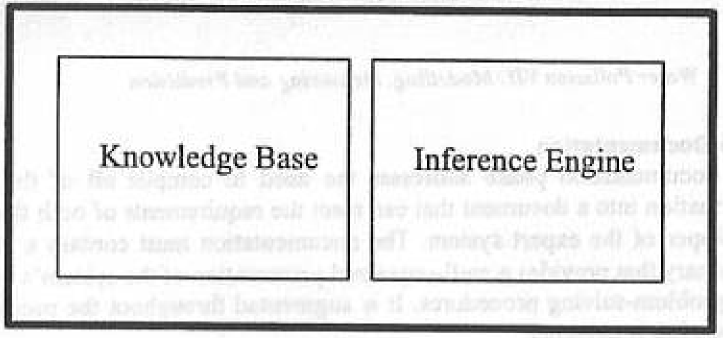


Figure 1: Expert system block diagram

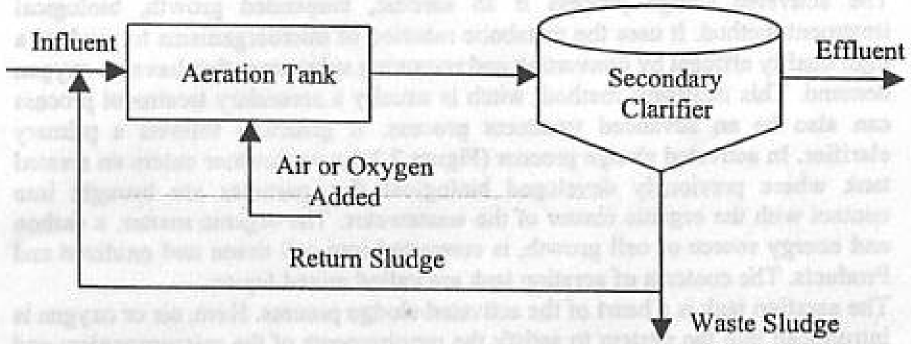


Figure 2: Typical activated sludge process

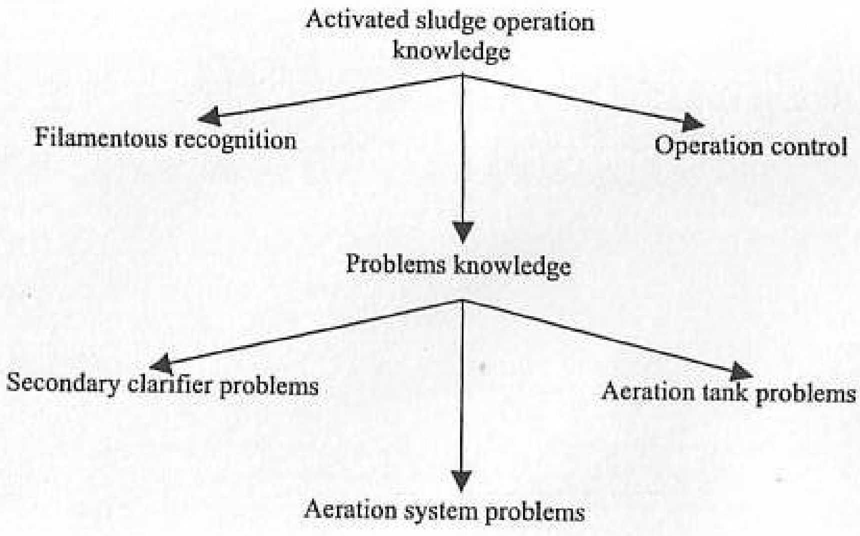
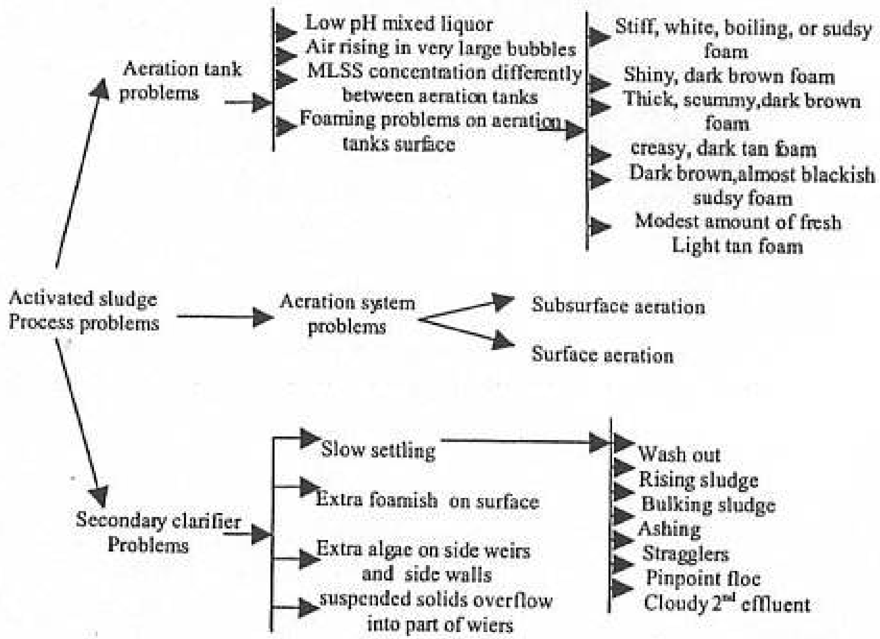


Figure 3: Organization of the ASPOEX knowledge base



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