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Development of an Intelligent Dynamic Modelling System for the Diagnosis of Wastewater Treatment Processes

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: Imran Khalid ………………………………………

Date: 11/10/2010

Abstract

In the 21st Century, water is already a limited and valuable resource, in particular the limited availability of fresh water sources. The projected increase in global population from 6 billion people in 2010 to 9 billion in 2050 will only increase the need for additional water sources to be identified and used. This situation is common in many countries and is frequently exacerbated by drought conditions. Water management planning requires both the efficient use of water sources and, increasingly, the re-use of domestic and industrial wastewaters. A large body of published research spanning several decades is available, and this research study looks specifically at ways of improving the operation of wastewater treatment processes.

Process fault diagnosis is a major challenge for the chemical and process industries, and is also important for wastewater treatment processes. Significant economic and environmental losses can be attributed to inappropriate Abnormal Event Management (AEM) in a chemical/processing operation, and this has been the focus of many researchers. Many researchers are now focusing on the application of several fault diagnosis techniques simultaneously in order to improve and overcome the limitations experienced by the individual techniques. This approach requires resolution of the conflicts ascribed to the individual methods, and incurs additional costs and resources when employing more than one technique. The research study presented in this thesis details a new method of using the available techniques. The proposal is to use different techniques in different roles within the diagnostic approach based upon their inherent individual strengths. The techniques that are excellent for the detection of a fault should be employed in the fault detection, and those best applied to diagnosis are used in the diagnosis section of a diagnostic system.

Two different techniques are used here, namely a mathematical model and data mining are used for detection and diagnosis respectively. A mathematical model is used which is based upon the principal of analytical redundancy in order to establish the presence of a fault in a process (the fault detection), and data mining is

used to produce production rules derived from the historical data for the diagnosis. A dataset from an industrial wastewater treatment facility is used in this study.

A diagnostic algorithm has been developed that employs the techniques identified above. An application in Java was constructed which allows the algorithm to be applied, eventually producing an intelligent modelling agent. Thus the focus of this research work was to develop an intelligent dynamic modelling system (using components such as mathematical model, data mining, diagnostic algorithm, and the dataset) for simulation of, and diagnosis of faults in, a wastewater treatment process where different techniques will be assigned different roles in the diagnostic system.

Results presented in Chapter 5 (section 5.5) show that the application of this combined technique yields better results for detection and diagnosis of faults in a process. Furthermore, the dynamic update of the set value for any process variable (presented in Chapter 5, section 5.2.1) makes possible the detection of any process disturbance for the algorithm, thereby mitigating the issue of false alarms. The successful embedding of both a detection and a diagnostic technique in a single algorithm is a key achievement of this work, thus reducing the time taken to detect and diagnose a fault. In addition, the implementation of the algorithm in the purpose-built software platform proved its practical application and potential to be used in the chemical and processing industries.

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Chapter 1
Research Overview

1.1 Background

Water sources, and their use, cannot be considered as an unlimited resource. The treatment and reuse of wastewater is now accepted practice worldwide and within Australia. Wastewater treatment is a very active area of research yielding many publications, however there are many challenges and significant aspects requiring improvement within the wastewater industries. In broad terms, there are two types of wastewater, namely municipal and industrial. Although different operations produce different wastewaters, the schematic process applied to water treatment is often very similar.

Wastewater treatment facilities are mostly government or state operated and, unlike other chemical and process industries, there is no revenue directly generated from the end product (the reclaimed water), except for reducing the use and cost of freshwater. Reviewing the treatment process highlights the need to increase the efficiency and effectiveness of operation by using a robust fault detection and diagnostic system, optimization of utilities, work force, assets, etc. Models have been developed to assist the engineers and operators understanding of the process, and hence apply effective fault detection and diagnostics and optimization techniques, e.g. Activated Sludge Model (ASM) series (Gujer et al., 1999) and Anaerobic Digestion Model (Copp et al., 2005).

Process fault diagnosis is one of the major challenges facing the chemical and process industries and significant economic and environmental losses can be attributed to poor Abnormal Event Management (AEM). There are two key approaches to fault diagnosis, namely process model based diagnosis and data driven diagnosis. Process model based approaches assume that a fault will cause changes to certain physical parameters, which in turn will lead to changes in some of the model parameters or states. It is then possible to detect and diagnose these faults by monitoring the estimated model parameters or states. This technique uses a diagnostic-driven mathematical model of a process (Simani et al., 2003) and generally exhibits good accuracy, since the process models are developed from the underlying fundamental principles. However, comprehensive theoretical models of complex processes are extremely challenging to develop due to their often inherent non-linear nature. Alternatively the use of computer aided systems means that data driven models are relatively easy to develop, and analysis of the data enables fault identification and diagnosis (Li, 2003).

A comprehensive review of the techniques available for fault detection and diagnostics, the strengths and challenges of each technique, and the key attribute required by an ideal diagnostic system, is given by Venkatasubramanian et al. (2003b, 2003c, 2003a). They determined that no single method has all the ideal desirable features for a diagnostic system, but some of these methods can complement one another resulting in an improved overall diagnostic system. The use of a hybrid system is a promising future research direction leading to developments in diagnostic systems. Integrating these complementary features is one way to develop hybrid systems that may overcome the limitations of an individual strategy. The drawbacks of single-method-based diagnostic systems are serious enough to limit their applications to small case studies and render them unsuitable for large-scale industrial situations. This makes the design and development of hybrid systems important (Venkatasubramanian et al., 2003c).

Few papers have been published on wastewater treatment in relation to process monitoring and control and fault diagnostics (Lee et al. 2006). Since 1998, 29 journal papers were published concerning the application of hybrid fault diagnostic systems. There are only two publications for fault detection and mathematical models (in 2003 and 2008).

1.2 Thesis Objectives

The main objective of this research work was to develop an intelligent modelling system to be used for dynamic simulation, and the diagnosis of wastewater processes using a hybrid of model based (mathematical model) and data driven (inductive data mining) to address the limitations exhibited by the individual approaches. Particular emphasis was placed upon the development of a hybrid diagnostic system for its reliability, flexibility, robustness, relative low-cost of development, and ease of utilization in wastewater treatment processes. The overall objective of this thesis was to develop an effective fault detection and diagnostic platform which employs a hybrid system of a mathematical model and a data driven technique to overcome the limitations of the individual fault detection and diagnostic methodologies. This was achieved by the following approach:

- Develop a software platform using Java for dynamic simulation and fault detection on the wastewater treatment process; this includes the implementation of the model libraries of full-scale wastewater treatment processes.
- Select the most suitable data driven technique for fault detection and then implement on the wastewater treatment data.
- Implement the hybrid algorithm in the Java-based platform; this includes the development of the hybrid algorithm.
- Validate the results against wastewater treatment process data.

1.3 Thesis Outline

The organization of the thesis is as follows:

Chapter 2 discusses in detail the process diagnostics including an overview, the techniques available, and a critical literature review of current developments identifying the limitation of process diagnostics.

Chapter 3 focuses on the wastewater process. It describes briefly the types of operating units in a wastewater process before presenting a mathematical model to be used for the fault detection. It also includes the rational which supports implementation of the derived model over other available process models.

Chapter 4 provides a comparative study of available data driven techniques leading to the selection of the preferred data driven technique (inductive data mining), the wastewater data is then used to generate results. Discussion on the output format of results and manipulation of the format for use in the diagnostic system is also included.

Chapter 5 contains the development of the software platform in Java and discusses its flexibility, ease of use, and customization. The wastewater model is imported and initial simulation results are discussed. It includes the development of the algorithm for a hybrid approach of the model plus data driven technique. The results and validation of the wastewater data are presented together with the accuracy and the computational efficiency.

Chapter 6 presents the research conclusions, and identifies areas of research recommended for further study.

Chapter 2

Literature Review

2.1 Introduction

This chapter provides a general overview of process diagnosis and wastewater treatment, in addition to a critical review of selected topics. This chapter includes details of hybrid diagnosis systems and the software platform used in wastewater treatment and process diagnosis.

2.2 Process Diagnosis

Diagnosis is defined as “the process of identifying the nature and causes of certain phenomenon”. It has been observed that the word “diagnosis” is always attributed to abnormal phenomenon rather than the normal situation. Similarly, process diagnosis is the study used to identify the nature and causes of an abnormal phenomenon occurring in a process. The abnormal phenomenon in the processing and manufacturing industries is termed a “fault”. Himmelblau (1978) described a fault as a departure from an acceptable range of an observed variable or a calculated parameter associated with a process. Hence, fault is a process abnormality or symptom, such as high temperature in a reactor or low product quality, etc. The underlying causes of this abnormality are called basic events, or root causes. The basic event is also referred to as a malfunction or a failure.

In broad terms, a fault is generally related to one (or more) of three main classes of failures or malfunctions. These are:

Gross parameter changes in a model: Parameter changes arise when there is a disturbance entering the process from the environment. An example is the change in the heat transfer coefficient due to fouling of a heat exchanger.

Structural changes: Structural changes refer to changes in the model itself. They occur due to the equipment hardware failures. An example is a controller failure which would imply that the manipulated variable is no longer functionally dependent on the controlled variable.

Malfunctioning sensors and actuators: Gross errors usually occur with actuators and sensors. These could be due to a fixed failure, a constant bias (positive or negative) or an out-of-range failure.

Process diagnosis is the study undertaken to identify the nature and causes of a fault in a process. This process usually includes the following four steps (Chiang et al., 2001):

Fault Detection - determining if a fault has occurred by observing the values of process variables or by user-defined fault indices.

Fault Identification - identifying the variable most relevant to the fault. The task of this step is to focus the attention of the plant operator on the particular subsystem which is most pertinent to the fault.

Fault Diagnosis - isolating the cause, type, location, and time of the fault.

Process Recovery - removing the fault and bringing the process back to normal conditions, or taking optimal steps to minimize loss of production.

Process diagnosis was traditionally performed by the process operators but this task has became more difficult due to the variety, uncertainty and time delay of malfunctions which can be very complex in their nature,. In the last decade, computer-aided systems have been investigated, implemented and proved to be a successful tool for fault diagnosis. A fault diagnostic system has two main components:

(i) type of knowledge used, and

(ii) type of diagnostic search strategy.

Diagnostic search strategy is usually strongly dependent on the knowledge representation scheme, which in turn is largely influenced by the type of prior knowledge available. Hence, the type of prior knowledge used is the most important distinguishing feature in diagnostic systems. The prior domain knowledge may be developed from a fundamental understanding of the process using a first principles approach. Such knowledge is referred to as deep, causal, or model-based knowledge (Simani et al., 2003). However it may also be obtained from past experience of the process and is then referred to as shallow, compiled, evidential, or process-history-based knowledge.

The process diagnostic techniques can be broadly classified into two categories, i.e. process-model-based methods and process-history-based (data-driven) methods as discussed below.

2.2.1 Process Model Based Methods

These methods use qualitative knowledge and quantitative models extracted from an understanding of the process principles. The models present the interacting relationships between the process variables based upon the assumption that a fault will cause changes to certain physical parameters which in turn lead to changes in some of the model parameters or states. It is then possible to detect and diagnose these faults by monitoring the estimated model parameters or states.

The process model based methods can be further sub-divided into qualitative causal models and quantitative methods (Dash and Venkatasubramanian, 2000, Venkatasubramanian et al., 2003a, 2003b).

Quantitative model based methods

Relying on an explicit model, all model based fault detection and isolation (FDI) methods require two steps. The first step is to generate inconsistencies between the actual and expected behavior, these are called residuals and reflect the potential faults of the system. The second step chooses a decision rule for diagnosis.

Some form of redundancy is required to check for the inconsistencies. There are two types of redundancies, namely hardware and analytical redundancy. Hardware redundancy uses redundant sensors and has been utilized in the control of safety-critical systems such as aircraft, space vehicles and nuclear power plants, but its applicability is limited due to the additional costs and space required. Alternatively, analytical redundancy is achieved from the functional dependence among the process variables and is usually provided by a set of algebraic or differential relationships among the states, the inputs, and the outputs of the system (Lou et al., 1986, Michle, 1988).

The essential element of analytical redundancy is to check the actual system behavior against the system model for consistency. Any inconsistency, expressed as residuals, can be used for detection and isolation purposes. The residuals should be close to zero when no fault occurs, but show a significant value when the underlying system changes. To generate the diagnostic residuals requires an explicit mathematical model of the system. The model may be obtained either analytically using first principles or empirically as a black-box model.

Most of the work on model-based diagnostic systems reported to date was mainly in the aerospace, mechanical or electrical engineering literature. There has not been much published research on its application for fault diagnosis in chemical process systems. There are some serious limitations that apply for its application in the chemical industries. One issue is the lack of availability, and the complexity, of models for chemical processes and their inherent non-linear nature. In addition to the modelling challenges, the model based qualitative methods do not include an explanation and descriptive facility. Furthermore, an estimation of classification errors cannot be provided when using these methods. Another disadvantage with these methods is that if a fault is not specifically and appropriately modelled, then there is no guarantee that the residuals will be able to detect it.

Qualitative model based methods

Qualitative models are usually developed based on the fundamental understanding of the physics and chemistry of the process. Various forms of qualitative models such as causal models and abstraction hierarchies have been developed. The strategy employed in qualitative models is causal-effect reasoning related to the system behavior. The most popular methods are fault-trees and signed digraphs (SDG). Fault trees (Lapp and Powers, 1977) use backward chaining until a primary event is found that presents a possible root cause for the observed process deviation from normal operation. SDG (Iri et al., 1979) is another representation of the causal information in which the process variables are represented as graph nodes and causal relations by directed arcs. Causal model-based methods mimic human reasoning and so generation of explanation is relatively straightforward making them more interactive. There were drawbacks of the early SDG methods mainly because their expressive capability is often limited (Hunag and Wang, 1999a). In an SDG, a node or a branch can often only take three values. i.e., -, 0, and + representing for example low, normal and high values for a node. This over simplified expression could create ambiguous solutions.

The two main concerns with qualitative model based methods are ambiguities and spurious/inauthentic solutions. Considerable research has been done in relation to the reduction of spurious solutions while reasoning with qualitative models.

2.2.2 Process History Based Methods

In contrast to the model-based approaches where a priori knowledge (either quantitative or qualitative) about the process is needed, in process history based methods, only the availability of a large amount of historical process data is needed. There are different ways in which this data can be transformed and presented as a priori knowledge to a diagnostic system. This is known as feature extraction, and this extraction process can be either qualitative or quantitative in nature. Two of the major methods that extract qualitative history information are expert systems and trend modelling methods. Methods that extract quantitative information can be broadly classified as non-statistical or statistical methods. Neural networks are an important class of non-statistical classifiers. Principal component analysis (PCA)/partial least squares (PLS), data mining and statistical pattern classifiers form a major component of statistical feature extraction methods. The knowledge can be available as rules and formulations.

2.3 Hybrid Diagnosis Systems

Venkatasubramanian and co-workers (see Venkatasubramanian et al., 2003b, 2003c, 2003a) have provided a very comprehensive review of the methods available for process diagnosis. A set of desirable characteristics that a diagnostic system should possess were also identified and listed. Different approaches were evaluated against a common set of requirements or standards. From their evaluation, it was revealed that no single method has all the desirable features stipulated for a diagnostic system. It was postulated that some of these methods can complement one another, resulting in better diagnostic systems. Integrating these complementary features is one way to develop hybrid methods that could overcome the limitations of individual solution strategies. Hence, hybrid approaches are attractive where different methods work in conjunction to solve parts of the problem. Although all the methods possess limitations, in the sense that they are only as good as the quality of information provided, it was shown that some methods might be better adapted to the knowledge available than others. For example, fault explanation through a causal chain is best done through the use of digraphs, whereas fault isolation might be very difficult using digraphs due to the qualitative ambiguity and then analytical model-based methods might be superior. It is expected that hybrid methods will provide a general, powerful problem-solving platform.

2.4 Software Platform

One of the challenges in the implementation of a diagnostic system is the software architecture (Venkatasubramanian et al., 2003c). The diagnostic task can be performed either off-line or on-line. In an off-line diagnostic task, the process behavior is recorded in the form of data or graphical trends. This data is then analyzed off-line using a suitable diagnostic method. This type of diagnostic is often used as a preventive action to save the process from repeating the same malfunction. Due to the complexity of chemical processes and the significant losses attributed to the poor management of faults, the online diagnostic is increasingly employed in the chemical industries for corrective actions. The online diagnostic system helps operators and engineers to manage an abnormal event (fault) as soon as it is encountered in the process. Using its knowledge base, the online diagnostic system will search for the most likely culprit for a specific fault. This vital information, along with the prior knowledge that the operators and engineers have about the process, will be critical in the isolation and diagnosis of a fault, thus reducing the losses and downtime and increasing process and personnel safety associated with the management of an abnormal event (fault).

From the literature review (Venkatasubramanian et al., 2003c), a software platform intended to be used for online diagnosis should posses the following characteristics.

i) Flexibility

Flexibility refers to the ability of software to accommodate different configurations of plant items and an ability to use different types of equipment for any unit operation or process. In relation to wastewater treatment where different configurations exist in different facilities due to variations of influents within a region (state or country), the software should have the timely ability to accommodate for such changes in configuration.

ii) Detection algorithm

The software should incorporate an algorithm that is capable of detecting any abnormality in the process. The algorithm will be highly dependent on the type of benchmarking information used to detect faults, i.e. if a mathematical model is used then the algorithm should be able to: (a) obtain values from the mathematical model; (b) obtain information from real processes; and (c) should have the threshold value for noise/bias in real data. After the comparison of values of a process variable from real operations and benchmarking, the algorithm will be able to detect a fault and draw the attention of operators to that variable.

iii) Data/Information import

Based on the detection algorithm requirements, it is essential that the software should be able to obtain information from the control system of a process for use in fault detection. The integration of a diagnostic software platform with the control module in a plant is a major challenge that requires precision skills in software architecture, and the availability of resources (e.g. a distributed control system of a pilot scale plant) for trials to validate the effectiveness, efficiency and robustness to the software platform.

iv) Diagnostic algorithm

After the detection of a fault, the most important aspect of the diagnostic system is to then diagnose the fault. This necessitates a diagnostic algorithm that will diagnose the fault using the knowledge-base used for diagnosis purposes.

v) Results display

An essential ingredient that a diagnostic software platform should possess is the display of diagnostic results in an easily understood format. This may be production rules, fault trees, decision trees, or any other acceptable form of results.

vi) Cost effectiveness

Although management of a fault in a process is essential, and is associated with significant economic benefits, it would be an optimal solution to have a cost effective diagnosis system without compromising the effectiveness of the system. Commercial software such as Gensym G2, which is widely used in the chemical industries for better management of abnormal process conditions, costs between $100,000 and $1 million. Although it may be cost effective, this is a critical investment decision for small-scale and service industries.

2.5 Wastewater Treatment

Water recycling and reuse is now generally accepted and adopted worldwide as an essential water resource. The average composition of municipal wastewater is 99.94% H_2O and 0.06% dissolved and suspended solids, which indicates the potential for the reuse of waste water.

Wastewater treatment facilities can process wastewater using either an aerobic, anaerobic or anoxic process. Each process has its own advantages and disadvantages. Wastewater treatment facilities are mostly government or state operated and, unlike other chemical and process industries, there is no direct revenue generated from the end product, i.e. the reclaimed water (although it can be used for irrigation or drinking purposes). Hence there is more attention given to reducing the running costs by optimization of utilities, workforce, assets, etc. Models have been developed to assist the engineers and operators understanding of the process, e.g. Activated Sludge Model (ASM) series (Gujer et al., 1999) and Anaerobic Digestion Model (Copp et al., 2005). Wastewater processes have been widely researched in recent years. Lee et al. (2006) addressed fault diagnosis of sensors in wastewater treatment processes but the methodology proposed is unable to identify the faulty senor which causes process transitions. Kim et al. (2002) calibrated ASM1 using genetic algorithms but the components of ASM1 were not calibrated in detail. Gernaey et al. (2004) used artificial intelligence and white-box based modelling and simulation for wastewater treatment processes, and demonstrated how different methodologies can complement and support the process knowledge included in white-box activated sludge models. Puteh et al. (1999) present a mathematical model of the aeration tank and the secondary settler of a wastewater treatment facility, proposing that the performance of wastewater treatment processes consisting of an incomplete mixing reactor described by tanks-in-series model is better than that of a completely mixed aeration tank. Rigger et al. (2006) proposed a model for the response time of the aeration systems concluding that if more calibrated applications of the aeration system model are available, it should be possible to develop a classification system for design purposes. Wintgens et al. (2003) presented the modelling of a membrane bioreactor replacing the conventional aeration system in wastewater treatment processes, which is more efficient than the traditional aeration tank in terms of investment cost but the operating cost is higher. Van Hulle and Vanrolleghem (2004) showed that model-based optimization is an efficient and cost-effective way to ensure that an industrial wastewater treatment plant functions well, but a more holistic evaluation is required before the proposed methodology can be applied.

Much research on wastewater is related to the treatment of industrial wastewaters with very specific requirements. Acharya et al. (2009b,2009a) used activated carbon prepared from Tamarind wood with zinc chloride activation for the removal of lead (II) and chromium (VI) from industrial wastewater. Hunag et al. (2009) developed an integrated neural-fuzzy process controller to control aeration in an aerated submerged biofilm wastewater treatment process (ASBWTP) which saved 33% of the operating costs during the time when the controller was used. Pai (2008) employed grey models (GM) to predict the effluent quality of a wastewater and compared the results with the use of artificial neural networks (ANN). The results indicated that GM can be used for effluent prediction while using less data than required in ANN. The amount of research work reported on wastewater is significant, and wastewater is indeed one research area that has attracted major attention worldwide.

2.6 Concluding Remarks

Process diagnosis is a key research area receiving significant attention from both academia and industry. In recent years this has lead to significant process improvements in abnormal event management with proposals for numerous new techniques. With the development of these techniques, the focus of research should now be on the development of a hybrid methodology that can address the weaknesses of individual techniques in order to further enhance the effectiveness of process diagnostics. So far, this area has not been studied in depth.

By comparison with other chemical processes, the wastewater treatment process is quite small in terms of the processes involved and the physical size of a facility. Furthermore, as discussed in Section 2.5, a municipal wastewater facility does not generate any direct revenue from its process, unless it is involved in the treatment of an industrial wastewater. Hence, the optimization of capital and operating costs must be a key focus. A purpose-built, cheap and effective software platform that can be used for process diagnosis in wastewater treatment, or any other small chemical industry, is one application for budget optimization. A significant contribution of this research study is the development of a flexible and low-cost software platform.

Chapter 3
Process Model-Based Methods for Wastewater Treatment Processes

3.1 Introduction

In this chapter, Sections 3.1 to 3.7 present the necessary background understanding of the typical wastewater treatment process. There is a significant amount of published literature on wastewater treatment processes and this large volume of information can pose a problem for someone new to this field needing an overview of the essential processes involved in water treatment. Therefore Sections 3.1-3.7 present a comprehensive, yet concise, review of wastewater and its treatment.

Process Model-Based (PMB) methods/techniques for Fault Detection and Diagnosis (FDD) are then discussed from Section 3.8. PMB methods are generally classified as quantitative or qualitative. An introduction and brief discussion of the quantitative and qualitative PMB techniques are presented, followed by explanation of how mathematical modelling will be used in this work for FDD. A mathematical model of a municipal wastewater treatment plant is presented in Section 3.10. Results obtained from the process simulations are reported and discussed in Section 3.11.

3.2 Wastewater

Wastewater is a general term for any water that has been used for either domestic or industrial purposes, and hence becomes contaminated by various waste materials. It can contain human excreta, food waste, and industrial toxins, along with many other pollutants in the form of dissolved and suspended material, and hence is unfit for human consumption and can damage aquatic systems. The composition of wastewater in terms of the water itself and the contained wastes varies widely between countries, and within each country, but the average composition of a wastewater is around 99% water and 1% solid.

Water shortages and deterioration in quality are major challenges faced by many countries, especially those pursuing economic and social development. Due to population growth and the associated increased use of water for agriculture, industry and recreation, the human consumption of natural waters has steadily increased over several centuries thus making it an increasingly valuable resource. This situation had lead many researchers to think about whether there will be enough water to accommodate the needs of future generations (Kumar, 2004). Water management strategies and specific techniques are being adopted in many countries for optimum water utilization based on defined water policies. Wastewater treatment compliments water management in two ways: (1) it increases the total available water resource by converting the wastewater into useable water; and (2) when the treated wastewater is discharged into a receiving body (lakes or rivers) after treatment, it does not deteriorate the overall water quality by being free from pollutants that may affect the aquatic system.

The composition of wastewater indicates the great potential for the application of wastewater treatment processes. Wastewater treatment is being increasingly adopted worldwide for optimizing water management systems.

3.3 Wastewater Treatment

Wastewater treatment is defined as the processing of wastewater for the removal or reduction of all undesirable constituents. Three types of processes are involved in the treatment of wastewater:

a) Mechanical,

b) Biological, and

c) Chemical.

Mechanical or physical treatment processes are used for the removal of large objects, heavy inorganic matter, oil, greases and particulate solids from the raw wastewater before it is treated using biological processes.

The biological process then converts the influent from mechanical treatment unit, to be almost free from dissolved and suspended solids (pollutants). This goal is achieved by the action of microorganisms that thrive on the pollutants in wastewater for their nutrients. Oxygen is required in this treatment stage as it is essential for the survival of living organisms.

The main purpose of chemical treatment is to achieve the final required water quality (specification) before it can be sent to a receiving body. Chemical agents, such as chlorine gas, are mainly used for disinfection of water in order to kill any microorganisms remaining after the biological treatment stage.

In any type of wastewater treatment plant, there are essentially the following stages:

a) Preliminary treatment,

b) Primary treatment,

c) Secondary treatment,

d) Tertiary treatment and

e) Advanced treatment systems.

The last stage, i.e. tertiary treatment, depends on the specified required quality for the effluent water and, unless a high quality of water is required, this stage is seldom used in treatment plants.

A typical preliminary treatment stage consists of screens, comminutors and grits. Only mechanical treatment is carried out in the preliminary stage. In the primary treatment stage, heavy solids and oils or greases are separated from the wastewater using gravity action in a sedimentation tank often called a primary settler/clarifier. Effluent from the primary settler/clarifier is treated in a bio-reactor where microorganisms eliminate, or significantly reduce, the amount of dissolved and suspended matter (pollutants). The effluent is then passed to a secondary settler where the clean water as supernatant is either released into the receiving body or is passed to tertiary treatment for further purification. Settled solids at the bottom of the settler are either recycled back to the reactor or disposed of after further treatment. The bio-reactor and the secondary settler comprise the secondary stage for wastewater treatment. An example of a typical wastewater treatment plant is given in the schematic of Figure 3.1.

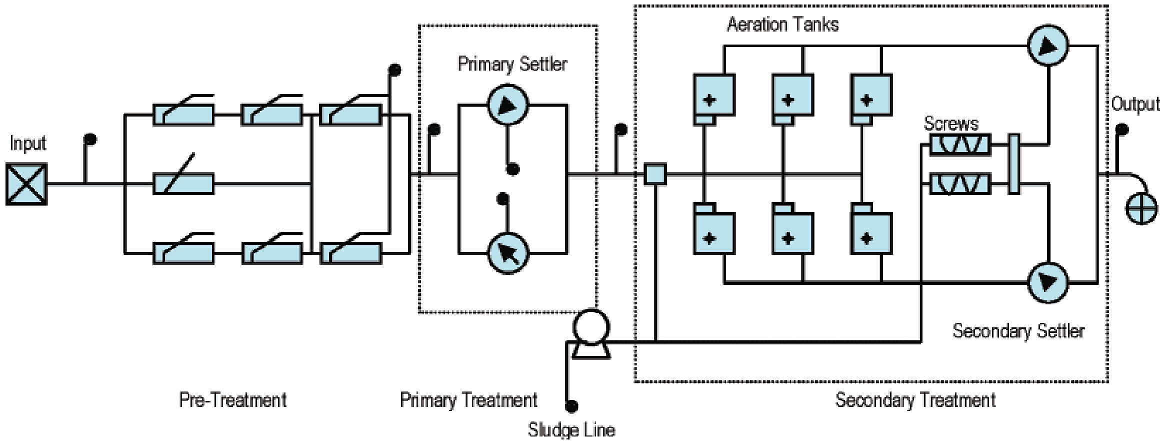


Figure 3.1 Structure of a wastewater treatment plant (Wang et al., 2004)

Wastewater has to pass through these three treatment stages before it can be released back into the environment. The following section provides further details of these stages and the equipment used in each stage.

3.4 Preliminary Treatment Stage

The preliminary stage consists of screens, comminutors and grits. A screen is a device with openings of uniform size that is used to retain solids present in the influent wastewater. Its principal role is to remove coarse material from the influent that could damage subsequent process equipment (Tchobanoglous et al., 2003). Screens are followed by Comminutors which are used to reduce the particle size of wastewater solids as large, stringy solids can easily plug pump impellers (Degremont., 1991, Forster, 2003). The last unit in the primary treatment is Grit chamber which is used to remove the heavy inorganic material present in wastewater, such as sand, eggshells, gravel and cinders, which have settling velocities and specific gravities substantially greater than the organic solids in the wastewater. (Tchobanoglous et al., 2003). Only mechanical treatment of wastewater is carried out with the aim to eliminate the large sized materials and heavy inorganic material from the wastewater before it can enter the primary settler for further purification.

3.5 Primary Treatment Stage

After the preliminary treatment of raw wastewater, the remaining solids are extracted by gravity in large sedimentation tanks in the primary stage of treatment. Sedimentation tanks further slow the influent flow of wastewater so that organic and inorganic suspended solids can settle to the bottom of the clarifiers. Floatable solids and grease are skimmed off by a rotating arm and deposited as a scum. A clarified supernatant liquid leaves from the top of the sedimentation tank, while concentrated sludge exits from the bottom of the sedimentation tank. The primary clarifiers remove about 60% of the Total Suspended Solids and about 30% of the Biochemical Oxygen Demand in the incoming wastewater. Two types of sedimentation tanks/clarifier are used in wastewater treatment plants, namely rectangular tanks and circular tanks (Tchobanoglous et al., 2003).

3.6 Secondary Treatment Stage

The secondary treatment stage of a wastewater treatment process is the most important as the removal of organic material (which represents the pollutants in wastewater) takes place in this stage. It comprises a biological unit that facilitates the growth of microorganisms requiring a sufficient supply of oxygen. The microorganisms use the organic material in the wastewater stream as food, thus reducing the pollutant contents in the wastewater. Treated wastewater from the biological unit is then passed to a secondary clarifier/tank where the solids settle to the tank bottom. The treated effluent stream is either released into the receiving body, or is subjected to tertiary treatment if a high quality of water purity is required. A brief overview of the principal types of reactors used in this stage is given below.

a) Batch Reactors

A batch reactor used for wastewater treatment will incorporate the following operational phases (Buchanan and Seabloom, 2004):

i. *Fill:* Raw wastewater that has been through primary treatment is added to the reactor. During this phase, aeration may or may not be supplied in order to provide alternating periods of high or low dissolved oxygen. This mode may occupy 25% of the total cycle time.

ii. *React:* Aeration is provided in an effort to obtain rapid biodegradation of organic compounds. This mode will typically require about 35% of the total cycle time.

iii. *Settle:* Aeration is shut off to allow the wastewater to become anoxic (for denitrification) and to allow for quiescent conditions that allow very effective liquid-solid separation. Clarification will usually take about 20% of the overall cycle time.

iv. *Draw:* Clarified raw water is removed as the supernatant liquid. The decanting is accomplished using adjustable or floating weirs. Periodically the excess biosolids must be removed. Decanting generally takes about 15% of the total cycle time.

An important requirement in the batch reactor process is that a tank is never completely emptied, and a portion of the settled solids are left to seed the next cycle. This allows the establishment of a population of organisms uniquely suited to treating the wastewater. By subjecting the organisms to periods of high and low oxygen levels, and to high and low food availability, the population of organisms becomes very efficient at treating wastewater. A typical hydraulic retention time for a batch reactor varies between 20 to 40 hours (Tchobanoglous et al., 2003).

b) Complete Mix Reactors

It is assumed that a complete mixing occurs instantaneously and uniformly throughout a complete mix reactor as fluid particles enters the reactor. Fluid particles leave the reactor in proportion to their statistical population. The actual time required for complete mixed conditions depend on the reactor geometry and the power input.

c) Plug-Flow Reactors

Fluid particles pass through the reactor with a little or no longitudinal mixing and exit from rector in the same sequence in which they enter. The particles retain their identity and remain in the reactor for a time equal to the theoretical detention time.

d) Packed Bed Reactors

A packed bed reactor is filled with some type of packing material, such as rock, slag, ceramic or plastic with plastic being the most commonly used. With respect to the flow, a packed bed reactor can be operated in either down or up flow mode. The input to the reactor can be continuous or intermittent. The packing material can also be continuous or arranged in multiple stages with flow from one stage to another.

e) Fluidized Bed Reactors

The fluidized reactor is similar to the packed bed reactor in many aspects, but the packing material is expanded by the upward movement of fluid through the bed.

3.6.1 Biological Treatment

Biological methods of wastewater treatment are based upon induced contact with microorganisms, which feed on the organic materials in the wastewater, thereby reducing the Biological Oxygen Demand **(**BOD) content of wastewater. BOD in wastewater is used as an indicator of pollutant level, where the greater the BOD, the greater the degree of pollution (Green-Ideas, 2009).

The basic principle behind biological treatment lies in the microorganisms consuming the suspended organic material present in the wastewater as their food source. The organic material is transformed into cellular mass by the metabolic process which is no longer suspended and hard to separate from the water, but can be precipitated by gravity at the bottom of a settling tank. Thus, the water exiting the biological system (biological treatment unit and clarifier) is much clearer than the entering water. Biological treatment based on the metabolic action of the microorganisms can be classified as anaerobic, anoxic and aerobic treatments.

The anaerobic treatment, carried out in the absence of oxygen, utilizes anaerobic bacteria to decompose suspended organic substances. Wastewater or sludge is introduced into a closed tank which is kept under anaerobic conditions and the retention time in the tank is from several days to several weeks. Anaerobic treatment is generally suitable for the treatment of wastes containing high concentrations of organic substances (often used for sludge treatment).

Anoxia is defined as a condition where water is without, or has very low levels of, dissolved oxygen (U.S-EPA, 2006) . Anoxic treatment refers to the growth of microorganisms in anoxic conditions. In wastewater treatment process, this treatment is carried out in anoxic tanks that ultimately reduce the concentration of nitrate in wastewater. Although this is not the primary metabolic reaction in aerobic treatment, anoxic treatment exists with aerobic treatment under favorable conditions.

Aerobic treatment is a means of oxidizing and decomposing organic substances in wastewater using aerobic microorganisms. Suspended organic substances are oxidized and decomposed by metabolic reactions of microorganisms, which also produces energy. Microorganisms multiply using a portion of this energy and the organic substances present, any excess of microorganisms grown must be separated and disposed of as excess sludge.

3.7 Tertiary Treatment Stage

The removal of nutrients such as phosphorous and nitrogen from the treated water using chemicals is considered as tertiary treatment of wastewater, although recently this has been performed using biological mass. Therefore, the removal of nutrients is performed close to the biological unit. The plant configuration can be such that the nutrient removal is either before or after the biological unit. Recent practice has used only the disinfection of treated water in the tertiary treatment stage (Norweco, 2006). The purpose of disinfection in the treatment of wastewater is to substantially reduce the number of microorganisms in the water that will be discharged back into the environment. Common means of disinfection include ozone, chlorine, or ultraviolet light.

3.8 PMB Techniques

Process Model-Based (PMB) methods/techniques for Fault Detection and Diagnosis (FDD) are discussed in this section. PMB methods are generally classified as quantitative or qualitative, an introduction and brief discussion is presented below. A detailed, but concise, review of these different methodologies is presented below.

3.8.1 Qualitative Model-Based Techniques

For qualitative model-based techniques, the relationships developed are based upon a fundamental understanding of the physical phenomena controlling the process that are expressed in terms of qualitative functions. The qualitative models can be developed either as qualitative causal models or abstraction hierarchies. Diagraphs, fault trees and qualitative physics are the most popular techniques that belong to the class of casual models. The abstraction hierarchy used for the FDD in a process can be further classified as structural or functional hierarchy. The following is a brief explanation of some of the most commonly used techniques used in qualitative model-based FDD (Venkatasubramanian et al., 2003b).

a) Digraphs based causal models

Cause and effect relations, or models, can be represented in the form of signed digraphs (SDG). Digraph is a graph with directed arcs between the nodes, and SDG is a graph in which the directed arcs have a positive or negative sign attached to them. The directed arcs lead from the 'cause' nodes to the 'effect' nodes. Each node in the SDG corresponds to the deviation from the steady-state value of a variable. SDGs have been the most widely used form of causal knowledge for process fault diagnosis and safety.

b) Fault Trees

Fault tree is a logic tree that propagates primary events or faults to the top level event or a hazard. The tree usually has layers of nodes. At each node different logic operations such as AND and OR are performed for propagation. Fault trees have been used in a wide range of risk assessment and reliability analysis studies. Before the construction of the fault tree, the analyst should possess a complete understanding of the system. The fault tree is constructed by asking questions such as: "What could cause a top level event?" In answering this question, one generates other events connected by logic nodes. Fault trees provide a computational means for combining logic in order to analyze system faults. The attraction of using a fault tree stems from the fact that different logic nodes can be used (OR, AND, XOR) instead of the predominantly OR node used in the digraphs. This helps in eliminating spurious solutions and representing the system in a concise manner. The biggest problem with fault trees is that the development is prone to mistakes at different stages. It is of primary importance that the underlying logic of the fault tree construction is correct, otherwise the entire model is faulty from the outset.

c) Qualitative Physics

Qualitative physics or "common sense" reasoning about physical systems has been an area of major interest in the artificial intelligence community. An important approach in qualitative physics is the derivation of qualitative behavior from the ordinary differential equations (ODEs). These qualitative behaviors for different failures can be used as a knowledge source. The goals of these methodologies are to reason from qualitative physical and equation-based descriptions. The advantage of these methods is their ability to yield partial conclusions from incomplete and often uncertain knowledge of the process.

d) Abstraction Hierarchy

Another form of model knowledge is through the development of abstraction hierarchies based on decomposition. There are two-dimensions along which abstraction at different levels is possible, i.e. structural and functional. The structural hierarchy represents the connectivity information of the system and its subsystems. The functional abstraction hierarchy represents the means-end relationships between a system and its subsystems. The majority of the work on fault diagnosis in chemical engineering depends on the development of functional decomposition, and the reason for its popularity is due to the complex functionalities of various units that cannot be expressed in terms of structure.

3.8.2 Quantitative Model-Based Techniques

Relying on an explicit model of the monitored plant, all model-based FDD methods require two steps. The first step generates inconsistencies between the actual and expected behavior known as "residuals". The second step chooses a decision rule for diagnosis. Some form of redundancy is always required in order to generate residuals to evaluate the inconsistency. There are two types of redundancies, hardware redundancy and analytical redundancy. Hardware redundancy has been utilized in the control of safety-critical systems such as aircraft, space vehicles and nuclear power plants, and requires redundant sensors. Its applicability in the chemical and process industry sector has been limited due to the additional costs and space required for the extra sensors. However, analytical redundancy is achieved from the functional dependence among the process variables and is usually provided by a set of algebraic or differential relationships among the states, and the inputs and the outputs of the system. The main concept used in the quantitative model-based FDD techniques is analytical redundancy based upon checking the actual system behavior against the system model for consistency. Any inconsistency, expressed as residuals, can be used for detection and isolation purposes. The residuals should be close to zero when no fault occurs, but show 'significant' values when the underlying system changes.

The generation of the residuals requires an explicit mathematical model of the system, either a model derived analytically using first principles or a black-box model obtained empirically. The first principles models are obtained based on a physical understanding of the process. In a chemical engineering process, mass, energy and momentum balances are used in the development of model equations. Historical models developed from first principles were seldom used in process control and fault diagnosis mainly because of their complexity. In addition, chemical engineering processes are often nonlinear which makes the design of fault diagnosis procedures more difficult. However, this is changing due to increased computational power and speed and better understanding of nonlinear controller design and synthesis(Venkatasubramanian et al., 2003a,b,c).

3.9 Mathematical Modelling

A mathematical model describes the fundamental physical phenomena controlling the process expressed in terms of mathematical functional relationships between the inputs and outputs of the system. Most of the work on quantitative model-based approaches has been based on general input-output and state-space models. However, there are a wide variety of quantitative model types that have been considered in fault diagnosis such as first-principles models, frequency-response models, etc. The first-principles models have not been very popular in fault diagnosis studies because of the computational complexity in utilizing these models in real time fault diagnostic systems, and the difficulty in developing accurate models. The most important class of models that have been heavily investigated in fault diagnosis studies are the input-output or state-space models. In this work, the equations describing first principals are used rather than the inputs-output or state-space model of the secondary stage of wastewater treatment. This dynamic model will provide transient values of the process measurements which can be used for the generation of residuals using the actual values from the process operation for the detection of a fault in the process.

3.10 Wastewater Treatment Mathematical Model

In order to promote development, and facilitate the application of practical models for design and operation of biological wastewater treatment systems, the International Association on Water Quality (IAWQ) formed a task group in 1983. The first goal was to review existing models and the second goal was to reach a consensus concerning the simplest mathematical model having the capability of realistically predicting the performance of single-sludge systems. The final result was presented in 1987 as the IAWQ Activated Sludge Model No. 1(ASM1). Although the model has been extended since then, for example to incorporate more fractions of COD (i.e. chemical oxygen demand), to describe growth and population dynamics of floc forming and filamentous bacteria and to include new processes for describing enhanced biological phosphorus removal, the original model is probably still the most widely used for describing WWT (wastewater treatment) processes all over the world (Jeppsson, 2003). Since then ASM1 has been the core of numerous models with a number of supplementary details added in almost every case. The model has grown more complex over the years, from ASM1 to ASM2, including biological phosphorus removal processes and to ASM2d including denitrifying PAOs. In 1998 the task group decided to develop a new modelling platform, the ASM3, in order to create a tool for use in the next generation of activated sludge models. The ASM3 is based on recent developments in the understanding of the activated sludge processes, among which are the possibilities of following internal storage compounds, which have an important role in the metabolism of the organisms (Henez et al., 2000).

The use of ASM1 as the core of recent models was the source of inspiration for adopting ASM1 as the basis for the mathematical modelling of wastewater in this research along with the fact that the data available for the validation (dated back to 1991) of the proposed model only covers the basic processes in the water treatment. The concepts of Monod's kinetics, population balance and Activated Sludge Model 1 (ASM1) are used to derive a mathematical model for the activated sludge treatment of wastewater which can then be used for fault detection. The major biological and chemical processes occurring in the activated sludge system for the treatment of wastewater are:

1) Production and decay of microorganisms (under different conditions)
2) Utilization of suspended organic material (substrate, i.e. food for microorganisms)
3) Oxygen consumption
4) Production of volatile suspended solids

1) Production and decay of microorganisms

The change in microorganism population due to production is given (Morley, 1979) as:

$$\left(\frac{dX}{dt}\right)_p = \mu X \tag{3.1}$$

where

X = concentration of microorganisms. This is the g/m^3 of microorganisms present in the activated sludge system for the conversion of wastewater into treated water.

μ = specific growth rate

The specific growth rate in equation 3.1 can be modelled using Monod's kinetics (Shuler and Kargi, 2002) as given by:

$$\mu = \mu_{max}\left(\frac{S}{Ks+S}\right) \tag{3.2}$$

where

μ_{max} = maximal specific growth rate

Ks = half saturation coefficient

S = substrate concentration (i.e. the food for micro-organisms). Substrate is the suspended solids present in the wastewater. As it is a source of food for the microorganisms to live on, the suspended solids are called “substrate” in this modelling exercise.

On substitution of equation 3.2 in 3.1, the change in microorganism population due to production is:

$$\left(\frac{dX}{dt}\right)_p = \mu_{max}\left(\frac{S}{K_s + S}\right)X \qquad (3.3)$$

Now, the decay rate of microorganisms due to endogenous metabolism (Morley, 1979):

$$\left(\frac{dX}{dt}\right)_d = -k_d X \qquad (3.4)$$

Hence, the net change in microorganism population can be modelled by:

$$\left(\frac{dX}{dt}\right) = \left[\mu_{max}\left(\frac{S}{Ks+S}\right) - k_d\right]X \qquad (3.5)$$

2) Utilization of suspended organic material

This section describes the dynamics of suspended solids (SS) in the wastewater treatment. The rate of substrate utilization (consumption) due to microorganisms (Morley, 1979) is given by:

$$\frac{dS}{dt} = -\frac{\mu X}{Y_{X/S}} \qquad (3.6)$$

where

S = concentration of substrate (suspended organic material in wastewater)

$Y_{X/S}$ = yield factor (indicates how many units of microorganisms are produced per unit of substrate. Similar to $Y_{X/S}$ are $Y_{X/O2}$ that is the unit of O_2 consumed by a unit of microorganisms)

On substitution of equation 3.2 in 3.6, the equation will become:

$$\frac{dS}{dt} = -\mu_{max}\left(\frac{S}{K_s + S}\right)\frac{X}{Y_{X/S}} \qquad (3.7)$$

3) Oxygen Concentration

The oxygen concentration in the wastewater system is reduced by aerobic growth of microorganisms. Similar to the consumption of suspended organic material (equation 3.7), the rate of oxygen depletion from the process can be derived as:

$$\frac{dS_o}{dt} = -\left[\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{So}{K_O+So}\right)\frac{X}{Y_{X/O_2}}\right] \tag{3.8}$$

Another important consideration is that the model equations are derived assuming the excess oxygen demand in the process. If the oxygen supply is limited or accounted for, then the factor (So/Ko+So) is to be incorporated in equations 3.5, and 3.7. The resulting models equations are given below by equations 3.9 and 3.10.

Net microorganism growth (equation 3.5):

$$\left(\frac{dX}{dt}\right) = \left[\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{S_O}{K_o+S_O}\right) - k_d\right]X \tag{3.9}$$

and the rate of substrate utilization (equation 3.7):

$$\frac{dS}{dt} = -\mu_{max}\left(\frac{S}{K_s+S}\right)\left(\frac{S_O}{K_o+S_O}\right)\frac{X}{Y_{X/S}} \tag{3.10}$$

4) Production of Volatile Suspended Solids

The decay of microorganisms contributes towards the volatile suspended solids. A portion of the dead microorganisms is recycled as a source of food for other microorganisms, while the particulate part of the dead microorganisms contributes to the concentration of volatile solids. The decay rate can be modelled using death-regeneration hypothesis and the model equation (Jeppsson, 2003) is given as:

$$\frac{dS_{VS}}{dt} = f_P\left(k_d X\right) \tag{3.11}$$

k_d = decay rate of microorganisms

f_P = fraction of biomass yielding particulate products

Equation 3.11 above describes the dynamics of Volatile Suspended Solids (VSS).

The derivation of an equation for the production of "Substrate" from equation 3.11 is based upon a fraction of biomass yielding particulate products, and the remainder is utilized as a food source. The equation then derived for the production of substrate is:

$$\frac{dS}{dt} = (1\text{-}f_P)\left(k_d X\right) \tag{3.12}$$

This equation affects equation 3.7 such that the net rate of substrate utilization is:

$$\frac{dS}{dt} = -\mu_{max}\left(\frac{S}{K_s+S}\right)\frac{X}{Y_{X/S}} + (1\text{-}f_P)\left(k_d X\right) \tag{3.13}$$

Mass Balance around Activate Sludge System

If F is the influent flow rate in the activated sludge process, a mass balance will yield:

$$\text{In-Out+Generation-Consumption=Accumulation} \tag{3.14}$$

Substrate (suspended organic solids) mass balance:

$$FSo\text{-}FS+0\text{-}(\mu X/Y_{X/S})V = V\frac{dS}{dt} \tag{3.15}$$

Simplifying the above equation yields:

$$\frac{F}{V}So\text{-}\frac{F}{V}S\text{-}(\mu X/Y_{X/S}) = \frac{dS}{dt} \tag{3.16}$$

where

V = volume of reactor

S = concentration of substrate in reactor

So = initial concentration of substrate in influent. This is the concentration of the suspended solids in influent wastewater whereas S is the concentration of suspended solids in effluent (treated wastewater).

F/V = D (dilution rate, i.e. inverse of residence time) (Shuler and Kargi, 2002)

Equation 3.16, using D will become:

$$DSo\text{-}DS\text{-}(\mu X/Y_{X/S})=\frac{dS}{dt} \tag{3.17}$$

Equation 3.17 predicts the dynamic behavior of the concentration of suspended solids in the activated sludge system.

Cell mass balance

Similarly to the substrate analysis, the microorganisms (cell) balance on the activated sludge process is modelled as:

$$FXo\text{-}FX+\mu XV\text{ -}k_dXV= V\frac{dX}{dt} \tag{3.18}$$

Simplifying equation 3.18 by using D for F/V:

$$DXo\text{-}DX+\mu X\text{-}k_dX=\frac{dX}{dt} \tag{3.19}$$

Equation 3.19 is similar to equation 3.17 and predicts the dynamics of cell mass in the activated sludge process.

Volatile Suspended Solids Balance

Using equation 3.14, a mass balance for the volatile solids is:

$$FS_{VS}\text{-}FS_{VS}+f_P\left(k_dX\right)V = V\frac{dS_{VS}}{dt} \tag{3.20}$$

Simplifying the above equation and using D for F/V:

$$DS_{VS}\text{-}DS_{VS}+f_P\left(k_HX_H+k_AX_A\right) = V\frac{dS_{VS}}{dt} \tag{3.21}$$

3.11 Results from Model Simulations

The following simulation results were obtained by using the model equations for the activated sludge system. The biological treatment of wastewater can be carried out using a batch or continuous process, the later is more widely used.

3.11.1 Batch Process

The simulation study on a batch reactor is further divided into three steps in order to obtain a better understanding of the process and the effects of different parameters.

1. Microorganisms and organic material

The first simulation is for aerobic growth of the heterotrophic microorganism, and their effect on the concentration of the organic material in the wastewater. It is assumed that an excess of dissolved oxygen (DO) exists in the process (i.e. no effect of oxygen concentration on microorganisms). The equations used are given below.

Microorganism concentration

The net change in the microorganism's concentration can be predicted from equation 3.5:

$$\frac{dX}{dt} = \left[\mu_{max} \left(\frac{S}{Ks+S} \right) - k_d \right] X$$

Organic material concentration

Using Equation 3.13 for the net concentration of the organic material (i.e. substrate) in the wastewater:

$$\frac{dS}{dt} = -\mu_{max} \left(\frac{S}{Ks+S} \right) \frac{X}{Y_{X/S}} + (1-f_P) k_d X$$

Simulation results from the above equations show how the concentration of microorganisms and organic material will change with time in a batch process.

Simulation Results and Discussion

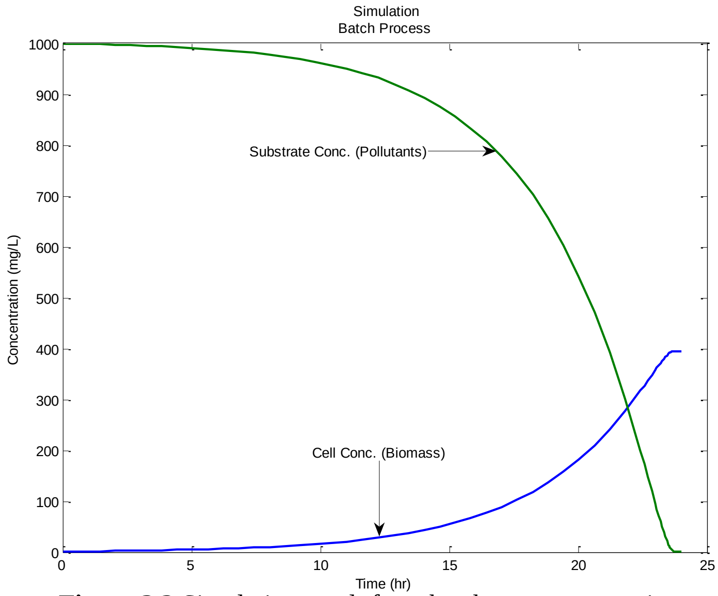


Table 3.1 Parameters used for the simulation in Figure 3.1

Parameter	Value	Units
Substrate initial concentration	1000	g/m^3
Cell initial concentration	1.5	g/m^3
Residence time	24	hr

Figure 3.2 Simulation result from batch process assuming excess DO

Figure 3.2 illustrates the dynamics of the wastewater reclamation process using activated sludge in batch conditions. The concentration of organic materials (i.e. pollutant or substrate) reduces to near zero at the end of batch operation.

Figure 3.3 is an extension of Figure 3.2 using the parameters in Table 3.1, it shows how the activated sludge (microorganisms or cell) concentration starts decreasing as the organic material in wastewater is completely consumed by cells.

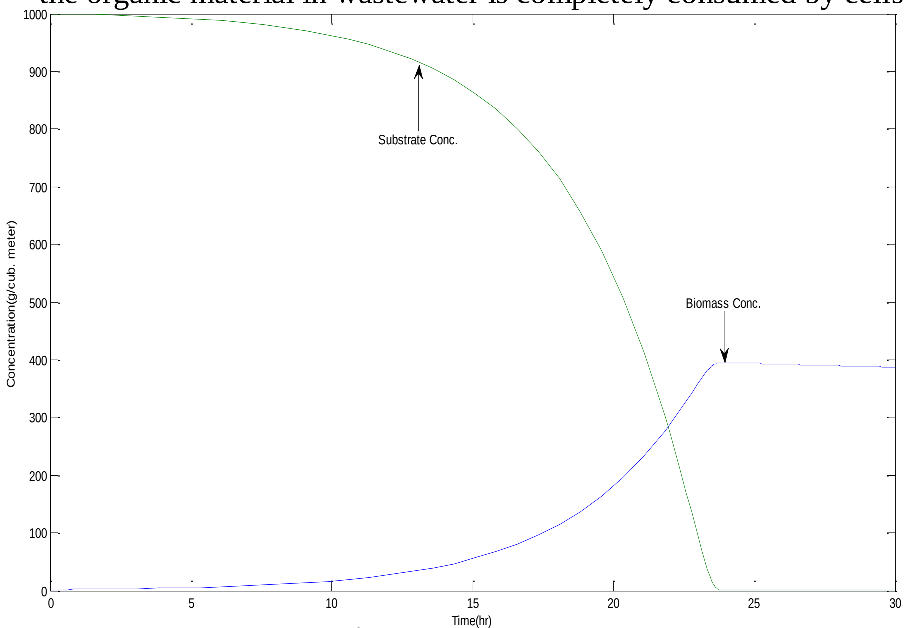


Figure 3.3 Simulation result from batch process assuming excess DO and a residence time of 30hr

2. Microorganisms, organic material and dissolved oxygen

For this simulation, the earlier assumption of excess DO is rejected. Now the microorganism growth (concentration) depends on the oxygen concentration at any time in the process. If enough DO is provided, the concentration of microorganism will increase resulting in the decrease of organic material concentration. The rate of growth will be reduced if DO is less than the oxygen demand of the microorganisms. The equations used are given below.

Microorganism concentration

Using equation 3.9 for the net growth of microorganism including oxygen concentration is:

$$\frac{dX}{dt}=\left[\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{So}{K_{OH}+So}\right)-k_d\right]X$$

Organic material concentration

The model equation for substrate utilization is then derived from equation 3.13 to include the effect of oxygen as:

$$\frac{dS}{dt}=-\left[\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{So}{K_{OH}+So}\right)\frac{X}{Y_{X/S}}\right]+\left(1-f_P\right)k_dX \tag{3.22}$$

Although oxygen is consumed in the batch process, it is provided continuously using turbines. Oxygen supply will fulfill the oxygen demand of microorganisms and also produce turbulence in the reactor that will help to keep the solution of organic material and microorganism suspended in the reactor, thus improving the contact between both phases and resulting in efficient removal of pollutants from wastewater. The amount of DO depends upon the Biological Oxygen Demand (BOD) of the wastewater and, in general, a minimum residual of 1mg of DO per liter of wastewater must be maintained (Buchanan and Seabloom, 2004).

The equation for oxygen consumption derived from equation 3.8 is:

$$\frac{dS_o}{dt} = DSo_{in} - \left[\mu_{max} \left(\frac{S}{Ks+S} \right) \left(\frac{So}{K_{OH}+So} \right) \frac{X}{Y_{X/O_2}} \right] \tag{3.23}$$

Simulation from the model equations above will predict the microorganisms and organic material concentration under the influence of the oxygen supplied.

Simulation Results and Discussion

Oxygen is always used in excess in the activated sludge treatment of wastewater treatment. For illustration purposes, Figure 3.4 shows the dynamics of activated sludge system using 2g/m^{3}of air.

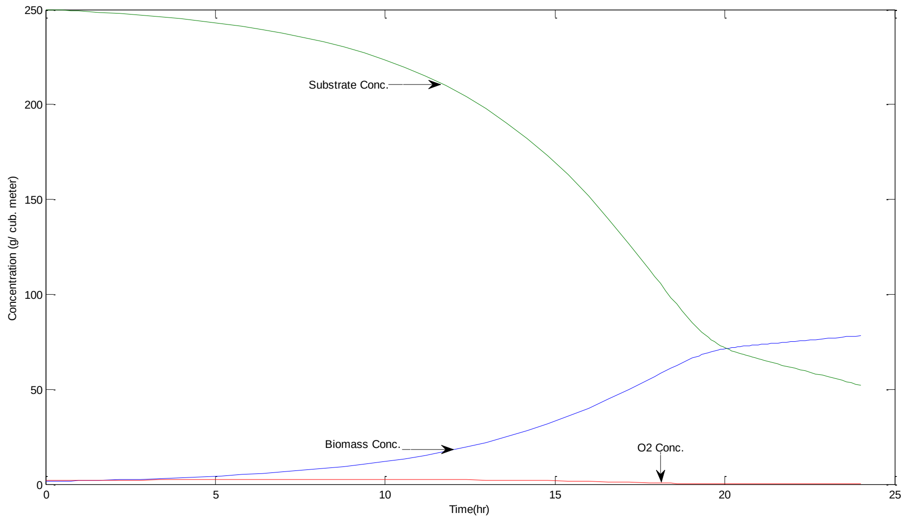


Figure 3.4 Dynamics of activated sludge system using oxygen concentration as 2g/m^3

3.11.2 Completely Mixed Reactor

Assume that complete mixing occurs instantaneously and uniformly throughout the reactor as the fluid-particles enter.

1) Microorganisms and organic material

For the activated sludge process, the model equations assuming an excess of dissolved oxygen (DO) are:

Microorganism concentration predicted using equations 3.5 and 3.14:

$$\frac{dX}{dt}=DX_{in}-DX_{out}+\mu_{max}\left(\frac{S}{Ks+S}\right)X-k_dX \tag{3.24}$$

Similarly, the organic material concentration from equations 3.13 and 3.15:

$$\frac{dS}{dt}=DS_{in}-DS_{out}-\mu_{max}\left(\frac{S}{Ks+S}\right)\frac{X}{Y_{X/S}}+\left(1-f_P\right)k_dX \tag{3.25}$$

Simulation results from the above equations will predict how the concentration of microorganisms and organic material will change with time in the activated sludge process.

Simulation Results and Discussion

It is desirable to study the effect of continuous operation on the wastewater process. This dynamic behavior is predicted by simulations using the parameters in Table 3.2, as shown in Figure 3.5.

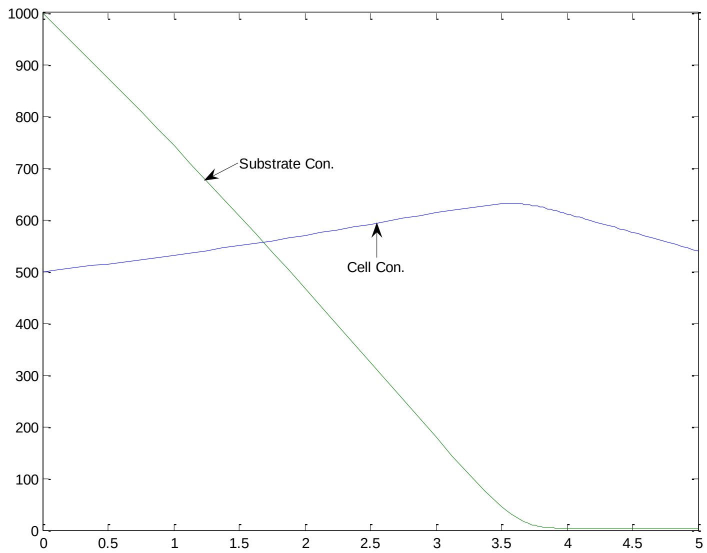


Table 3.2 Simulation parameters for continuous process

Parameter	Value	Units
Substrate initial concn.	1000	g/m^3
Cell initial concn.	500	g/m^3
Residence time	4	hr
Substrate influent	250	g/m^3
Substrate effluent	10	g/m^3
Cell influent	0	g/m^3
Cell effluent	400	g/m^3

Figure 3.5 Simulation dynamics for a continuous process using excess DO

2) Microorganisms, organic material and dissolved oxygen

The model equations for microorganisms and organic material considering the DO concentration are:

Microorganism concentration using equations 3.9 and 3.14:

$$\frac{dX}{dt}=DX_{in}-DX_{out}+\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{So}{K_{OH}+So}\right)X-k_dX \qquad (3.26)$$

Similarly for the organic material:

$$\frac{dS}{dt}=DS_{in}-DS_{out}-\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{So}{K_{OH}+So}\right)\frac{X}{Y_{X/S}}+(1-f_P)k_dX \qquad (3.27)$$

Oxygen concentration is predicted using equation 3.23:

$$\frac{dS_o}{dt}=DSo-\left[\mu_{max}\left(\frac{S}{Ks+S}\right)\left(\frac{So}{K_{OH}+So}\right)\frac{X}{Y_{X/O_2}}\right]$$

Simulations obtained using these model equations predict the microorganisms and organic material concentrations under the influence of the oxygen supplied.

Simulation, results and discussion

Simulation results used to study the dynamic behavior of the processes discussed above are shown in Figure 3.6, and using the simulation parameters given in Table 3.3.

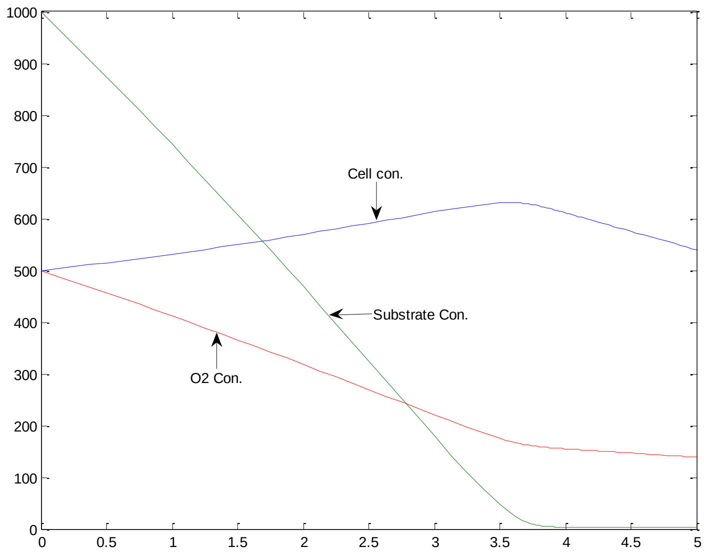


Table 3.3 Parameters used to study the effect of O_2 consumption

Parameter	Value	Units
Substrate initial concn.	1000	g/ m3
Cell initial concn.	500	g/ m3
Residence time	4	hr
Substrate influent	250	g/ m3
Substrate effluent	10	g/ m3
Cell influent	0	g/ m3
Cell effluent	400	g/ m3
DO	500	g/ m3

Figure 3.6 Wastewater treatment dynamics for controlled oxygen supply

Table 3.4 shows all parameters that are used in the simulations discussed above. The parameters are adopted from the ASM1 model described by Jeppsson (2003).

Table 3.4 Parameters used in modelling and simulation with literature values

Notation	Explanation	Value
μ_{max}	Maximum specific growth rate	0.25 hr^{-1}
$Y_{X/S}$	Yield factor (unit of microorganisms produced per unit of substrate)	0.4
$Y_{X/O2}$	Unit of microorganisms per unit of O2	0.9 - 1.4
$Y_{X/NO2}$	Unit of microorganisms per unit of NO	0.24
K_S	Half saturation coefficient	23 m^{-3}
K_{OH}	Oxygen half saturation constant	0.2 m^{-3}
K_{NO}	Nitrate half saturation constant	0.5 m^{-3}
η_g	Correction factor for anoxic growth	0.8
f_P	Fraction of biomass yielding VSS	0.15
k_d	Decay rate of microorganisms	0.005 hr^{-1}
F	Influent flow rate	936 hr^{-1} m^3
V	Volume of reactor	4021 m^3
D	F/V	0.23 hr^{-1}

3.12 Model Validation

The model developed is then validated before it can be used for the diagnostic purposes. It is essential to establish that the model does actually predict the behaviour of activated sludge process for the treatment of wastewater. Though it is evident from the simulation results (Figure 3.2 to 3.6) that the model does follow the expected behaviour of an activated sludge system, it is still to be established that how accurate the proposed model is. The wastewater treatment plant (WWTP) data (discussed in detail in section 4.5) is used for the validation of the model.

The value of an input parameter from the WWTP data (Appendix A) is used as the initial value for the simulations study of the model to obtain the output value of the parameter. This output value is then compared to the actual output given in the data set to validate the proposed model. Table 3.5 summarizes the results obtained during the validation of proposed model.

Table 3.5 Results for model validation

Date	Input Parameter	Input Value (WWTP data set)	Output Parameter	Output Value (WWTP data set)	Output value (simulations)	Difference (%)
11/1/90	SS-E	192	SS-D	100	107	7
1/3/90	SS-E	166	SS-D	94	98	4
3/5/90	SS-D	88	SS-S	49	53	8
29/7/90	SS-D	90	SS-S	34	37	9
28/09/90	SSV-E	57	SSV-D	77	81	5
30/11/90	SSV-E	75	SSV-D	83	89	7
15/1/90	SSV-D	71	SSV-S	76	81	7
8/3/91	SSV-D	64	SSV-S	85	88	4
21/5/91	DBO-E	238	DBO-D	101	105	4
31/7/91	DBO-E	170	DBO-D	101	100	1
6/8/91	DBO-D	90	DBO-S	16	18	12
16/10/91	DBO-D	121	DBO-S	33	36	9

Table 3.5 summarizes the results obtained from the validation of the activated sludge model proposed. The discrepancy in the model and actual values ranges from 1 – 12% with an average of 6.5%.

3.13 Summary Comments

A brief review of the processes involved in the wastewater treatment facility is presented, and a mathematical model derived from the ASM1 model. This model is used in this research work for the detection step of the fault detection and diagnosis system. The ideology used for fault detection is the analytical redundancy where the value of an observed parameter in a process is compared to the value obtained from mathematical model simulations, in order to decide whether the parameter under observation is out of the normal operating limit.

Chapter 4

Process History Based Method

4.1 Introduction

Process History Based (PHB) methods for fault detection and diagnosis are discussed in this chapter. This includes an introduction and explanation of the different techniques available including a detailed review of data-mining, a technique used in this research work. Data mining is then applied to the dataset of a wastewater treatment plant, and the results are presented, analyzed and discussed. Some modifications are suggested and implemented in the selected technique of data mining that further improves its efficiency and effectiveness in order to interpret data for fault detection and diagnosis. An introduction and explanation of the Wastewater Treatment Plant (WWTP) dataset used in this work is included.

4.2 PHB Techniques

In contrast to the depth of knowledge required for fault detection and diagnosis when using Process Model Based methods, PHB methods only require access to the historical and/or operational data. This data is then used to extract knowledge for input to a diagnostic system. This process of knowledge extraction is known as feature extraction. The PHB methods are classified as either qualitative or quantitative on the basis of the type of knowledge extracted from the database. Expert System (ES) and Qualitative Trend Analysis (QTA) are the most important and widely applied techniques from the class of qualitative PHB approaches. Quantitative techniques are further divided into statistical and non-statistical approaches. Principal Component Analysis (PCA), Independent Component Analysis (ICA) and Partial Least Squares (PLS) form the majority of the statistical quantitative PHB approaches, while the best known techniques in non-statistical quantitative PHB approach is Artificial Neural Networks (ANN). Each of these techniques has its own strengths and weaknesses. During the diagnosis stage of FDD, the onsite operator or engineer has to identify the symptoms, analyze the symptomatic information, interpret the various error messages and indications, and decide upon the correct diagnosis for the situation. Due to the inherent complexity of chemical processes, the diagnosis requires extensive technical skills and process experience, in addition to a complete understating of the process and some general concepts of diagnosis, in order to carry out the diagnostic operation when a fault is identified in the process. This requires a very experienced engineer with the deep domain-specific knowledge and the knowledge of the "ins-and-outs" of the system (Sun et al., 2007). Many diagnosis methods have been proposed to help operators and engineers perform diagnostic fault analysis. For example, expert systems, neural networks, and genetic algorithms are the most popular approaches among the PHB techniques. The application of an expert system is limited due to the knowledge acquisition because the knowledge-based systems developed from expert rules are very system specific, their representational ability is quite limited, and they are difficult to update. The complexity of a process makes the diagnosis methods based on ANN and Genetic Algorithm (GA) difficult, in addition the inherent nature of ANN approach means they lack the explanation and adaptability properties of a diagnostic system (Chen and Mo, 2004, Venkatasubramanian et al., 2003c, Sun et al., 2007, Yang et al., 2005).

The most helpful presentation of a domain-specific knowledge for a non-expert is the cause-symptom relationship that enables the quick comprehension of the situation. Production rules are the knowledge formalized into "rules" containing an If part and a Then part that explains the cause-symptom relationship in a process. Production rules are one of the most popular and widely used knowledge representation languages.

4.3 Data Mining

In modern processes, the computer control and data logging systems are able to easily collect large amounts of data. This data can be used for process monitoring and fault diagnosis, as well as in other decision making activities - if properly analyzed. Data mining is a powerful new technique with the potential to help engineers explore and focus on the most important information available from the analysis of the historical and/or operational data available from a process. Data mining is defined as "The nontrivial process of extracting implicit, previously unknown, and potentially useful, information from data" (Fayyed et al., 1996). It uses machine learning, statistical and visualization techniques to discover and present discovered knowledge in a form which can be easily understood. It allows users to analyze large databases to solve decision problems encountered in an industry or business sector. The primary goal of data mining is the extraction of knowledge from the available data and is often known as Knowledge Discovery and Data Mining (KDDM).

4.3.1 Data Mining Process Description

Data Mining is a complex process which typically involves the following procedures (Fayyed et al., 1996).

Understanding: Developing an understanding of the application domain, the relevant prior knowledge, and the goals of mining.

Creating a target data set: Selecting a data set, or focus on a subset of variables or data samples, on which discovery is to be performed.

Data pre-processing and cleaning: This is frequently time consuming; data pre-processing is needed because most large databases were created for a different purpose from their current applications. Therefore, the data within these databases are not immediately ready to use in knowledge discovery algorithms or other information processing techniques. For example, the data may contain information that is not uniform, the data may be blank or inconsistent, certain data may be continuous while others are categorical, some data may contain sensitive information and require encryption, and finally, some data may contain uncertainties. Hence data pre-processing and cleaning involves basic operations such as the removal of noise or outliers if appropriate, collecting the necessary information to model, deciding on strategies for handling missing data fields, and accounting for noise, time sequence information and known changes.

Data reduction and projection: Finding useful features to represent the data depending on the aim of the task, using dimensionality reduction or transformation, or finding invariant representation from data.

Choosing the data mining task: Depends mainly on the application domain and on the interest of the miner. Decide whether the goal of the KDDM process is summarization, clustering, classification and regression, etc., and identification of several types of data mining tasks for which data mining offers possible answers.

Choosing the data analysis algorithm(s): Selection of the methods to be used to search for patterns in the data. This includes deciding which models and parameters may be appropriate (e.g. models of categorical data are different from models on vectors over the real data) and matching a particular data mining method with the overall criteria of KDDM process.

Data mining: searching for patterns of interest in a particular representational form, or a set of such representations, including clustering, dependency modelling, analysis, visualization, etc. The following steps can significantly aid the data mining process.

a) Interpretation - interpreting mined patterns, and possible return to any of the previous steps. This step can also involve visualization of the data given the extracted models.

b) Using discovered knowledge - this step involves acting directly on discovered knowledge, incorporating the knowledge into another system for further action, or documenting and reporting the knowledge. It also includes checking and resolving potential conflicts with previously believed or extracted knowledge.

c) Evaluation of KDDM purpose - newly discovered knowledge is often used to formulate new hypotheses; also new questions may be posed using the enlarged knowledge base. In this step, the KDDM process is evaluated for possible further use in both refinement and expansion.

The overall process, representing the move from data to information, and ultimately knowledge, is shown in Figure 4.1**.** Sometimes the analysis step itself is referred to as data mining, although this term is better applied to the whole process.

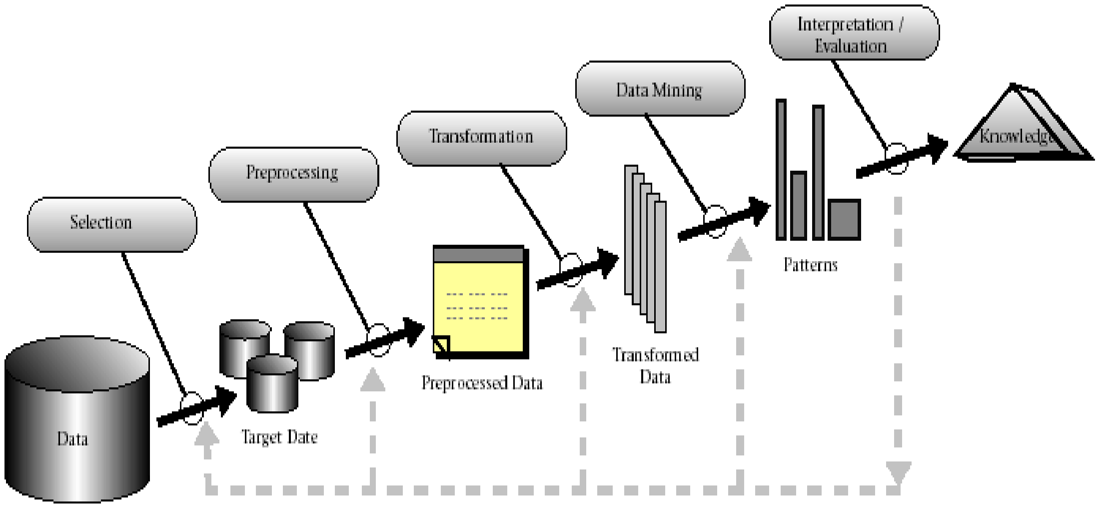


Figure 4.1 An overview of the knowledge discovery process, showing the move from data to knowledge or information, through various steps.(Buontempo, 2005)

4.3.2 Applications for Data-Mining

The technique of data mining has attracted much interest, not only from information technology companies but also from the industrial and business sectors. The following is the list of domains where this technique is being, or potentially can be, applied (Wang, 1999).

Manufacturing Process Analysis **-** identifying the causes of faults in manufacturing processes.

Production Design **-** developing a system which will give product designers access to data and information from a range of corporate databases deemed essential to their function, in particular, customer complaints, product material features, R&D testing. Access to this data may point to fundamental design anomalies or inefficiencies which would not have been otherwise apparent.

***Scientific Data Analysis* -** cataloguing in surveys, the basic processing needed before high-level scientific analysis can occur, scientific discovery over a large data set, e.g. the SKICAT system from JPL/Caltech was used to automatically identify stars and galaxies in a large-scale sky survey for cataloguing and scientific analysis. In the global climate area, spatio-temporal patterns such as cyclones were predicted from large simulated and observational datasets.

***Experimental Results Analysis* -** summarizing the experimental results and the predictive models.

***Marketing and Sales Data Analysis* -** identifying potential customers, establishing the effectiveness of a sales campaign.

***Investment Analysis* -** predict a portfolio return on investment.

***Intelligent agents and World Wide Web (WWW) navigation* -** model user preferences from data, collaborative filtering, advertising, etc.

***Fraud detection* -** identify fraudulent transactions.

***Loan approval* -** establishing the credit worthiness of a customer requesting a loan.

***Portfolio Trading* -** trade a portfolio of financial investments by maximizing returns and minimizing risks.

4.3.3 Data Mining Approaches

Data mining approaches can be broadly categorized as either descriptive or predictive. Descriptive approaches aim to discover patterns that characterize the data, whereas predictive approaches aim to construct models to predict the outcome of a future event by learning from the observed parameters (Charaniya et al., 2008).

4.3.3.1 Descriptive approaches

The descriptive approaches fall into two categories; (a) identifying interesting patterns in the data; and (b) clustering the data into meaningful groups.

a) Pattern discovery

Algorithms for finding patterns in very large datasets are one of the key success stories of data mining research. These methods aim to analyze the parameters of various runs to identify a pattern that is observed in a large number of runs. Patterns discovered from process data can provide insights into the relationship between different parameters, and can also be used to discover association rules. Various algorithms have been developed that can mine process data to discover relationships between the parameters of the different runs that satisfy certain properties. The most efficient approaches for finding these patterns are FPgrowth and LPminer (Han et al., 2004).

b) Clustering

Clustering methods can be used to group different process runs into subsets (groups) according to the similarity in the behavior of some parameters. Clustering methods can be differentiated along multiple dimensions, one of them being the top-down (partitional) or bottom-up (agglomerative) nature of the algorithm. Partitional methods commence with all process runs (or object/record) belonging to one cluster and they are divided into designated number of clusters. *K*-means, Partitioning Around Medoids (PAM), Self-Organizing Maps (SOM), and graph-based clustering methods are popular examples of partitional algorithms.

By contrast, agglomerative methods start with each run belonging to a separate cluster and the clusters are merged, based on the similarities of their parameter profiles, until the runs have been grouped into a pre-specified number of clusters. Hierarchical agglomerative clustering is the most commonly used agglomerative method (Jain et al., 1999). Most statistical packages, such as S-Plus and R Project provide a range of clustering methods (R-Foundation, 2008, TIBCO-Software-Inc, 2008)

4.3.3.2 Predictive approaches

Predictive approaches can be used to analyze a set of process runs that exhibit different outcomes (e.g. final product concentration) to identify the relationship between process parameters and the outcome. The discovered relationships (called model or classifier) can be used to predict the process outcome and provide key insights into how the predicted outcome might affect other parameters of the run, thereby allowing for an intelligent outcome-driven refinement of the process parameters. Commonly used predictive methods include regression, Support Vector Machines (SVM), Artificial Neural Networks (ANN) and Decision Trees (DT). These methods have been designed for problems that arise when process runs are divided into classes. Two of the commonly used predictive methods are discussed below.

Artificial Neural Networks (ANN)

ANN models attempt to imitate the signal processing events that occur in the interconnected network of neurons in the brain. An ANN consists of several nodes that are organized into two or more layers. The first layer serves as input for process parameters and the final layer determines the run outcome. Any intermediate layers are referred to as hidden layers. Every node of a hidden layer receives all inputs from the previous layer, performs a weighted average of the inputs, and sends its output to the next layer after a threshold transformation. This process is continued until the final output layer is reached. The weighting factors and threshold parameters are learnt from the training runs in an attempt to minimize the error in classifying the runs (Krogh, 2008).

Decision Trees (DT)

DT-based methods classify runs recursively based on chosen thresholds for one or more parameters. The process parameter that provides most information about the classes is used to split the runs into two or more branches. Splitting thus results in ‘child’ nodes that are most separated from each other in terms of the class. Thus, selecting a parameter and its threshold for the split is a key exercise for DT classifiers. This division is repeated until all the runs at a particular node belong to a single class (terminal node) or one or more stopping rules are satisfied. A top-down interpretation of a decision tree is intuitive and it also allows ranking of process parameters according to their relevance (Quinlan, 1990).

4.4 Inductive Data Mining

Inductive data mining refers to the technique used for the generation of the decision tree and production rules from a dataset. It is also an effective approach for automated acquisition of expert knowledge to be built into the knowledge base of an expert system. Classification problem is the current research focus in the area of data mining, and decision tree is one of the most widely used classification methods.

The appeal of decision trees for data analysis and as classifier systems originate primarily from three inherent properties: their ability to model non linear relationships; their ease of interpretability; and their nonmetric nature. Decision trees have been found to be able to handle large-scale problems due to their computational efficiency, to provide interpretable results and, in particular, to identify the most representative attributes for a given task. The traditional approach to inducing decision trees based upon given training data involves recursive partitioning which selects partitioning variables and their value in a greedy (indiscriminate acquisition?) manner to optimize a given measure of purity. A greedy algorithm makes each choice in a locally optimized manner and progresses making one greedy choice after another and reduces the problem to a smaller one this way. This methodology has numerous benefits including classifier interpretability and the capability of modelling non linear relationships.

While capable of modelling nonlinear relationships, decision trees retain a high level of interpretability. The typical structure of a decision tree consists of a root node linked to two or more child nodes which may or may not link to further child nodes. Each nominal node within the tree represents a point of decision or data splitting based upon the data (DeLisle and Dixon, 2004)

Most inductive data mining methods for decision tree generation use supervised learning, i.e. learning from a set of pre-classified cases. Many algorithms have been proposed for decision tree generation, e.g. ID3, C4.5, See5.0, CART, SLIQ, SPRINT and BOAT. The best known algorithms used are CART and See5.0 (with earlier versions as ID3 and C4.5). The decision tree created by CART is a binary tree in which each split generates exactly two branches. In the decision tree created by See5.0, each split can generate more than two branches; also See5.0 can solve the classification problem with continuous-valued attributes. It was developed by Quinlan (1993, 1986, 1990, 1996), and is similar to most other decision tree algorithms in that See5.0 consists of two phases, a building (growing) phase followed by a pruning phase.

a) Building Phase

In the building phase, a subset of the training set called the window is chosen at random and a decision tree is formed from it; this tree correctly classifies all objects in the window. All other objects in the training set are then classified using the tree. If the tree gives the correct answer for all these objects, then it is correct for the entire training set and the process terminates. If not, then a selection of incorrectly classified objects is added to the window and the process continues. A decision tree is then constructed in a top-down fashion by iteratively selecting the most informative attribute at the current node in the tree. The most informative attribute for the current node is determined by the splitting criterion, i.e. Gain Ratio (Quinlan, 1993). The Gain Ratio is calculated in the following manner.

Step 1: Calculate Info(S) to identify the class in the training set S.

$$Info(S)=-\sum_{i=1}^{n}\left[\left\{ freq(Ci,S) \middle/ |S| \right\} log_2 \left\{ freq(Ci,S) \middle/ |S| \right\}\right] \tag{4.1}$$

where,

n = number of classes

C_i = a class

|S| = total number of cases in the training set S

freq (Ci, S) =$|S_i|$ = number of cases in S belonging to the class Ci

Step 2: Calculate the expected information value, $Info_X(S)$ for test X to partition S:

$$Info_X(S) = -\sum_{i=1}^{m}\left[\left(\frac{|S_i|}{|S|}\right) Info(S_i)\right] \tag{4.2}$$

when,

m = number of outputs from test X

Step 3: Calculate the information gain after partition according to test X:

$$Gain\ (X) = Info(S) - Info_X(S) \tag{4.3}$$

Step 4: Calculate the partition information value SplitInfo(X) acquiring for S partitioned into m subsets:

$$SplitInfo = -\frac{1}{2}\sum_{i=1}^{m}\left[\left(\frac{|S_i|}{|S|}\right)log_2\left(\frac{|S_i|}{|S|}\right) + \left\{1-\left(\frac{|S_i|}{|S|}\right)\right\}log_2\left\{1-\left(\frac{|S_i|}{|S|}\right)\right\}\right] \tag{4.4}$$

Step 5: Calculate the Gain Ratio of Gain(X) over SplitInfo(X):

$$GainRatio(X) = \frac{Gain(X)}{SplitInfo(X)} \tag{4.5}$$

The Gain Ratio (X) compensates for the weak point of Gain(X) which represents the quantity of information provided by X in the training set. Therefore, an attribute with the highest Gain Ratio (X) is taken as the root of the decision tree.

b) Pruning phase

A large decision tree constructed from a training set usually does not retain its accuracy over the whole sample space for over-training or over-fitting. Therefore, a fully grown decision tree needs to be pruned by removing the less reliable branches to obtain better classification performance over the whole instance space, even though it may have a higher error over the training set. A number of empirical methods have been proposed for pruning a decision tree and they can be divided into two types: construction-time pruning (or pre-pruning) and pruning after building a fully grown tree (or post pruning). Pre-pruning methods (e.g. threshold method and X2 test method) are used to decide when to stop expanding a decision tree. A serious limitation in the pre-pruning method is that the criterion to stop a tree is often based on local information. In contrast, the post-pruning methods (e.g. cost-complexity, critical value and reduced error) use global information. The See5.0 algorithm applies an error-based post-pruning strategy to deal with the over-training problem, which is a pessimistic error pruning method. In practice for each classification node, See5.0 calculates a predicted error rate based on the total aggregate of misclassifications at that particular node (See5.0, 2008).

4.5 Wastewater Treatment Plant (WWTP) dataset

A wastewater treatment plant database containing 527 cases representing 527 days of operation is used in this study for the generation of production rules (to be used as the fault libraries for process fault diagnosis). It was collected by Poch and made publicly available by Bejar and Corts of the University of Catalonia, Spain (Sanchez et al., 1997). Each data case is represented by 38 attributes, i.e. process parameters/variables. Out of the 38 attributes, 7 are the output variables, 9 are related to process operational performance, and the rest are the variables related to the influent into the biological unit of a wastewater treatment plant. The 38 attributes are listed in Table 4.1. All attributes are numeric and have continuous values. The units for all parameters are g/m^3 except the input flow to plant (Q-E) which has the unit m^3/day. The WWTP used in this study consists of Sequential Batch Reactor (SBR).

Table 4.1 Process variables of the wastewater treatment plant (Wastewaterdatabase, 2006)

No.	Attribute	
Pre Treatment		
1	Q-E	(input flow to plant)
2	ZN-E	(input zinc to plant)
3	PH-E	(input pH to plant)
4	DBO-E	(input biological demand of oxygen to plant)
5	DQO-E	(input chemical demand of oxygen to plant)
6	SS-E	(input suspended solids to plant)
7	SSV-E	(input volatile suspended solids to plant)
8	SED-E	(input sediments to plant)
9	COND-E	(input conductivity to plant)
Primary Treatment		
10	PH-P	(input pH to primary settler)
11	DBO-P	(input biological demand of oxygen to primary settler)
12	SS-P	(input suspended solids to primary settler)
13	SSV-P	(input volatile suspended solids to primary settler)
14	SED-P	(input sediments to primary settler)
15	COND-P	(input conductivity to primary settler)
Secondary Treatment		
16	PH-D	(input pH to secondary settler)
17	DBO-D	(input biological demand of oxygen to secondary settler)
18	DQO-D	(input chemical demand of oxygen to secondary settler)
19	SS-D	(input suspended solids to secondary settler)
20	SSV-D	(input volatile suspended solids to secondary settler)
21	SED-D	(input sediments to secondary settler)
22	COND-D	(input conductivity to secondary settler)
Performance Inputs		
23	RD-DBO-P	(performance input biological demand of oxygen in primary settler)
24	RD-SS-P	(performance input suspended solids to primary settler)
25	RD-SED-P	(performance input sediments to primary settler)
26	RD-DBO-S	(performance input biological demand of oxygen to secondary settler)
27	RD-DQO-S	(performance input chemical demand of oxygen to secondary settler)
28	RD-DBO-G	(global performance input biological demand of oxygen)
29	RD-DQO-G	(global performance input chemical demand of oxygen)
30	RD-SS-G	(global performance input suspended solids)
31	RD-SED-G	(global performance input sediments)
Outputs		
32	PH-S	(output pH)
33	DBO-S	(output biological demand of oxygen)
34	DQO-S	(output chemical demand of oxygen)
35	SS-S	(output suspended solids)
36	SSV-S	(output volatile suspended solids)
37	SED-S	(output sediments)
38	COND-S	(output conductivity)

The Process Details

The plant is an activated sludge process located in Manresa, a town near Barcelona (Catalonia, Spain) population of 100,000 inhabitants. It treats a daily flow of approx. 35,000 m^3 comprising mainly domestic wastewater, although other wastewaters from industries located near the town are also received in the plant. The plant consists of three main treatment sections (Albazzaz et al., 2005):

(i) Pre-treatment,

(ii) Primary treatment and

(iii) Secondary treatment by means of activated sludge.

The database has been used for studies in classification by Sanchez et al., (1997) where two methods, the K-means clustering method and Linneo+ methodology, a knowledge acquisition tool with unsupervised learning strategy, were investigated. (Sanguesa and Cortes (1997) used the data to study a possibilistic network. Hunag and Wang (1999) used the data in developing fuzzy casual networks. Wang et al. (2004) used this data set to present an approach for multidimensional visualization of multiple principal coordinates using a technique called parallel coordinates for the purpose of process monitoring. This data was also used for the historical data analysis and an empirical comparison was made between multidimensional visualization using parallel coordinates, PCA based multivariable statistical process control charts, the T2 and SPE charts, and a clustering approach (Albazzaz et al., 2005). Ma and Wang (2009) used the data for a new approach to data mining using Genetic Programming. Dellana and West (2009) used the data in their work for the predictive modelling of wastewater. West and Mangiameli (2000) employed the WWTP data for the identification of process conditions.

There is an adequate amount of research work in literature where people have used different dataset for the fault detection and diagnosis systems but the data set they used, is normally not available publically. Researchers usually use dataset from industry with which they have research ties. Furthermore, all the researchers who have used this WWTP data-set which in non-linear in nature, only rely on it and didn't use any other data-set for any validation etc. There is only one publication in the writer's knowledge that use another dataset for validation but the dataset used there was from their own source and that dataset is not available.

Out of the 38 attributes, the database has some missing values for about 144 days out of the 527. Missing data is a common problem for data mining, because in many of these situations, the missing data cannot be re-collected or reproduced. Albazzaz et al. (2005) used eight different methods available in the commercial statistics software system SPSS (ver. 11.5) to deal with the missing values in the database. Only three approaches, i.e., linear trend at point, series mean, and series median were able to give estimations for all the missing values. It was found that the estimations for the missing values using these three methods were reasonably close. A further comparison was made between series mean and linear trend. Both approaches were used to fill in all the missing values, and then calculated such statistics as minimum, maximum, mean, median, and standard deviation for all the 38 attributes in the wastewater treatment plant dataset. It was found that the differences in these statistics between the two approaches were negligible. Eventually the series mean method was used to fill in the missing values. The cleaned data (data after the missing values were filled) is used in this work.

4.6 Development of Production Rules from WWTP data

The data discussed above is used for the development of production rules via decision trees that are intended to be used in the diagnostic section of the hybrid system.

Step 1

To classify the data into normal, high or low operating conditions, either a descriptive approach of data mining (i.e. pattern recognition or clustering) or a prior knowledge about the process parameter under observation can be used. In this work, the normal value of a parameter using prior knowledge is used rather than using pattern recognition and clustering. The rational is that it is mandatory to provide the normal value (value that can be used to classify the data) of a parameter under study for Inductive Data Mining using See5.0. Furthermore, this information is readily available from the process. Initially the parameter SS-S, i.e. Suspended Solids out from Secondary stage of wastewater is used for the study and the normal value is 20mg/L.

Step 2

The final product value (concentration, flow rate, etc.) in the chemical or process industries is not always fixed to a single numeric value. There exists a range (or limits) for a parameter such that if the output value for the parameter falls between the limits, it is assumed to be normal; otherwise it is high or low if the value is above or below the range for normal operation. From the diagnostic point of view, this is known as the Tolerance Limit of a parameter. As an example, tolerance limit of 15% is used below. This 15% tolerance limit means that if the value of the parameter under observation changes more than 15% of its set value, it indicates the presence of a fault.

Step 3

By applying the tolerance limit on the normal value, the range for normal operation of SS-S is calculated to be 17-23mg/L. The entire data is then split into normal, high and low classes using this limit with each class representing the corresponding operating condition. Although the low value of output product (concentration of pollutant in this case) in a wastewater is desired, the data that corresponds to a low value of SS-S is classified as at low operating condition.

Step 4

This data is then segregated into training and test data. Training data is used by the algorithm for its learning process, whereas the test data is unseen (by the algorithm) data which it uses for the validation of the model and its results. In this exercise, 75% of the total data is used for training and 25% for test.

Results from WWTP Dataset

After the processing of data as described above, it is then used in See5.0 to obtain production rules via decision tree. As we intend to use these results in fault diagnosis, the set of results that explains the cause-consequence relationship for process parameters while the process is in normal operating condition is rejected. This means that the production rules belonging to the normal class are not used any further, although this information may be important and helpful for other decision-making activities. The number of cases occurring in different classes for the WWTP data is reported in Table 4.2.

Table 4.2 WWTP data in different classes

Class	Total Data	Training	Test
Normal	199	149	50
Low	193	143	50
High	135	101	34

The production rules explaining only low and high classes are listed in Table 4.3.

Table 4.3 Production rules for SS-S

CLASS HIGH

RULE NO 1:
IF RD-SS-G ≤ 86.9
& DBO-E > 89.0
& SS-E > 168.0
(53)

RULE NO 2:
IF 86.9 < RD-SS-G ≤ 90.2
& SS-E > 214.0
& DBO-E ≤ 283.0
(17)

RULE NO 3:
IF RD-SS-G ≤ 83.3
& DBO-E > 89.0
& SS-E ≤ 168.0
(20)

RULE NO 4:
IF RD-SS-G > 90.2
& SED-S > 0.03
& SSV-E ≤ 71.7
& Q-E ≤ 33999
& SS-E > 238
(7)

CLASS LOW

RULE NO 1:
IF 86.9 < RD-SS-G ≤ 90.2
& 144.0 < SS-E ≤ 214.0
& DQO-E ≤ 340.0
(2)

RULE NO 2:
IF 90.2 < RD-SS-G ≤ 90.8
& SED-S ≤ 0.03
& SS-E ≤ 176.0
(15/2)

RULE NO 3:
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& SS-E > 194.0
& RD-DQO-S ≤ 66.7
(27)

RULE NO 4:
IF RD-SS-G > 90.2
& SED-S > 0.03
& SSV-E > 71.7
(3)

RULE NO 5:
IF RD-SS-G > 90.8
& SED-S ≤ 0.03
& SS-E ≤ 194.0
(61)

RULE NO 6:
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& 194.0 < SS-E ≤ 262.0
& RD-DQO-S > 66.7
(23/1)

RULE NO 7:
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& SS-E > 262.0
& DQO-S ≤ 17.0
& RD-DQO-S > 81.8
& PH-D ≤ 7.9
(7)

RULE NO 8:
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& SS-E > 262.0
& DQO-S ≤ 17.0
& RD-DQO-S > 81.8
& PH-D > 7.9
& Q-E ≤ 41073
(2)

These derived rules are then used in fault libraries for the diagnosis of an abnormal event. Fault libraries are a knowledge-base that the diagnostic algorithm uses to determine the reason for, and solution to, an abnormal event in a process. Rule No.1 from the high class corresponding to high operating condition of the process is used for illustration and explanation as follows.

Rule No 1:

If RD-SS-G $\leq$ 86.9

& DBO-E > 89.0

& SS-E > 168.0

(53)

Production Rule No. 1 implies that if at any stage of operation the value of global performance input for suspended solids RD-SS-G starts decreasing, and at that instance the biological demand of oxygen and suspended solids inputs to the plants are greater than 89.0 and 168.0 respectively, there is a probability of at least 53% that the output value for suspended solids from the plant will be higher than 23 mg/l (i.e. the maximum allowable limit for SS-S). The number (53) is the number of cases that have been classified to be at high operating condition (w.r.t. SS-S) by the information obtained from Rule No. 1. This probability can then determine if the total numbers of cases that belong to the high operating condition are known (101 in this case, see Table 4.2).

4.7 Weighting of Production Rules

A modification is suggested here for the enhancement of the production rules to be used in a diagnosis system. A methodology for weighting the production rules is presented and the production rules that correspond to the same class (for example high or low class) are arranged according to their weighting to further simplify and enhance the process of diagnosis.

There are a total of four production rules that describe the reason for a shift of the process to high operating condition. If a fault has been detected in the process indicating high operating condition and the plant operator/engineer is provided with the four possible cause-symptom relationships in the form of production rules for diagnosis, then the first essential question to be answered is: “Which of the four production rules is most important and requires attention first?” As a timely response is very critical at that stage, information that can provide an operator/engineer with guidance in decision making regarding the most promising production rules is very helpful. As an example, there are 8 production rules that give comprehensive information about the reason why the process is in low operating condition. The number of production rules normally increases with an increase in the amount of data, therefore a large number of production rules are possible if there is much historical/operational data available from a process. In this case, the number of production rules can itself pose a challenge in the diagnosis of abnormal event. A simple concept of “weighting function” is introduced here that will help prioritize the knowledge obtained from production rules in the diagnostic process. Weighting function can be obtained from the relationship described in equation 4.6 below:

$$wtF_i = W_i \Big/ \sum_{i=1}^{n} W_i \tag{4.6}$$

where

wtFi = weight function of production rule “i”

$\sum_{i=1}^{n} W_i$ = total weight for all production rules (belonging to one class)

W_i = weight of production rule “i” (calculated from equation 4.7) given as:

$$W_i = \left(C_c - C_{mc} \big/ T_c \right) \Big/ n \tag{4.7}$$

when

C_c= number of cases correctly classified by the production rule “i”

C_{mc}= number of cases misclassified by the production rule “i”

T_c = total number of cases that belong to a class “i” (e.g. high or low)

n = number of leaf nodes/variables in production rules

If the production rules are arranged according to their weight function then this will help a plant operator/engineer to prioritize the knowledge during the decision-making process. The weight function for the production rules is reported in Table 4.4. The production rules reported in Table 4.3 are then rearranged using this weighting concept. This concept will help develop a hierarchy of production rules on the basis of their ability to diagnose a fault more accurately. The production having the highest weight function becomes the first candidate out of all those possible in the event of a fault diagnosis. The revised production rules are reported in Table 4.5.

Table 4.4 Production rules for low and high class by their weight function (ascending order)

Class Low		**Class High**	
Production Rule No.	*Weight Function*	*Production Rule No.*	*Weight Function*
3	0.143	1	0.173
5	0.048	3	0.067
6	0.038	2	0.056
4	0.030	4	0.014
7	0.010		
2	0.006		
1	0.003		
8	0.002		

Table 4.5 Production rules for SS-S arranged by weight function

CLASS HIGH

RULE NO 1*(RANK UNCHANGED):*
IF RD-SS-G ≤ 86.9
& DBO-E > 89.0
& SS-E > 168.0
(53)

RULE NO 2*(FORMALY RULE NO 3):*
IF RD-SS-G ≤ 83.3
& DBO-E > 89.0
& SS-E ≤ 168.0
(20)

RULE NO 3*(FORMALY RULE NO 2):*
IF 86.9 < RD-SS-G ≤ 90.2
& SS-E > 214.0
& DBO-E ≤ 283.0
(17)

RULE NO 4*(FORMALY RULE NO 4):*
IF RD-SS-G > 90.2
& SED-S > 0.03
& SSV-E ≤ 71.7
& Q-E ≤ 33999
& SS-E > 238
(7)

CLASS LOW

RULE NO 1*(FORMALY RULE NO 3):*
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& SS-E > 194.0
& RD-DQO-S ≤ 66.7
(27)

RULE NO 2*(FORMALY RULE NO 5):*
IF RD-SS-G > 90.8
& SED-S ≤ 0.03
& SS-E ≤ 194.0
(61)

RULE NO 3*(FORMALY RULE NO 6):*
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& 194.0 < SS-E ≤ 262.0
& RD-DQO-S > 66.7
(23/1)

RULE NO 4*(FORMALY RULE NO 4):*
IF RD-SS-G > 90.2
& SED-S > 0.03
& SSV-E > 71.7
(3)

RULE NO 5*(FORMALY RULE NO 7):*
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& SS-E > 262.0
& DQO-S ≤ 17.0
& RD-DQO-S > 81.8
& PH-D ≤ 7.9
(7)

RULE NO 6*(FORMALY RULE NO 2):*
IF 90.2 < RD-SS-G ≤ 90.8
& SED-S ≤ 0.03
& SS-E ≤ 176.0
(15/2)

RULE NO 7*(FORMALY RULE NO 1):*
IF 86.9 < RD-SS-G ≤ 90.2
& 144.0 < SS-E ≤ 214.0
& DQO-E ≤ 340.0
(2)

RULE NO 8*(FORMALY RULE NO 8):*
IF RD-SS-G > 92.7
& SED-S ≤ 0.03
& SS-E > 262.0
& DQO-S ≤ 17.0
& RD-DQO-S > 81.8
& PH-D > 7.9
& Q-E ≤ 41073
(2)

Similar to the development of production rules for the one output variable discussed above (i.e. Suspended Solids, SS-S), the production rules for other output variables namely Volatile Suspended Solids(VSS-S), Sediments (SED-S), Biological Oxygen Demand (DBO-S), and Chemical Demand of Oxygen (DQO-S) are developed and presented in Tables 4.6 to 4.9 respectively.

Table 4.6 Production rules for VSS-S arranged by weight function

CLASS HIGH

RULE NO 1*(FORMALY RULE NO 2)*:
IF COND – P > 921
& COND – D > 51
& SS-D > 2550
(6)

RULE NO 2*(FORMALY RULE NO 1):*
IF COND – P > 921
& COND – D > 51
& DBO – D ≤ 78.9
& PH – D ≤ 104
& SS – D > 1846
& SED – D > 11
& ZN – E ≤ 1.8
& RD – DBO – P ≤ 8.0
& 235 < RD – SED – P ≤ 274
(3)

CLASS LOW

RULE NO 1*(RANK UNCHANGED):*
IF COND – P ≤ 921
& SS – D ≤ 863
(5)

RULE NO 2*(FORMALY RULE NO 4):*
IF COND – P ≤ 921
& SS – D > 863
& COND – E > 829
& RD-DBO-G > 90.4
(3)

RULE NO 3*(FORMALY RULE NO 2):*
IF COND – P > 921
& COND – D > 51
& DBO – D ≤ 78.9
& SS – D ≤ 921
(3)

RULE NO 4*(FORMALY RULE NO 3):*
IF COND – P ≤ 921
& SS – D > 863
& COND – D > 829
& RD – DBO – G ≤ 90.4
& SED – D ≤ 12
(3)

Table 4.7 Production rules for SED-S arranged by weight function

CLASS HIGH

RULE NO 1*(RANK UNCHANGED):*
IF RD-SS – G > 79.5
& RD – DQO –G > 81.7
& COND – D ≤ 39
& RD – SED – P > 204
(3)

RULE NO 2*(RANK UNCHANGED):*
IF RD-SS – G > 79.5
& SSV – P > 63.6
& PH – E > 7.6
& 39 < COND – D ≤ 52
& RD – DQO –G > 86.8
(4)

CLASS LOW

RULE NO 1*(FORMALY RULE NO 2):*
IF RD – DQO – G ≤ 55.6
& COND – P > 1165
(3)

RULE NO 2*(FORMALY RULE NO 3):*
IF COND – D > 103
& 55.6 < RD – DQO – G ≤ 66
& RD – SED – P ≤ 220.0
(3)

RULE NO 3*(FORMALY RULE NO 1):*
IF RD – DQO – G ≤ 55.6
& COND – P ≤ 1165
& RD – DQO – S ≤ 74.4
(3)

RULE NO 4*(FORMALY RULE NO 4):*
IF COND – D > 103
& 55.6 < RD – DQO – G ≤ 66
& RD – SED – P > 220.0
& DBQ – E > 488
(3)

Table 4.8 Production rules for DBO-S arranged by weight function

CLASS HIGH

RULE NO 1*(FORMALY RULE NO 2):*
IF COND – P > 2340
& SS –D > 2550
(6)

RULE NO 2*(FORMALY RULE NO 1):*
IF COND – P > 2340
& 921 < SS –D ≤ 2550
& RD – SED – P ≤ 295
(2)

CLASS LOW

RULE NO 1*(RANK UNCHANGED):*
IF SS-D ≤ 921
& DQO-D ≤ 0.1
(6)

RULE NO 2*(FORMALY RULE NO 3):*
IF SS-D ≤ 921
& SS-P ≤ 278
& DQO-D > 0.2
(5)

RULE NO 3*(FORMALY RULE NO 2):*
IF SS-D ≤ 921
& SS-P ≤ 278
& 0.1 < DQO-D ≤ 0.2
& COND-D > 64
(3)

Table 4.9 Production rules for DQO-S arranged by weight function

CLASS HIGH

RULE NO 1*(FORMALY RULE NO 2):*
IF SED-E ≤ 7.0
& RD-DBO-G > 88.7
& RD-SS-P ≤ 64
& DBO-P > 134
(4)

RULE NO 2*(FORMALY RULE NO 1):*
IF SED-E ≤ 7.0
& RD-DBO-G > 88.7
& RD-SS-P > 64
& RD-SED-G ≤ 99.7
& DBO-D > 64.5
& DBQ-E > 297
& DBO-P > 296
& ZN-E > 0.4
(2)

CLASS LOW

RULE NO 1*(FORMALY RULE NO 4):*
IF SED-E ≤ 7.0
& RD-DBO-G ≤ 88.7
& DBO-P ≤ 145
& RD-SED-P ≤ 317
& RD-DBO-P ≤ 7.8
& RD-DBO-S > 16
& DBQ-E > 319
(6)

RULE NO 2*(FORMALY RULE NO 3):*
IF SED-E ≤ 7.0
& RD-SS-P > 64
& RD-SED-G > 99.7
& RD-SS-G > 90.7
& DBO-P ≤ 146
& RD-DBO-G > 92.7
(3)

RULE NO 3*(FORMALY RULE NO 2):*
IF SED-E ≤7.0
& DBQ-E > 297
& DBO-P > 145
& DBO-D > 64.5
& 84.1< RD-DBO-G ≤ 88.7
& COND-D > 100
& 159 < SS-P ≤ 228
& RD-DBO-P ≤7.8
& RD-DBO-S ≤31
(4)

4.8 Validation of Production Rules

Validation of a model is a very critical step in model development (either a mathematical model or model in the form of production rules). A model may initially produce very encouraging results but its accuracy on the new process or data set actually decides if the model is fit for the intended purposes. In this case study, the WWTP data set was divided into two portions i.e. 75% and 25%. The major portion of the data was used as training data-set for the learning of See 5.0 and the development of production rules. The remaining 25% is then used as a test data-set to validate the model (to measure the accuracy of the production rules See 5.0 developed on the training data-set). The following table summarizes the results obtained on the output variables used in this study.

Table 4.10 Validation results of Production Rules developed by See 5.0

	See 5.0 Results (% accuracy)	
Variable	**Training data-set**	**Test data-set**
SS-S	97.5	96.9
VSS-S	97.3	95.5
SED-S	98.1	96.6
DBO-S	99.7	94.7
DQO-S	96.4	91.7

4.9 Concluding Remarks

A review of different data driven techniques is presented. The underlying principles of Inductive Data Mining, a technique selected for the research work, are discussed. Production Rules are developed using Inductive Data Mining on the Spanish data set of a wastewater treatment plant in order to build the knowledge base (fault libraries) of the diagnostic system. A new concept of Weight Factor is introduced and implemented on the production rules generated in the chapter. This concept helps arrange the production rules for easy retrieval.

Chapter 5

Diagnostic Algorithm and Java Application

5.1 Introduction

An algorithm is presented that uses the mathematical model from Chapter 3 for the detection of faults (as discussed in chapter 3) and the fault libraries that are made up of the production rules (derived from the WWTP dataset in chapter 4) for the diagnosis purposes. These component parts provide a complete fault detection and diagnosis system. The ideology behind development of this diagnostic system, together with the assumptions made, is discussed below, and is followed by the development of a software platform (a Java application). This Java application is used for simulation of the process using the mathematical model for the detection of faults. The implementation of the diagnostic algorithm enables the Java application to be used for the diagnosis of faults in the process. A discussion of the development and architecture of the application is presented, followed by the results obtained.

5.2 Diagnostic Algorithm

As discussed in Section 2.4, it has been shown by Venkatasubramanian and co-workers (2003b, 2003c, 2003a) that a diagnostic system is a valuable area of research in fault detection and diagnosis. This section presents a new diagnostic system for the detection and diagnosis of fault in a process.

Analogous to the medical profession, where graduates have the opportunity to apply their expertise in many fields of medicine as a physician or a surgeon, it is proposed here that instead of using available techniques to perform simultaneously detection and diagnosis of faults, these techniques should be classified into Detection and Diagnosis techniques on the basis of their strengths. Furthermore, any future research should be focused on improving the specialty of a technique (either detection or diagnosis of faults). Based on this idea, a diagnostic algorithm is presented here that uses analytical redundancy based upon the mathematical model for the detection of a fault and production rules for the diagnosis.

While developing the algorithm, the following assumptions were made:

a) Due to the complexity, multiple faults are not considered in this study.
b) For the detection of faults, the data is considered to be noise free.
c) The term: "multi faults" used in this work (later in Table 5.2) refers to the two faults that occur simultaneously with distinct characteristics and no interconnecting relationship exists between the two.

The structure of a typical fault detection and diagnosis system is shown in Figure 5.1.

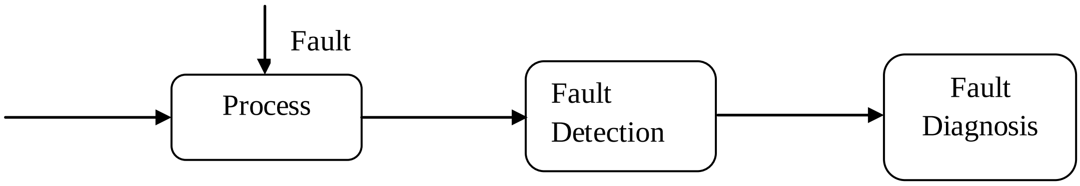


Figure 5.1 A schematic of fault detection and diagnosis

Fault detection is the first step in a diagnosis system. Fault detection is determining whether a fault has occurred in the process under observation. It helps engineers/operators identify if a fault exists.

Fault diagnosis is the determination of the cause of the observed out-of-control status of a process variable. In other words, fault diagnosis is determining the type, location, magnitude and time of the fault. This step is essential in counteraction or elimination of a fault.

Some researchers split diagnosis further into the fault isolation and its identification - which when combined have the same meaning as that defined above. In this work, rather than fault isolation and identification, the term fault diagnosis is used. Another term, "diagnosis system", when used in this work refers to both the fault detection and the diagnosis system rather than only the diagnosis system.

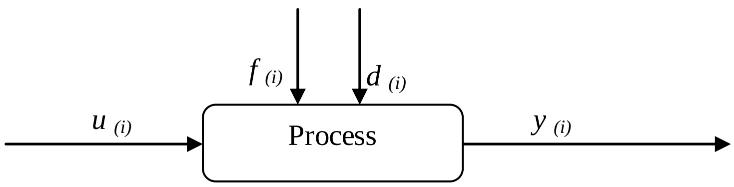
5.2.1 The Algorithm

A comprehensive survey of available and most commonly used techniques for the detection and diagnosis of faults is given by Venkatasubramanian et al. (2003b, 2003c, 2003a). In their extensive review, it was shown that despite all the research for improvement in detection and diagnosis of process faults, it is a widely accepted by most researchers that none of the techniques introduced so far have the potential to meet the key requirements of a practical diagnosis system (as defined by the ten key characteristics of a diagnostic system in Venkatasubramanian et al. (2003a)). One possibility for enhancing the effectiveness of a diagnosis system is to adopt the hybrid methodology. This is based on the assumption that these methods can complement each other's limitations in different areas, thus resulting in an overall improved diagnostic system. As an example, fault explanation through a causal chain is best done through the use of digraphs, whereas fault isolation might be difficult using digraphs due to the qualitative ambiguity (Venkatasubramanian et al., 2003a).

Building upon the detailed review by Venkatasubramanian et al. (2003b, 2003c, 2003a), this work presents a new approach for fault detection and diagnosis employing both mathematical models and historical data from a wastewater treatment plant (for detection and diagnosis respectively). The knowledge base of the diagnostic system is built up of the historical data using inductive data mining and application of the commercial software See5.0. The mathematical model is used for the detection of faults in the process. A step by step overview of the system is given below.

a) Fault Detection

Assume the system has inputs $u_{(i)}$ and outputs $y_{(i)}$ (i = 1 to n). Under the fault free operational mode, the output $y_{(i)}$ will conform to the input $u_{(i)}$. Now consider the system with a fault $f_{(i)}$ and/or a process disturbance $d_{(i)}$ as shown below:

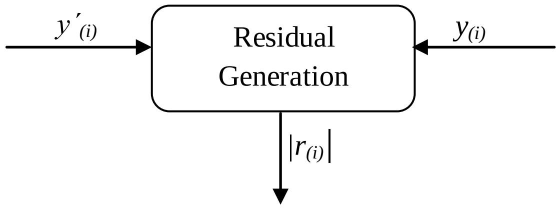


Step 1: Residual Generation

The first step in the system is the residual generation where residual (***r***) is defined as an error in a result. In the context of fault detection and diagnosis, it is the difference between the actual and the desired value of any process parameter. The residual in the output parameter can be calculated from the following equation:

$$\boldsymbol{r}_{(i)} = \boldsymbol{y}_{(i)} - \boldsymbol{y'}_{(i)}$$

where $y_{(i)}$ is the output variable and $y'_{(i)}$ is the desired (set) value for parameter $y_{(i)}$. For the purpose of its implementation in computer code, although the value of $\boldsymbol{r}_{(i)}$ is calculated above but $|\boldsymbol{r}_{(i)}|$ will be used in next steps (the Java application need only positive value to decide if the process is performing above or under the control limits).



The desired value $y'_{(i)}$ can be obtained in a number of ways. It includes historical data, prior knowledge and principal models of the process. A statistical method can be applied on historical data to determine a value of the output that is considered to be in the normal operating state. Prior knowledge from plant engineers and operators can be useful in deciding the normal operating value for any output variable. Another way to obtain the normal operating value for a process variable as used in this work is the use of mathematical models. A mathematical model can be obtained by carrying out a simple mass and energy balance on the process under consideration. For a given input **u**, it is possible to find out the expected normal value of the output via mathematical models by the aid of computer simulations. In this study, the wastewater mathematical model (chapter 3) is used for the simulation. And before it can be employed for the residual generation in this step, it was validated against the wastewater data-set.

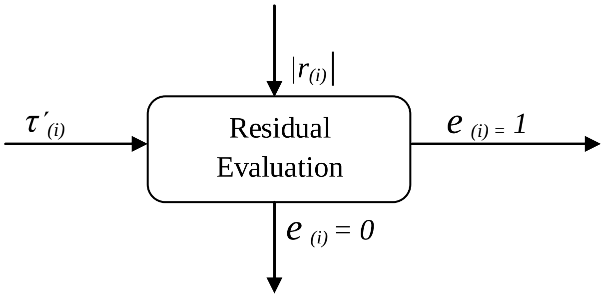
Step 2: Residual Evaluation

Once the residual is generated in Step 1, the next critical step is to evaluate this residual to establish if any inconsistency exists in the system. This is known as residual evaluation. The inputs to this step are the outputs from residual generation, i.e. $|\boldsymbol{r}_{(i)}|$, and $\tau'_{(i)}$ which is the tolerance for each residual generated. Tolerance is similar to the desired value and can be obtained in different ways. Tolerance helps to identify if the process, although deviated from the expected value, is still within the normal operating state. If not, then determine the direction of the drift, i.e. +ve (operating state above the allowable maxima; i.e. high) or –ve (operating state below the allowable minima; i.e. low). The final calculation in this step yields the value of error **e** (which potentially indicates a fault), and it can be calculated from the following relationships:

$$e_{(i)} = 0,\ |r_{(i)}| \leq \tau'_{(i)}$$

and

$$e_{(i)} = 1,\ |r_{(i)}| > \tau'_{(i)}$$

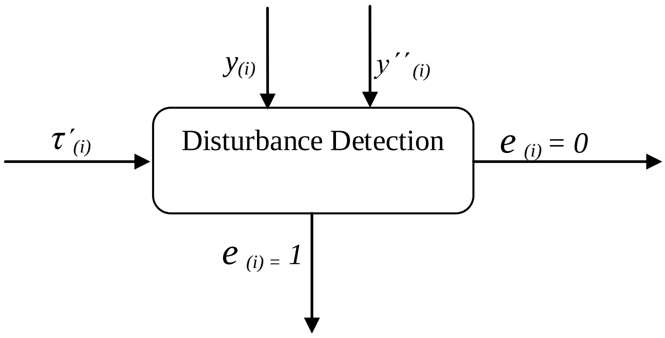


A value of $e_{(i)} = 0$ indicates that the system is in normal operating state, where a value of $e_{(i)}=1$ indicates the presence of a potential fault. Further analysis is carried out once the value of $e_{(i)}$ has been assigned.

Step 3: Disturbance Detection

The decoupling of a disturbance from a fault is a key research area in fault detection and diagnosis. Recursive use of mathematical models is employed in this diagnosis system which can isolate a disturbance from a process fault. A mathematical model is employed using process input $u_{(i)}$ to calculate the expected value of the output variable, i.e. $y''_{(i)}$. With the new expected value of the output variable and output value from the process $y_{(i)}$, then Step 2 and Step 3 are repeated for the detection of disturbance in this step. The value of **e** now determines whether this unwanted incident in the process is an uncontrollable input (process disturbance) or a fault;

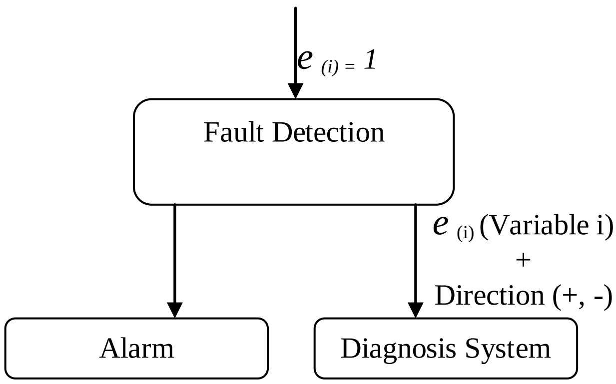
where $e_{(i)} = 0$ indicates a disturbance in input $u_{(i)}$; and $e_{(i)} = 1$ indicates a fault in the process.



Depending on the nature of the disturbance, i.e. step, ramp or continuous (reconfiguration of input), the new calculated value of $y''_{(i)}$ can be passed onto Step 2 for either temporary or permanent use as the set value of output $y_{(i)}$.

Step 4: Fault Detection

If Step 3 produces $e_{(i)} = 1$, then it indicates the presence of a fault in the process which effects the value of the output variable $y_{(i)}$. The results are then passed to the diagnosis section of the system along with the information about the variable, i.e. $y_{(i)}$, and the direction of fault, i.e. (+ve or –ve drift).



An integrated overview of the fault detection section for this diagnostic methodology is given in Figure 5.2.

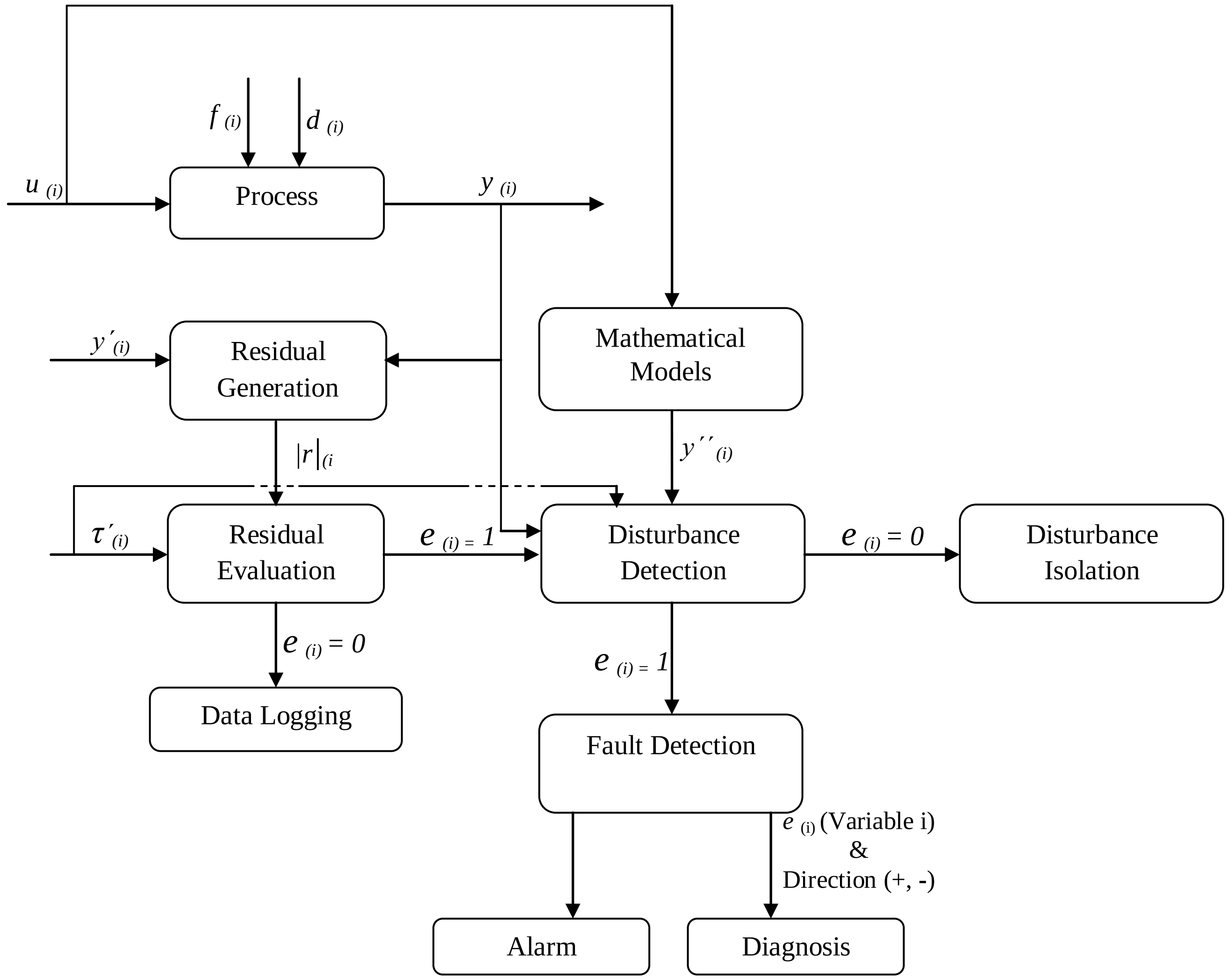


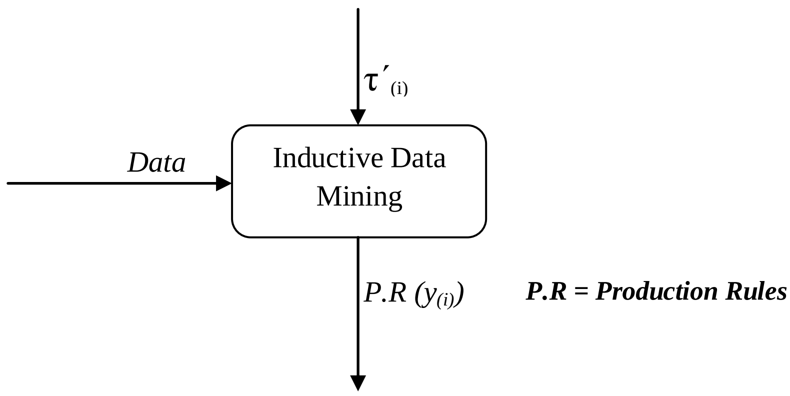
Figure 5.2 Integrated view of Fault detection

b) Fault Diagnosis

After the detection of a fault, the output variable away from the normal operating condition and its direction (+ve drift or –ve drift, where +ve refers to the process performing above the control limit and –ve refers to its performance under the control limit) is then passed onto the diagnosis section of this diagnostic system. For diagnosis of a fault, the major requirement is a knowledge base that can be used to compare symptoms and produce a corrective action for the fault under observation. In this diagnostic methodology, the knowledge base is produced from the historical data. Valuable information and hidden interactions between the process variables can be obtained by exploring the data. The commercial software See5.0 is used in this work to conduct inductive data mining on the historical data available from a wastewater plant. The results can be obtained in the form of a decision tree or production rules.

Step 1: Inductive data mining

Two inputs are required in this step in order to produce a meaningful relationship between the measured variables of the process, i.e. data, and the classification basis for the data. The data is classified using the numeric values from the tolerance $\tau'_{(i)}$ used in the detection section of this work. It should be noted that classification of data needs to be carried out on every measurable output $y'_{(i)}$ using its respective tolerance $\tau'_{(i)}$. The production rules for each of the variables used are obtained here. These production rules explain the reason for the deviation of a variable from its normal operating state. There will be essentially two sets of production rules, one that explains the +ve drift of the variable and other for –ve drift.



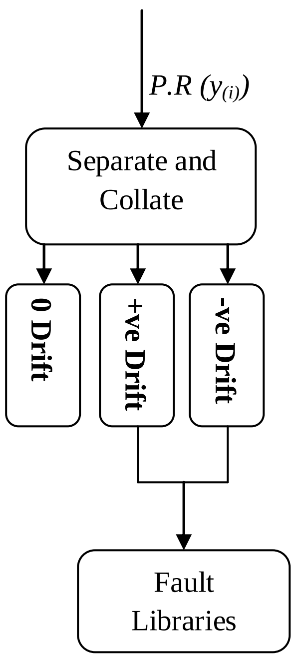
Step 2: Fault Libraries

From the production rules obtained in the above step, fault libraries are built in order to compare the fault symptoms and hence correctly diagnose the fault. The structure of a fault library used in this work is as follows;

Table 5.1 The fault libraries used in the knowledge base of the diagnosis system

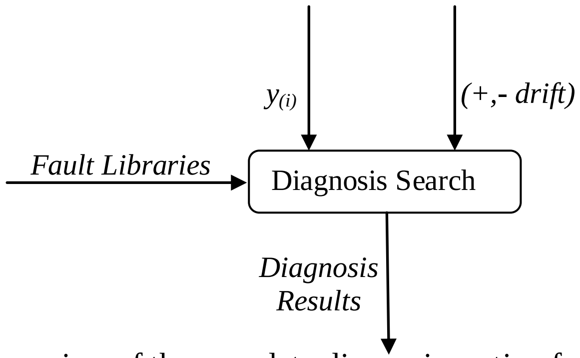
Fault Library								
Parameter	$y_{(1)}$		$y_{(2)}$		$y_{(3)}$		$y_{(n)}$	
Drift	+	-	+	-	+	-	+	-
Production Rules	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….	If…. and… and… and… and… and… and… then….

The production rules belonging to each parameter need to be organized in the fault library for access by the system when required.



Step 3: Diagnosis Search

This is the final step for the fault diagnosis system before it can present results for the mitigation of a fault, and hence recovery of the process back to its normal operating state. Using the information obtained from the fault detection system, i.e. $y_{(i)}$ and (+,- drift), the diagnosis system searches for the best candidate out of the fault library. The initial step of the search methodology is to match the variable to from those available in fault library. When the variable is identified; the search method will display the result (production rules) from the available drift (+ve or -ve).



An integrated overview of the complete diagnosis section for the proposed diagnostic system is presented in Figure 5.3.

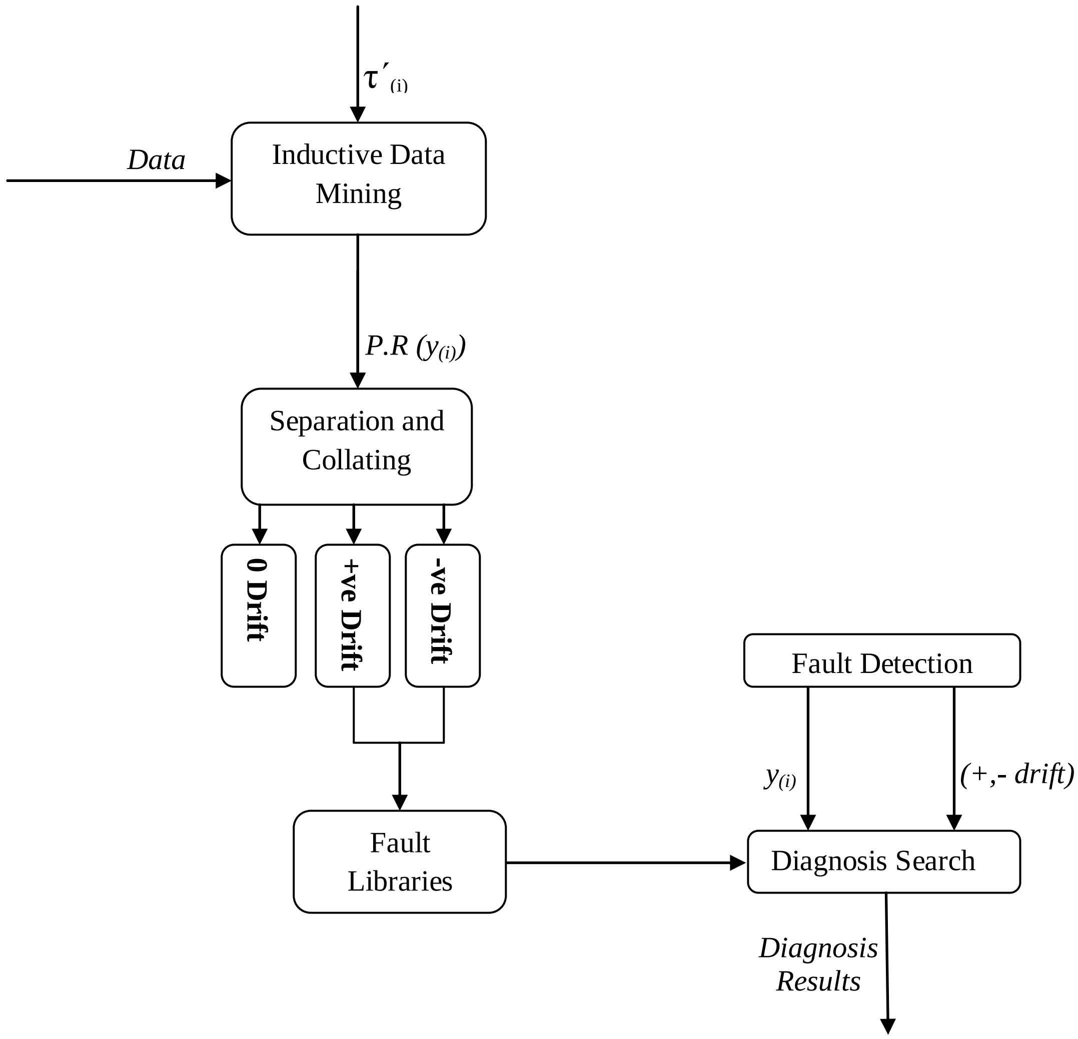


Figure 5.3 An integrated view of the components in the diagnosis section

5.3 Software Platform

After the successful development of a new diagnostic algorithm, efforts were made to develop a software platform that can be used for the simulation (to be used in the detection of faults using mathematical models), and diagnosis of faults using production rules from the fault libraries. Java Development Kit (**JDK** version 6) and NetBeans IDE (Integrated Development Environment version 6.1) is used for the development of the application. A brief introduction to Java and NetBeans is given below before presenting the development of the Java application.

Java

Java is the most influential and widely used programming languages of the 21^{st} century (TIBCO-Software-Inc, 2008). The language derives much of its syntax from languages C and C++ (once the most widely used languages and now second in application). Java applications can run on any Java Virtual Machine (JVM) regardless of computer architecture. Java is general-purpose, object-oriented and is specifically designed to have as few implementation dependencies as possible. Java is used for application software through to web applications. It was originally designed for use on digital mobile devices, such as cell phones. However, when Java 1.0 was released to the public in 1996, its main focus had shifted to use on the Internet. Since 1996 it has evolved as a successful language for use both Internet and other uses. A decade later, it is still an extremely popular language used by over 6.5million developers worldwide (Palmer, 2003).

The following reasons lead to the choice of Java rather than other languages in this work, relating to a few key principles from the original Java design (Leahy, 2010):

- ***Easy to Use:*** The fundamentals of Java came from a programming language called C++. Although a powerful language, it was felt to be too complex in its syntax, and inadequate for all of Java's requirements. Java is built using improved ideas, to provide a programming language that is powerful and simple to use.
- ***Reliability:*** Java needed to reduce the likelihood of fatal errors from programmer mistakes. With this in mind, object-oriented programming was introduced. Once data and its manipulation were packaged together in one place, it increased Java's robustness.
- ***Security:*** As Java was originally targeting mobile devices that would be exchanging data over networks, it was built to include a high level of security. Java is probably the most secure programming language to date.
- ***Platform Independent:*** Programs needed to work regardless of the machine upon which they were being executed. Java was written to be a portable language that does depend upon a particular operating system, or the computer hardware.

In addition to these points, Java is available under the GNU General Public License (GPL), thus making it free software.

NetBeans

The NetBeans IDE is an open-source integrated development environment. NetBeans IDE supports development of all Java application types. It provides the "plumbing" for the Graphical User Interface (GUI) in any Java application that conventionally every developer had to write themselves otherwise. NetBeans provides these entire straight “out of the box” thus saving a developer a significant amount of time and work (NetBeans, 2010).

NetBeans is available as open source free software. It can be run on most operating systems including Windows, Linux, Mac OS X and Solaris (Fears, 2008).

5.4 Architecture of the Application

The GUI of the application “WWTP-Simulation and Diagnosis” is presented in Figure 5.4. The application consists of the following five screens and a graphical applet.

1. U.D. Inputs
2. Flowsheet
3. Results
4. Online Data
5. Faults

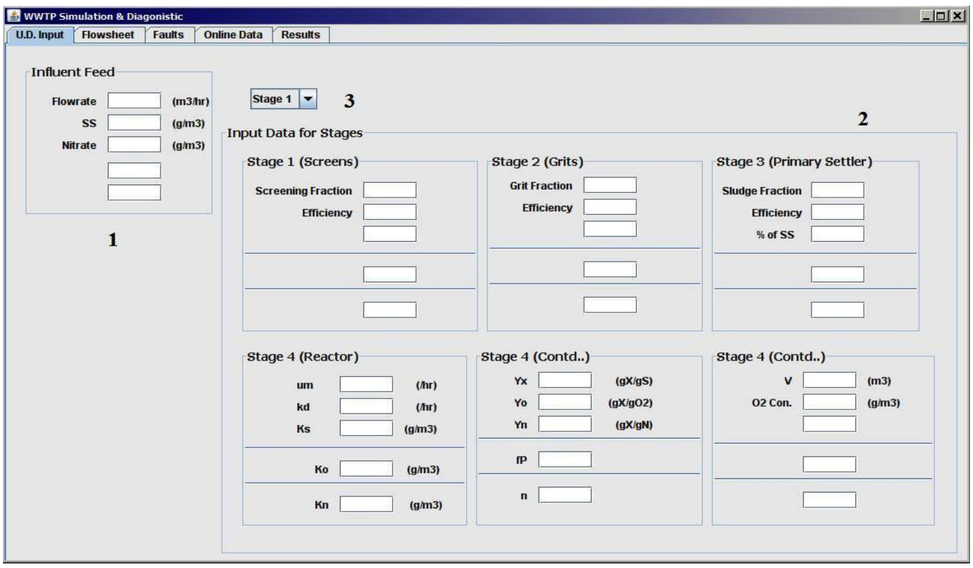


Figure 5.4 The Graphical User Interface (GUI) of the application

Figure 5.4 shows the main screen of the "WWTP-Simulation and Diagnostic" application. The first screen to be discussed is the "U.D. Inputs (used defined inputs)".

The inputs to the WWTP are declared in the field marked as "1" in figure 5.4.

Field "2" points to the process parameters used in the different stages of the WWTP. Most of the process parameters are discussed in Chapter 3.

This application can be used for the simulation of different stages of the wastewater in a sequential and cumulative manner by selecting the number of stages (section "3" on figure 5.4). A point of emphasis here is that if Stage 2 is selected, then this will give the simulation of stages 1 and 2; whereas selecting stage 3 will simulate stage 1, 2 and 3.

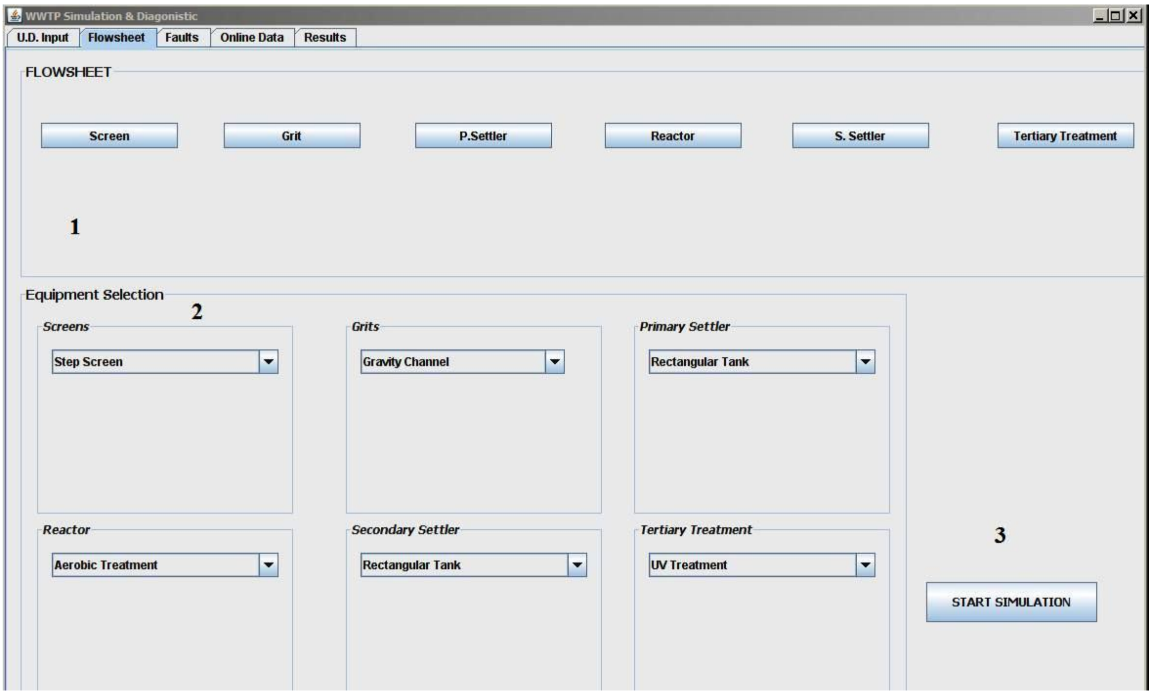


Figure 5.5 Flowsheet screen of the WWTP application

Equipment selection, simulation command, and selection of an individual stage is developed in the "Flowsheet" tab of WWTP application. In figure 5.5, "3" indicates the simulation command button of the application that will initiate the simulation of required stages (as discussed above under figure 5.4) using the inputs on the "U.D. Inputs" screen and a file "WWTP.java" that includes the model equations. The file “WWTP.java” is solved using the Runge-Kutta 4 (RK4) method (also coded in Java).

The next screen next to Flowsheet is the “Results” of this application. The numeric results obtained from the simulation of the model are displayed in the screen on the execution of the software. The “Results” screen is used mainly to display the results from the simulation. Although graphical presentation is used to display the simulation results, it was also considered useful to display the results in numeric form in the WWTP application. The reasons were the use of numeric data for the detection of faults, and the assumption that the simulated data may be used in future research work. For example, the data may be required for the validation of some experimental results.

The detection of faults occurred in the screen labeled as “Online Data”.

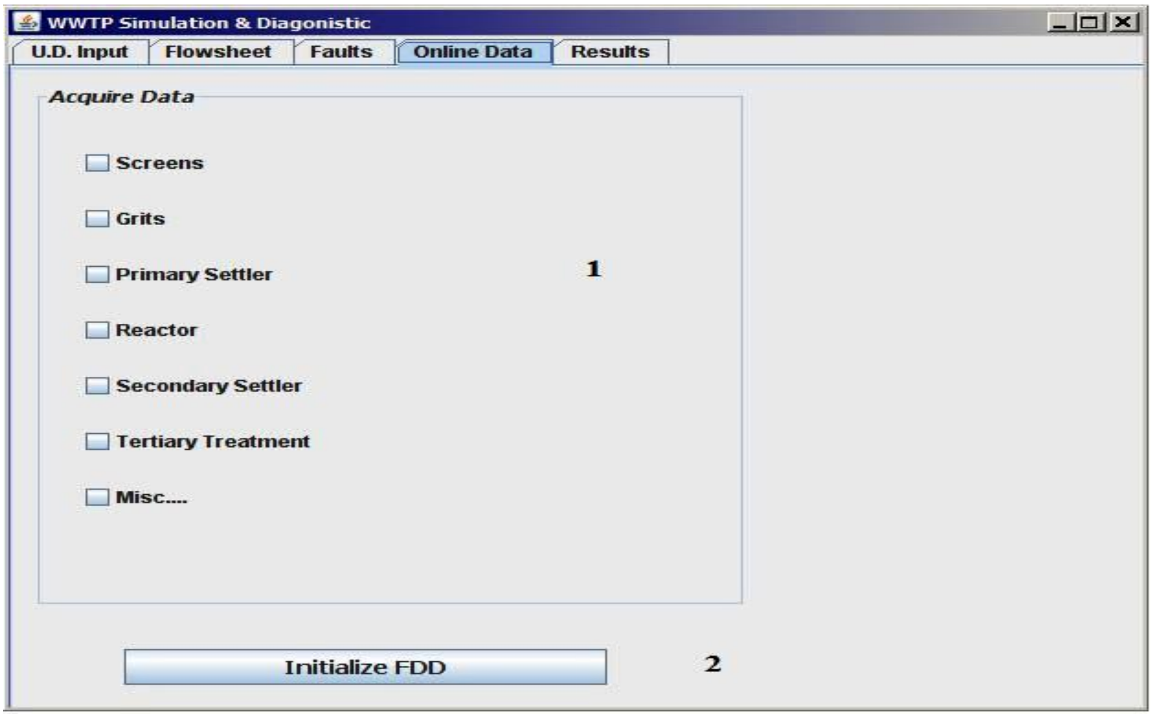


Figure 5.6 Detection and Diagnosis Algorithm command window

The check boxes (No. “1” in figure 5.6) were designed so that that once selected, it will import the online data when coupled to the control system of a wastewater treatment facility. However, it was not possible to obtain technical support from any local wastewater treatment facility (preventing activation and use of this screen). For the WWTP application, the data for the detection of a fault is entered manually into the file. After the acquisition of data (in this application, manual entry of data in the file), the detection and diagnosis of a fault can be initiated using the command box labeled "Initialize FDD" (labeled as "2" in figure 5.6).

The diagnostic results are the displayed in the last tab labeled as "Faults". A screenshot of this screen is given in figure 5.7 below.

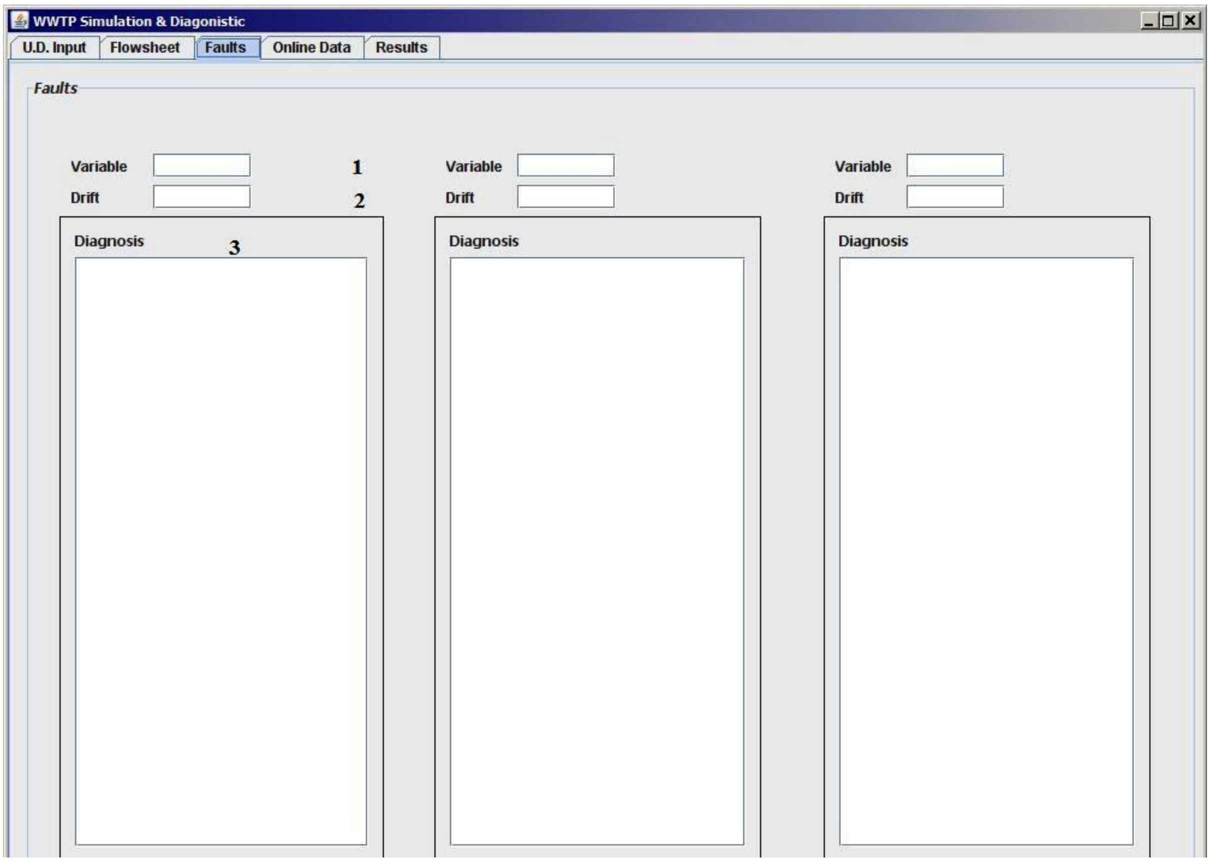


Figure 5.7 Screen for the display of the diagnostic results

The variable suspected of faulty behavior (for example, SS, VSS, etc.) is displayed in the field labeled as "1" in figure 5.7, whereas the drift (i.e. high or low) is displayed in the field below labeled as "2". The production rules (developed in Chapter 4) are displayed in the field labeled "3" with the title "Diagnosis".

5.5 Results and Discussion

The diagnostic algorithm proposed earlier in this chapter, and the WWTP application developed, along with the WWTP dataset were used to generate results. From the WWTP dataset, input values were selected and used in the WWTP Java application, the known output values (from WWTP dataset) were fed to the software for detection purposes. The production rules for the diagnostic suggestion were used for the development of the fault libraries as the knowledge base of the FDD platform. When the suspended solids reduction was inhibited due to the poor production of microorganisms, the algorithm was able to detect and eventually provide suggestions for the diagnostics. Figure 5.8 below shows the inputs used for the fault scenario when the suspended solids concentration in effluent eventually increased. Figures 5.9 and 5.10 present the graphical results from the simulation and the diagnostic results after the detection of fault, respectively.

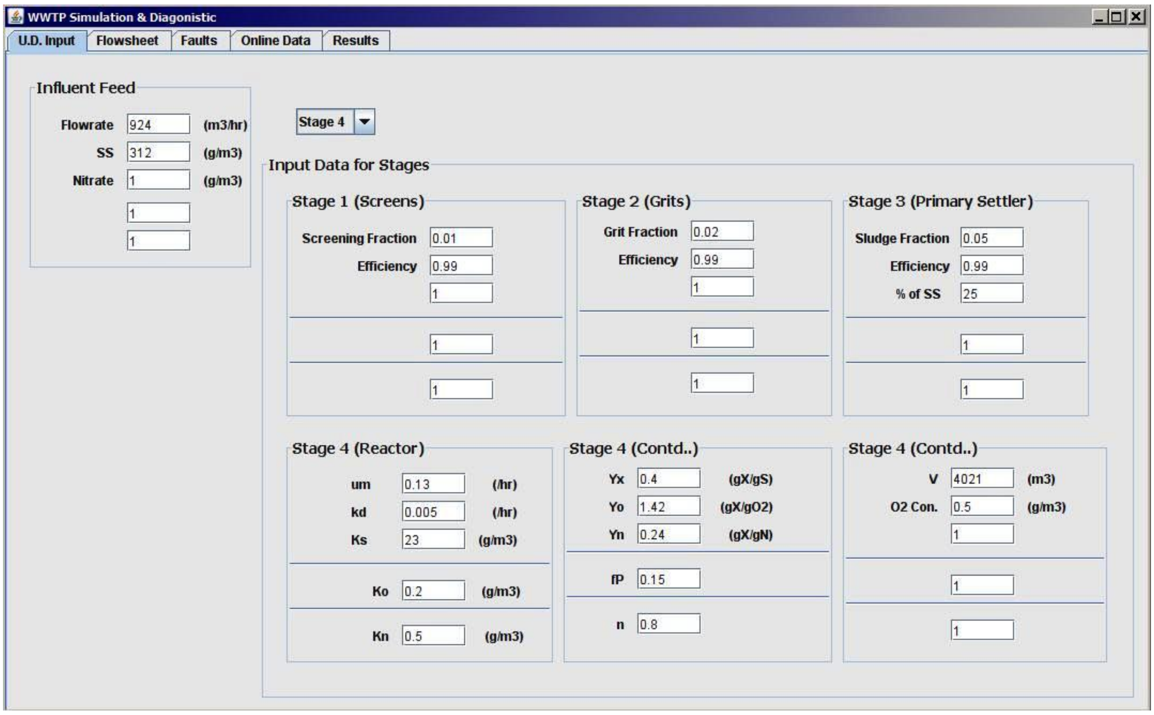


Figure 5.8 Input of process parameters for simulation

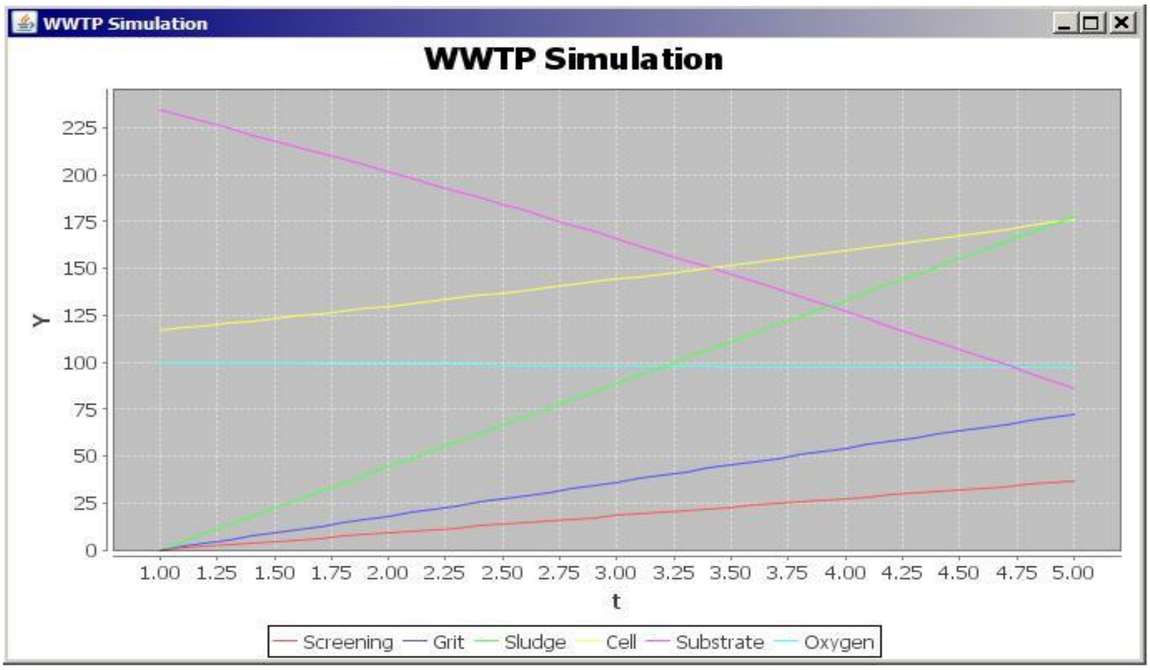


Figure 5.9 Graphical presentations of the simulation results

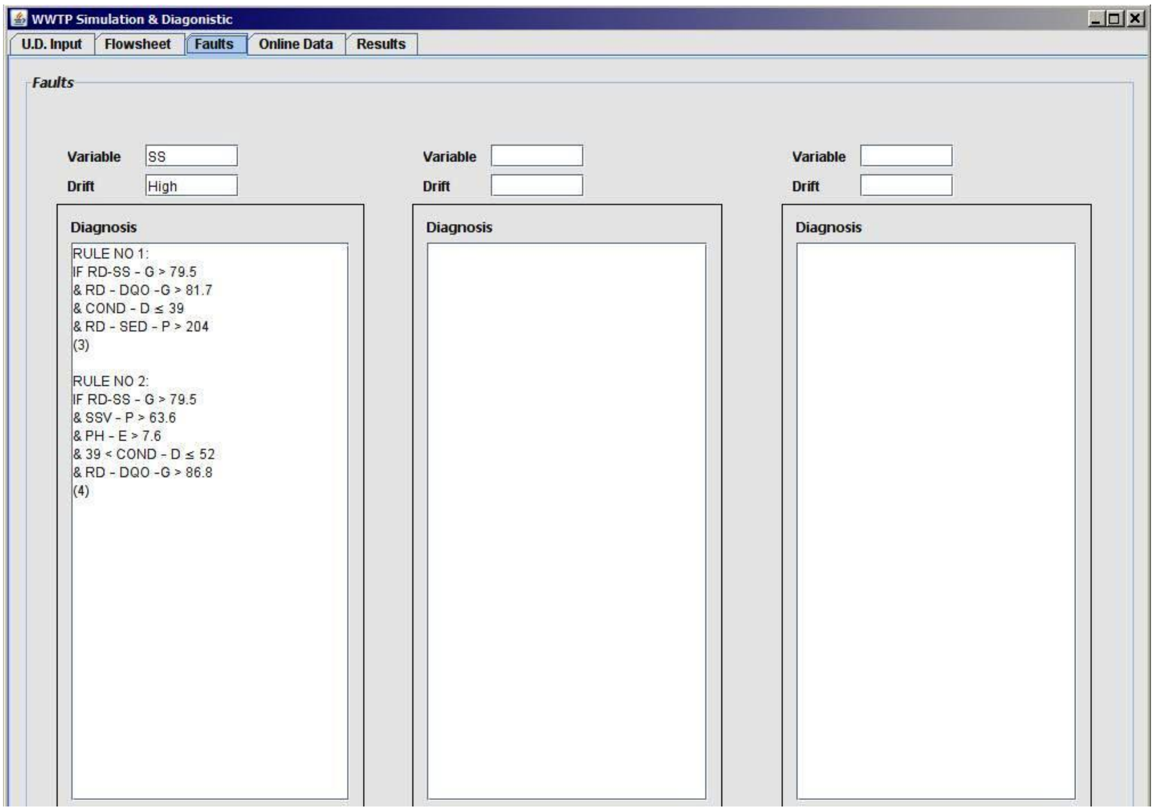


Figure 5.10 Diagnostic results for high SS value

Similarly when a low concentration of suspended solids in effluent was detected (although in practice, the low concentration of suspended solids is not a fault, but is considered as a fault in this study), the WWTP software was able to detect and diagnose this fault.

The graphical presentation of the results and the diagnostic suggestions from the fault scenario discussed above are presented in figures 5.11 and 5.12 respectively.

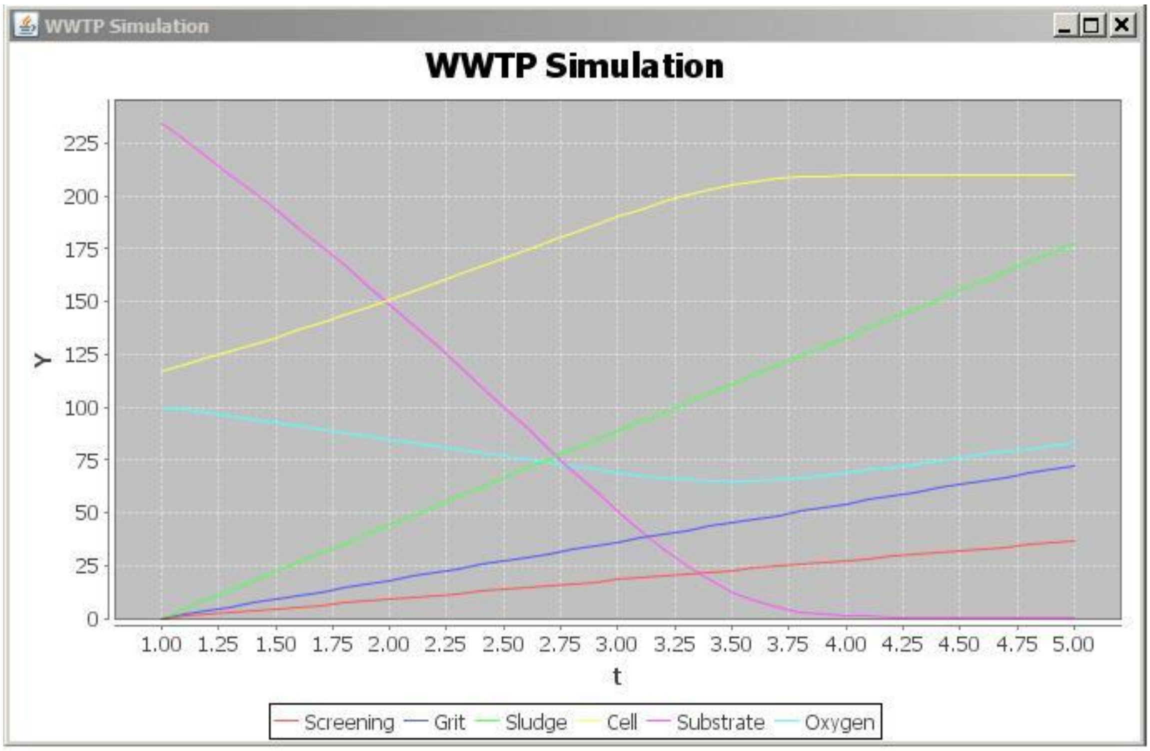


Figure 5.11 Simulation indicating low SS value

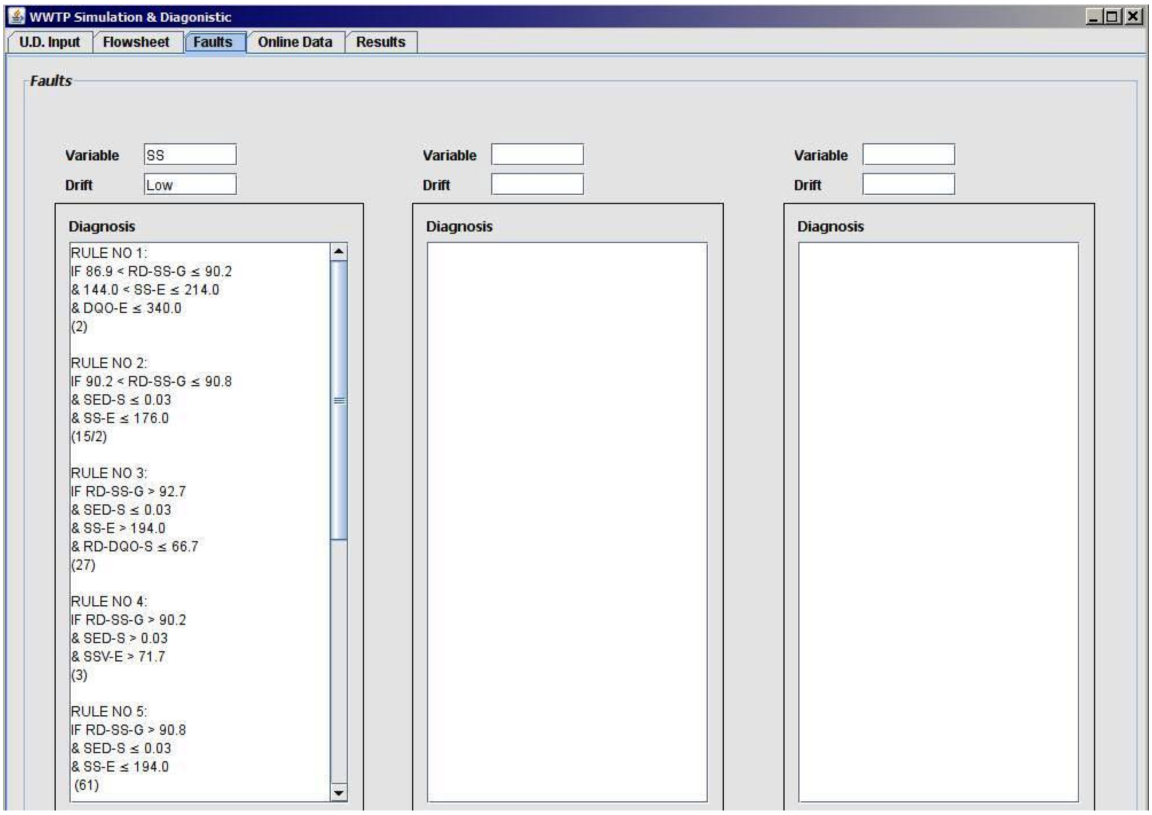


Figure 5.12 Set of diagnostic results for low value of SS

Further scenarios using other output variables were studied and results are reported in Table 5.2.

Table 5.2 Results of the diagnostic methodology

	Variable	Direction	Detection	Diagnosis	Time(Sec)
Single Fault	SS	+	✓	✓	1.5
	SS	-	✓	✓	1.5
	SSV	+	✓	✓	1.5
	SSV	-	✓	✓	1.5
Disturbance	SS	+	✓	✓	1
	SS	-	✓	✓	1
	SSV	+	✓	✓	1
	SSV	-	✓	✓	1
Multi Fault	SS & SSV	+ & +	✓	No	2
	SS & SSV	- & -	✓	No	2
	SS & SSV	+ & -	✓	No	2
	SS & SSV	- & +	✓	No	2

The results show that the most troublesome scenario for the proposed methodology is if two faults occur simultaneously. It is determined that there is a need to expand the knowledge base obtained from data mining in order to accommodate multiple faults. Recommendations to enhance this methodology are discussed in Chapter 6.

5.6 Concluding Remarks

An algorithm based on a new approach is presented in this chapter, and the results obtained confirmed its suitability. A software application is also developed to implement the algorithm and yielded reliable simulation results. Although there remain some challenges to be overcome with the proposed software application (see Chapter 6: Conclusions and Future Work) and also with the proposed algorithm (also see Chapter 6), this study serves its objective to develop an initial platform for future researchers intending to use different techniques to perform different roles in process diagnostics.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

An algorithm is proposed which has been applied to a data set from a wastewater treatment plant. A mathematical model was used for detection, whereas the production rules were employed for the diagnosis, of process faults. The accuracy of detection of faults using the mathematical model was calculated to be 93% (Table No. 3.5) whereas, the production rules exhibited 95% accuracy on the validation step (Table No. 4.10). It was not possible to compare the response time for the detection and diagnosis of faults using this technique with other systems because that data is not available in the literature. A Java application was designed for the implementation of the algorithm and it performed successfully, although some aspects still require improvement.

A new technique of ranking the production rules is proposed and was applied in this research to reduce the large number of production rules and improve the efficiency of the predictions. In this study, the production rules are used to build the knowledge base of the algorithm, and are subsequently used in the diagnosis. The production rules were obtained by using a data-set of WWTP, and an inductive data mining technique using See 5.0 was applied to yield the production rules.

A mathematical model was derived, mainly based upon the ASM1 model, to be used for the detection of faults. The model was validated against the WWTP data-set. An accuracy of 93% on the validation was considered acceptable in this work, but it is expected that calibration of the proposed model would improve the effectiveness of this technique.

One major issue encountered in this research work was the lack of technical input and data sets from any local wastewater treatment facilities. Therefore, a data-set from 1991 was used, which mainly covers the dynamics of suspended solids removal from an activated sludge system.

Despite the lack of extensive technical data, the average response time of 1.5 sec for the proposed software (for the detection of fault and/or disturbance, search of the best possible diagnostic strategy from the fault libraries, and the display of results on screen), 93% model accuracy, 95% production rules accuracy demonstrate the validity and represent the key achievements from this work.

6.2 Recommendations for Future Work

The following areas are identified for continuation of this research work:

a. Modeling errors are a common problem especially when a model is to be used for process fault detection and diagnosis. It is suggested that if the mathematical model and operational data for a process is available, then genetic algorithm or programming (a technique well established and used for optimization) can be used to fit that model to the operational data thus improving the output (predictions) obtained from the model.
b. It is expected that the "WWTP-Simulation and Diagnostic" has the potential to be used in the chemical and processing industries. Thus it is recommended to apply this technique on a more complex process where: (a) an elaborated and exhaustive mathematical model of the process is available; and (b) where abundant historical and process data covering almost all aspects and variables of the process are available, in order to test the robustness of this technique.
c. Detection of multiple faults in a process is a challenging task. It is proposed that if sufficient operational or historical data containing multiple faults scenarios is available, then data mining should be employed for determination of the root causes and the process behavior when multiple faults are present.

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"Every reasonable effort has been made to acknowledge the owners of copyright material. I would be pleased to hear from any copyright owner who has been omitted or incorrectly acknowledged".

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Appendix

Data Statistics:-

No.	Attrib.	Min	Max	Mean	St-dev
1	Q-E	10000	60081	37226.56	6571.46
2	ZN-E	0.1	33.5	2.36	2.74
3	PH-E	6.9	8.7	7.81	0.24
4	DBO-E	31	438	188.71	60.69
5	DQO-E	81	941	406.89	119.67
6	SS-E	98	2008	227.44	135.81
7	SSV-E	13.2	85.0	61.39	12.28
8	SED-E	0.4	36	4.59	2.67
9	COND-E	651	3230	1478.62	394.89
10	PH-P	7.3	8.5	7.83	0.22
11	DBO-P	32	517	206.20	71.92
12	SS-P	104	1692	253.95	147.45
13	SSV-P	7.1	93.5	60.37	12.26
14	SED-P	1.0	46.0	5.03	3.27
15	COND-P	646	3170	1496.03	402.58
16	PH-D	7.1	8.4	7.81	0.19
17	DBO-D	26	285	122.34	36.02
18	DQO-D	80	511	274.04	73.48
19	SS-D	49	244	94.22	23.94
20	SSV-D	20.2	100	72.96	10.34
21	SED-D	0.0	3.5	0.41	0.37
22	COND-D	85	3690	1490.56	399.99
23	PH-S	7.0	9.7	7.70	0.18
24	DBO-S	3	320	19.98	17.20
25	DQO-S	9	350	87.29	38.35
26	SS-S	6	238	22.23	16.25
27	SSV-S	29.2	100	80.15	9.00
28	SED-S	0.0	3.5	0.03	0.19
29	COND-S	683	3950	1494.81	387.53
30	RD-DBO-P	0.6	79.1	39.08	13.89
31	RD-SS-P	5.3	96.1	58.51	12.75
32	RD-SED-P	7.7	100	90.55	8.71
33	RD-DBO-S	8.2	94.7	83.44	8.4
34	RD-DQO-S	1.4	96.8	67.67	11.61
35	RD-DBO-G	19.6	97	89.01	6.78
36	RD-DQO-G	19.2	98.1	77.85	8.67
37	RD-SS-G	10.3	99.4	88.96	8.15
38	RD-SED-G	36.4	100	99.08	4.32

WWTP Data:-

The WWTP data used in this research work is included here.

Date	Q-E	ZN-E	PH-E	DBO-E	DBQ-E	SS-E	SSV-E	SED-E	COND-E	PH-P	DBO-P	SS-P	SSV-P	SED-P	COND-P	PH-D	DBO-D	DQO-D	SS-D	SSV-D	SED-D	COND-D	PH-S	DBO-SS	DQO-S	SS-S	SSV-S	SED-S	COND-S	RD-DBO-P	RD-SS-P	RD-SED-P	RD-DBO-S	RD-DQO-S	RD-DBO-G	RD-DQO-G	RD-SS-G	RD-SED-G
D-1/3/90	44101	1.5	7.8	183	407	166	66	4.5	2110	7.9	197	228	70	5.5	2120	7.9	119	280	94	72	0.3	2010	7.3	18	84	21	81	0	2000	40	59	96	85	70	90	79	87	100
D-2/3/90	39024	3	7.7	183	443	214	69	6.5	2660	7.7	197	244	75	7.7	2570	7.6	119	474	96	79	0.4	2700	7.5	18	91	17	94	0	2590	40	61	95	85	81	90	80	92	100
D-4/3/90	32229	5	7.6	183	528	186	70	3.4	1666	7.7	197	220	73	4.5	1594	7.7	119	272	92	78	0.2	1742	7.6	18	128	21	81	0.1	1888	40	58	96	85	53	90	76	89	99
D-5/3/90	35023	3.5	7.9	205	588	192	66	4.5	2430	7.8	236	268	73	8.5	2280	7.8	158	376	96	77	0.4	2060	7.6	20	104	20	97	0	1840	33	64	95	87	72	90	82	90	100
D-6/3/90	36924	1.5	8	242	496	176	65	4	2110	7.9	197	236	58	4.5	2020	7.8	119	372	88	68	0.2	2250	7.6	19	108	22	66	0	2120	40	63	96	85	71	92	78	88	100
D-7/3/90	38572	3	7.8	202	372	186	69	4.5	1644	7.8	197	248	66	8.5	1762	7.7	150	460	100	76	0.3	1768	7.5	20	100	28	82	0	1764	40	60	97	87	78	90	73	85	100
D-8/3/90	41115	6	7.8	183	552	262	64	5	1603	7.8	197	320	68	6.5	1608	7.8	192	376	122	72	0.4	1668	7.5	21	76	26	85	0.1	1703	40	62	94	89	80	90	86	90	99
D-9/3/90	36107	5	7.7	215	489	334	41	6	1613	7.6	197	304	54	8	1557	7.6	181	350	90	71	0.4	1596	7.5	17	162	18	67	0	1606	40	70	96	91	54	92	67	95	100
D-11/3/90	29156	2.5	7.7	206	451	194	69	4.5	1249	7.7	206	220	62	4	1219	7.7	111	282	124	77	0.3	1233	7.5	16	118	19	84	0	1338	46	44	93	86	58	92	74	90	99
D-12/3/90	39246	2	7.8	172	506	200	69	5	1865	7.8	208	248	66	6.5	1929	7.8	164	463	100	78	0.6	1825	7.6	19	157	27	87	0	1616	21	60	91	88	66	89	69	87	100
D-13/3/90	42393	0.7	7.9	189	478	230	67	5.5	1410	8.1	173	192	63	5	1406	7.7	172	412	104	71	0.4	1562	7.6	152	306	131	80	3.5	1575	0.6	46	92	12	26	20	36	43	36
D-14/3/90	42857	1.5	7.7	238	319	292	34	3.5	1261	7.6	170	268	31	4.2	1204	7.6	116	276	104	52	0.3	1261	7.4	320	350	238	74	2	1304	32	61	93	85	70	90	79	19	43
D-15/3/90	42911	0.7	7.6	114	252	116	59	1.2	1238	7.9	148	136	65	3	1208	7.7	79	216	70	83	0.3	1177	7.5	84	172	104	79	0.1	1221	47	49	92	85	20	26	32	10	95
D-16/3/90	40376	1.5	8.1	204	333	174	68	3	2390	7.8	231	156	74	2.5	2540	7.8	136	325	78	80	0.4	2580	7.6	32	153	98	88	0	2550	41	50	84	77	53	84	54	44	100
D-18/3/90	40923	3.5	7.6	146	329	188	57	2.5	1300	7.6	162	132	64	2	1324	7.6	109	243	88	82	0.2	1467	7.5	19	94	41	83	0	1545	33	33	90	83	61	87	71	78	99
D-19/3/90	43830	1.5	7.8	177	512	214	59	5.5	1605	7.7	164	256	72	5.5	1599	7.7	118	320	70	89	0.4	1401	7.6	25	203	20	85	0	1110	28	73	93	79	37	86	60	91	100
D-20/3/90	39165	1.2	7.4	250	447	252	61	7	1533	7.4	275	216	57	6.5	1501	7.4	138	269	90	73	0.5	1458	7.3	14	9	20	83	0	1402	50	58	92	90	97	94	98	92	100
D-21/3/90	35791	1.2	7.8	277	466	246	63	4	1556	7.7	197	288	65	6	1846	7.7	166	419	174	81	1.3	1664	7.5	24	124	26	83	0	1606	40	40	78	86	70	91	73	89	99
D-22/3/90	37419	1.2	7.6	219	446	222	61	5.5	1600	7.7	266	240	70	5	1645	7.6	172	345	102	84	0.4	1670	7.5	42	175	53	84	0	1780	35	58	92	76	49	81	61	76	100
D-23/3/90	40983	3	7.6	182	431	214	57	7	1591	7.5	219	248	58	5.5	1473	7.5	175	376	88	66	0.4	1537	7.5	23	120	25	68	0	1597	20	65	94	87	68	87	72	88	100
D-25/3/90	42217	8.5	7.5	138	333	240	55	3.8	1087	7.5	153	184	67	4	1109	7.5	108	194	82	85	0.4	1136	7.1	16	62	17	94	0	1223	29	55	91	85	68	88	81	93	100
D-26/3/90	47665	1.2	7.7	156	405	200	74	4	1856	7.6	178	184	72	3.5	1976	7.5	128	302	92	78	0.3	1920	7.6	19	71	23	78	0	1706	28	50	91	85	77	88	83	89	100
D-27/3/90	44314	3	7.8	155	389	308	49	6	1927	7.7	252	308	49	6.5	2150	7.7	121	302	108	72	0.6	1950	7.6	15	87	23	70	0	1869	52	65	91	88	71	90	78	93	100
D-28/3/90	40841	1	7.6	179	389	168	69	3.5	1240	7.8	202	272	72	6	1381	7.8	148	302	92	78	0.3	1425	7.9	16	83	20	85	0	1416	27	66	95	89	73	91	79	88	100
D-29/3/90	41157	3	8	145	398	192	67	4.5	2240	8	213	240	62	6	2010	8	140	287	84	79	0.4	2270	7.8	15	87	21	81	0	2290	34	65	94	89	70	90	78	89	100
D-30/3/90	40078	1.4	7.9	198	464	228	65	4.6	1431	7.6	243	272	65	7.5	1606	7.8	177	319	88	82	0.2	1556	7.8	17	102	22	82	0	1475	27	68	97	90	68	91	78	90	100
D-1/2/90	44365	7.5	7.9	183	365	212	62	3.5	1339	7.9	197	184	65	4.7	1380	7.8	119	321	92	74	0.5	1386	7.5	18	75	20	75	0.1	1377	40	50	89	85	77	90	80	91	99
D-2/2/90	43080	4.3	7.8	95	349	136	77	2.5	1063	7.8	132	188	75	2	1139	7.8	123	317	98	69	0.4	1218	7.5	19	67	24	83	0	1220	6.8	48	80	85	79	80	81	82	100
D-4/2/90	29414	3	7.6	160	374	168	69	3.1	1042	7.6	220	246	70	4.6	1057	7.6	126	299	112	75	0.2	1085	7.4	19	79	28	82	0	1087	43	55	96	85	74	88	79	83	100
D-5/2/90	37312	1	8.1	205	492	192	71	4	1454	8.1	197	200	72	5.5	1489	7.9	217	433	134	79	0.3	1423	7.7	32	114	37	84	0	1275	40	33	95	85	74	84	77	81	100
D-6/2/90	38568	0.7	8.2	233	506	204	67	6.7	1692	8.3	218	212	66	11	1614	7.9	188	355	88	82	0.2	1516	7.5	47	116	59	81	0.1	1483	14	59	99	75	67	80	77	71	99
D-7/2/90	38655	1.5	7.9	179	344	172	65	3.8	1379	8	148	156	74	4	1412	7.8	155	301	86	81	0.2	1426	7.5	26	97	35	83	0	1470	40	45	95	83	68	86	72	80	100
D-8/2/90	34193	2	8	166	396	176	71	4	1265	8	178	188	70	5.5	1380	7.8	165	368	90	78	0.2	1434	7.5	26	106	31	84	0	1442	7.3	52	96	84	71	84	73	82	100
D-9/2/90	36332	3.5	7.9	120	455	184	67	4	1224	8.1	205	188	68	5.5	1217	7.7	168	333	90	78	0.2	1353	7.6	24	98	32	81	0	1420	18	52	96	86	71	80	79	83	100
D-11/2/90	32484	0.9	7.5	183	388	170	77	3.5	1130	7.6	197	178	75	4	1149	7.7	164	310	102	82	0.2	1212	7.5	22	89	33	91	0.1	1274	40	43	96	87	71	90	77	81	99
D-12/2/90	37724	1	7.9	183	526	206	71	5.5	1422	7.9	197	218	72	6	1461	7.8	175	382	108	82	0.2	1595	7.5	34	128	40	84	0	1342	40	51	97	81	67	90	76	81	100
D-13/2/90	36446	1	7.7	183	710	366	56	6.5	2400	7.8	197	256	63	6	2450	7.8	192	450	120	67	0.5	2330	7.6	18	295	88	76	0.3	2390	40	53	93	85	34	90	59	76	96
D-14/2/90	35636	1.2	8	203	469	264	65	5.2	1489	8.1	197	304	66	8.5	1690	7.9	155	361	100	80	0.4	1718	7.5	23	97	38	88	0.1	1716	40	67	95	85	73	89	79	86	99
D-15/2/90	34746	1	7.7	208	427	192	75	4.5	1426	7.7	195	236	75	7	1375	7.7	186	334	104	81	0.4	1518	7.4	27	78	33	85	0	1636	4.6	56	94	86	77	87	82	83	100
D-16/2/90	34893	1.2	8	235	400	228	75	7	1532	8	232	252	78	8	1532	7.8	165	345	92	80	0.3	1478	7.6	25	125	25	91	0	1445	29	64	97	85	64	89	79	89	100
D-18/2/90	37102	2	7.8	196	353	174	68	4	1315	7.8	152	162	77	3	1322	7.7	127	270	100	74	0.8	1337	7.6	24	71	24	92	0	1509	16	38	73	81	74	88	80	86	100
D-19/2/90	41598	1.2	8.2	194	419	186	72	0.4	1310	8	210	208	71	4.5	1333	7.9	157	341	118	73	1	1474	7.6	23	71	33	79	0	1340	25	43	78	85	79	88	83	82	94
D-21/2/90	38058	1	7.8	193	424	170	74	4	1406	7.7	226	356	72	4.5	1324	7.7	187	352	118	78	0.5	1360	7.5	24	88	29	87	0	1445	17	67	90	87	75	88	79	83	100
D-22/2/90	40716	3.5	8.1	183	524	222	68	5.8	1597	8.1	230	248	66	7.5	1512	7.9	154	300	96	77	0.5	1521	7.4	29	76	25	84	0	1422	33	61	93	81	75	90	86	89	100
D-23/2/90	40868	1.5	8.1	206	490	190	68	5.2	1392	8	220	224	70	6	1505	8.1	178	363	92	80	0.4	1532	7.7	16	86	26	82	0	1574	19	59	93	91	76	92	82	86	100
D-25/2/90	36358	2	7.7	192	298	162	68	4	1241	7.7	160	188	68	4.5	1243	7.7	118	278	110	75	0.7	1285	7.5	30	98	45	74	0.1	1399	26	42	84	75	65	84	67	72	99
D-26/2/90	40879	1.2	7.6	183	435	196	68	4.5	1421	7.7	197	264	70	7	1469	7.7	119	408	120	73	0.6	1532	7.6	18	102	23	84	0	1354	40	55	91	85	75	90	77	88	100
D-27/2/90	44150	1	8.1	183	516	164	76	3.5	1548	8.1	197	232	74	5.5	1545	7.9	119	326	94	94	0.6	1415	7.6	18	113	37	96	0	1409	40	60	90	85	65	90	78	77	99
D-28/2/90	45779	3	7.8	183	376	194	69	5	2020	7.8	197	276	62	7.5	2390	7.7	119	326	82	68	0.4	2260	7.6	18	66	15	93	0	2400	40	70	95	85	80	90	82	92	100
D-1/1/90	41230	0.4	7.6	120	344	136	54	4.5	993	7.5	197	188	55	3	972	7.6	119	259	70	49	0.2	921	7.5	16	97	17	52	0	903	40	63	93	85	63	87	72	88	99
D-2/1/90	37386	1.4	7.9	165	470	170	77	4	1365	7.9	197	192	71	4.5	1399	7.9	156	368	96	73	0.3	1338	7.6	22	97	18	81	0	1481	40	50	94	86	74	87	79	89	100
D-3/1/90	34535	1	7.8	232	518	220	66	5.5	1617	7.9	230	202	71	4	1593	7.8	155	364	76	82	0.2	1594	7.5	29	146	31	77	0	1492	33	62	95	81	60	88	72	86	100
D-4/1/90	32527	3	7.8	187	460	180	68	5.2	1832	7.9	219	236	66	5.5	1920	7.8	190	355	100	80	0.3	1646	7.5	28	105	30	82	0	1590	13	58	96	85	70	85	77	83	100

D-7/1/90	27760	1.2	7.6	199	466	186	74	4.5	1220	7.5	225	176	82	4	1208	7.5	139	314	94	87	0.2	1315	7.4	21	122	25	84	0	1411	38	47	95	85	61	89	74	87	100
D-8/1/90	36281	2	7.8	183	612	226	71	8	1544	7.9	197	268	66	8	1503	7.8	158	259	100	80	0.4	1443	7.5	38	106	34	87	0	1239	40	63	96	76	59	90	83	85	100
D-9/1/90	38055	3.5	7.8	221	524	188	72	5	1540	7.9	197	252	78	4.5	1477	7.8	128	299	82	90	0.2	1506	7.5	29	136	39	84	0	1503	40	68	96	77	55	87	74	79	100
D-10/1/90	34064	1	8.1	230	535	242	67	6.5	1652	7.9	197	264	70	5.4	1700	7.9	174	322	100	72	0.3	1577	7.5	28	101	36	83	0.1	1552	40	62	94	84	69	88	81	85	99
D-11/1/90	31447	3.5	7.9	190	374	192	71	6.5	1494	7.8	204	184	71	4.5	1462	7.7	121	259	100	82	0.5	1562	7.5	21	108	22	84	0.1	1596	41	46	89	83	58	89	71	89	99
D-12/1/90	32127	17	7.7	183	526	292	64	7.5	2240	7.6	244	344	63	9	2220	7.7	193	450	134	70	1.3	2450	7.5	28	92	36	81	0	2580	21	61	86	86	80	90	83	88	100
D-14/1/90	31059	3.5	7.8	202	431	200	74	5	1302	7.7	199	184	78	4.7	1307	7.6	124	269	96	75	0.4	1334	7.4	17	63	20	85	0.1	1473	38	48	92	86	77	92	85	90	99
D-15/1/90	36470	4.5	7.8	227	526	212	69	4.5	1542	7.8	232	240	75	5.5	1583	7.8	172	411	106	83	0.2	1607	7.4	30	99	41	85	0.1	1395	26	56	96	83	76	87	81	81	99
D-16/1/90	47449	1.7	7.8	170	401	158	67	4	1292	7.8	184	172	70	3.5	1413	7.8	167	345	102	75	0.7	1568	7.5	26	87	27	78	0.1	1635	9.2	41	80	84	75	85	78	83	99
D-17/1/90	43940	3.5	7.8	149	361	186	62	3.2	1651	7.8	204	204	67	5	1751	7.9	155	345	106	70	0.5	1623	7.5	27	103	38	82	0.1	1597	24	48	90	83	70	82	72	80	98
D-18/1/90	40347	1.8	7.7	155	338	132	70	2.7	1332	7.7	180	160	69	2.5	1366	7.7	152	319	94	72	0.6	1442	7.4	22	87	27	78	0.1	1482	16	41	76	86	73	86	74	80	98
D-19/1/90	40267	1.8	7.9	180	433	186	72	4	1729	7.9	200	174	76	3.7	1820	7.8	127	354	86	79	0.4	1856	7.5	19	110	26	83	0	1861	37	51	89	85	69	89	75	86	100
D-21/1/90	37976	1	7.7	148	345	162	78	3.2	1432	7.6	145	166	74	3.8	1415	7.6	137	302	94	85	0.5	1461	7.4	17	60	21	91	0.1	1572	5.5	43	87	88	80	89	83	87	98
D-22/1/90	47368	2	7.9	156	417	152	74	4.5	1608	7.9	207	164	67	4.5	1798	7.8	147	321	76	76	0.4	1627	7.4	29	99	26	85	0	1490	29	54	91	80	69	81	76	83	100
D-23/1/90	48086	5	8	247	444	166	74	3.5	1700	8.1	207	182	66	3.5	1724	7.9	176	360	112	77	0.4	1768	7.6	27	52	29	86	0	1764	15	39	89	85	86	89	88	83	100
D-24/1/90	47642	5	7.9	157	428	204	54	4	1989	7.7	187	250	53	4.5	1869	7.8	219	303	90	69	0.4	1735	7.5	19	73	18	75	0	1800	40	64	92	91	76	88	83	91	100
D-25/1/90	43174	4.5	7.7	179	420	158	68	2.5	1260	7.7	200	160	69	3.5	1256	7.8	183	376	110	71	1	1369	7.4	23	136	17	88	0	1365	8.5	31	71	87	64	87	68	89	100
D-26/1/90	39891	2	7.6	178	416	188	61	4.5	1301	7.6	174	166	70	3.5	1267	7.6	164	368	106	70	0.4	1280	7.3	22	140	20	70	0	1262	5.7	36	89	87	62	88	66	89	100
D-28/1/90	32257	3.5	7.5	246	583	504	45	7.3	1016	7.5	228	436	42	7.5	1079	7.5	85	236	76	68	0.5	1088	7.3	21	75	25	72	0.1	1164	63	83	94	75	68	92	87	95	99
D-29/1/90	40498	10	8.1	202	476	300	49	3.7	1636	8	206	252	51	3.5	1579	7.9	186	394	108	72	1.3	1413	7.5	27	75	22	91	0.1	1291	9.7	57	63	86	81	87	84	93	99
D-30/1/90	40221	2	8.1	177	407	172	58	2.5	1379	8	231	248	55	4.6	1454	8	188	379	108	72	0.7	1529	7.5	27	95	26	77	0	1542	19	57	85	86	75	85	77	85	100
D-31/1/90	46669	1.8	7.8	183	340	168	71	2.3	1477	7.8	197	228	65	4.5	1379	7.8	119	368	110	73	0.6	1550	7.6	18	84	19	81	0	1445	40	52	87	85	70	90	79	91	100
D-1/6/90	34669	1.2	7.8	198	381	216	52	3.5	1415	7.8	183	220	56	3.5	1453	7.7	123	246	76	79	0.2	1432	7.7	29	91	26	81	0.1	1390	33	66	94	76	63	85	76	88	99
D-3/6/90	41824	1.2	7.8	161	281	164	59	2.3	1075	7.8	144	192	53	2.5	1068	7.8	118	233	88	71	0.4	1121	7.8	14	63	19	74	0	1246	18	54	84	88	73	91	78	88	100
D-4/6/90	51520	2	7.3	156	336	192	63	5.5	1320	7.8	158	184	57	4	1327	7.6	79	198	92	63	0.3	1175	7.9	15	59	19	79	0	1054	50	50	93	81	70	90	82	90	100
D-5/6/90	39421	1	7.9	189	457	1004	26	24	1218	7.8	234	1384	25	35	1257	7.7	156	323	140	66	0.3	1308	7.8	19	79	21	81	0.1	1172	33	90	99	88	76	90	83	98	100
D-6/6/90	36131	1	7.9	215	500	252	62	4.7	1512	7.8	233	348	49	7.5	1427	7.8	147	327	102	69	0.3	1436	7.9	25	75	23	78	0	1409	37	71	96	83	77	88	85	91	100
D-7/6/90	33251	1	7.6	225	578	256	66	5.5	1510	7.6	224	276	54	6.5	1486	7.7	119	319	102	65	0.3	1492	7.6	15	151	25	77	0.1	1461	47	63	95	87	53	93	74	90	99
D-8/6/90	35789	1.5	7.4	316	533	264	55	5.5	1361	7.4	352	344	47	6.5	1453	7.5	190	361	160	51	1.5	1518	7.5	39	150	54	74	0.1	1506	46	54	77	80	58	88	72	80	98
D-10/6/90	40106	0.6	7.8	238	504	292	59	6.5	1109	7.8	361	352	51	7	1113	7.8	147	256	128	66	0.8	1113	8	19	80	20	70	0.1	1238	59	64	89	87	69	92	84	93	99
D-11/6/90	45191	2	8	125	324	362	36	5	1093	7.7	297	804	33	13	1086	7.9	84	204	124	53	0.6	1105	7.9	28	128	14	74	0	1008	72	85	95	67	37	78	61	96	100
D-12/6/90	43308	1.4	7.9	265	330	562	27	7.5	1866	7.9	242	680	30	13	1858	7.9	133	206	120	48	0.6	1850	7.8	24	70	11	62	0	1800	45	82	95	82	66	91	79	98	100
D-13/6/90	37615	1.2	7.8	199	404	232	53	5	1310	7.8	416	544	43	11	1366	7.7	143	299	114	61	0.4	1466	7.6	25	85	19	65	0	1404	66	79	96	83	72	87	79	92	100
D-14/6/90	42596	3	7.7	138	259	456	23	4	1007	7.6	160	584	27	7.5	1039	7.6	101	176	126	48	0.5	1113	7.6	22	59	16	69	0	1194	37	78	93	78	67	84	77	97	100
D-15/6/90	41948	1.5	7.7	198	396	216	53	3	1282	7.8	245	328	48	5	1321	7.7	109	244	120	57	0.3	1304	7.8	23	105	32	71	0	1295	56	63	94	79	57	88	74	85	99
D-17/6/90	34647	1	7.5	193	342	260	51	3	985	7.6	230	424	44	6	1008	7.6	132	223	174	51	0.4	992	7.3	18	84	22	69	0	1218	43	59	93	85	70	90	79	92	100
D-18/6/90	36967	1	7.6	202	426	248	81	5.5	2310	7.7	326	404	56	7	2180	7.7	142	280	146	66	0.6	1909	7.7	33	92	23	73	0	1813	56	64	92	77	67	84	78	91	100
D-19/6/90	34879	1	7.5	319	465	214	64	5.5	1308	7.6	364	388	51	7.5	1344	7.7	143	261	100	70	0.4	1378	7.7	18	104	11	87	0	1345	61	74	95	87	60	94	78	95	100
D-20/6/90	34365	6	7.6	236	444	236	63	4.9	1400	7.7	259	440	50	10	1439	7.6	140	246	122	59	0.3	1458	7.7	24	115	17	71	0.1	1480	46	72	97	83	53	90	74	93	99
D-21/6/90	34291	8	7.9	192	433	300	57	7	1395	7.9	269	436	51	12	1335	7.9	138	294	108	69	0.3	1378	7.8	15	60	12	92	0	1423	49	75	98	89	80	92	86	96	100
D-22/6/90	34886	8	7.7	211	488	268	54	5.8	1212	7.9	265	348	58	8.5	1274	7.7	151	306	88	80	0.2	1309	7.7	15	63	12	83	0	1320	43	75	98	90	79	93	87	96	100
D-24/6/90	38731	1.2	7.5	200	402	184	64	2.8	1127	7.5	188	218	63	3	1140	7.5	122	233	90	78	0.2	1200	7.7	17	64	17	77	0	1317	35	59	95	86	73	92	84	91	100
D-25/6/90	39308	3	7.8	217	349	172	70	3.5	1454	7.8	174	208	65	4	1487	7.8	98	261	78	77	0.2	1360	7.9	18	92	20	80	0	1230	44	63	95	85	65	90	74	88	100
D-26/6/90	44198	7	7.7	257	667	1016	32	22	1478	7.8	212	572	36	13	1422	7.9	135	210	108	57	0.2	1358	8	16	56	15	73	0	1378	36	81	98	88	73	94	92	99	100
D-27/6/90	39003	1.2	7.8	183	456	232	66	5	1262	7.8	198	216	56	4.5	1247	7.9	107	266	84	57	0.2	1305	7.8	19	60	12	75	0	1234	46	61	97	82	77	90	87	95	100
D-28/6/90	34487	0.7	7.9	183	380	192	63	4.5	1339	7.8	196	216	56	6	1403	7.8	128	270	68	71	0.1	1409	8	13	63	15	67	0	1344	35	69	98	90	77	93	83	92	100
D-29/6/90	35198	0.8	7.7	185	372	164	61	3	1623	7.8	210	192	65	3	1508	7.8	124	278	74	73	0.1	1482	7.9	18	78	15	67	0	1491	41	62	97	86	72	90	79	91	100
D-1/5/90	27617	1	7.6	285	436	218	68	6	1095	7.6	292	238	67	5.5	1149	7.5	160	284	80	80	0.2	1139	7.5	26	104	41	73	0.5	1146	45	66	96	84	63	91	76	81	92
D-2/5/90	37881	3	7.7	257	588	328	60	7	1392	7.7	213	272	60	6.5	1432	7.8	174	344	116	71	0.8	1356	7.6	26	92	44	74	0.3	1213	18	57	88	85	73	90	84	87	96
D-3/5/90	39024	1.2	7.9	268	467	224	66	6.5	1409	7.9	328	312	63	9.5	1376	7.9	152	338	88	77	0.2	1336	7.7	29	148	49	80	0.1	1334	54	72	98	81	56	89	68	78	99
D-4/5/90	38990	1.4	7.8	189	357	172	67	4	1160	7.7	213	212	62	5.5	1232	7.7	123	255	80	80	0.3	1237	7.6	30	122	42	81	0.1	1304	42	62	95	76	52	84	66	76	99
D-6/5/90	37710	3	7.5	312	388	204	62	4	1026	7.5	211	214	65	5	1020	7.5	111	222	86	77	0.2	1016	7.4	42	154	69	83	0.1	1092	47	60	96	62	31	87	60	66	98
D-7/5/90	25957	0.6	8.1	404	455	448	38	5	1229	7.8	491	692	39	12	1279	7.8	285	274	110	71	0.4	1156	7.8	20	83	25	91	0.1	1021	42	84	97	93	70	95	82	94	99
D-8/5/90	38623	1.5	8.1	243	299	180	54	2.5	1615	8	291	324	65	3.5	1630	7.9	166	265	96	60	0.2	1485	7.8	26	82	36	74	0	1345	43	70	94	84	69	89	73	80	99
D-9/5/90	41746	1	8	352	471	208	65	5.5	2150	7.9	386	216	65	5.5	2320	7.6	198	348	118	75	0.5	2290	7.5	24	91	32	84	0	2290	49	45	92	88	74	93	81	85	100
D-10/5/90	43291	0.8	7.7	215	447	164	61	5.5	1177	7.7	258	256	53	5	1207	7.9	141	285	86	70	0.2	1324	7.7	19	75	32	77	0	1390	45	66	96	87	74	91	83	81	100
D-11/5/90	41436	1.2	7.9	191	356	192	63	7	1434	7.9	226	288	56	10	1427	7.7	130	257	84	71	0.1	1467	7.6	28	103	34	77	0	1469	43	71	99	79	60	85	71	82	100
D-13/5/90	39402	1.2	7.9	283	274	162	59	3	937	7.9	190	178	58	2.8	944	7.8	117	212	78	77	0.1	970	7.7	28	74	25	88	0	1060	38	56	98	76	65	90	73	85	100
D-14/5/90	39383	0.6	8	216	529	248	61	6.3	1179	8	429	220	66	5	1294	7.8	140	337	138	64	1.5	1155	7.7	23	94	22	84	0	1107	67	37	70	84	72	89	82	91	100

D-15/5/90	37106	0.7	7.8	163	468	202	57	4.5	1525	8	319	292	59	7	1587	7.8	146	353	230	56	0.2	1328	7.7	14	100	19	87	0	1309	54	21	97	90	72	91	79	91	100
D-16/5/90	36591	1.2	7.8	183	499	248	57	6.5	1213	7.8	197	304	58	7.2	1264	7.8	119	334	98	78	0.2	1420	7.6	18	77	20	75	0	1395	40	68	97	85	77	90	85	92	100
D-17/5/90	33711	2.5	8	345	457	288	60	7.5	1272	7.9	197	348	63	9	1336	7.9	119	372	146	73	2	1369	7.8	19	88	19	79	0	1437	40	58	78	85	76	95	81	93	100
D-18/5/90	35081	0.8	7.7	431	532	210	66	5	1535	7.6	409	224	59	6	1561	7.8	210	360	98	65	0.2	1472	7.7	13	132	13	50	0	1516	49	56	97	94	63	97	75	94	100
D-20/5/90	32372	1.5	7.8	174	404	192	64	3.5	1056	7.7	182	210	61	4.5	1064	7.7	140	243	104	77	0.4	1078	7.7	13	55	18	83	0	1165	23	51	91	91	77	93	86	91	100
D-21/5/90	37283	2	7.7	327	376	184	58	4	1226	7.7	287	236	46	3.5	1223	7.8	102	255	84	74	0.2	1199	7.8	15	47	13	69	0	1136	65	64	94	85	82	95	88	93	100
D-22/5/90	42202	1	7.6	184	238	316	30	3	1079	7.7	163	344	29	4	1113	7.6	122	214	92	63	0.2	1139	7.6	27	95	39	59	0	1176	25	73	95	78	56	85	60	88	100
D-23/5/90	50942	3	7.8	159	234	292	33	3	1140	7.8	182	344	33	4	1125	7.9	111	218	100	52	0.3	1231	7.8	12	36	14	77	0	1276	39	71	94	89	84	93	85	95	100
D-24/5/90	44040	1	7.9	275	330	180	56	3	1376	7.9	190	200	60	2.5	1392	7.9	118	260	76	76	0.3	1435	7.7	25	109	24	75	0	1399	38	62	90	79	58	91	67	87	100
D-25/5/90	43117	1.2	8.4	134	302	208	58	3.3	1160	8	159	276	61	3.5	1201	8	116	233	80	78	0.2	1264	7.9	16	66	20	80	0	1333	27	71	94	86	72	88	78	90	100
D-27/5/90	48333	0.7	7.6	132	188	172	47	2.5	940	7.7	210	192	47	2	924	7.7	102	176	76	79	0.1	1001	7.7	17	78	21	88	0	1107	51	60	95	83	56	87	59	88	100
D-28/5/90	46540	1.2	7.8	132	297	176	46	1.5	1140	8	133	172	44	1.3	1072	7.9	98	246	84	62	0.3	1111	7.6	24	63	16	69	0	1014	26	51	81	76	74	82	79	91	100
D-29/5/90	46057	1	8.1	133	288	162	57	2.3	1050	8.1	133	152	63	2.5	1116	8	97	220	70	77	0.2	1142	7.9	32	128	40	83	0.1	1187	27	54	94	67	42	76	56	75	98
D-30/5/90	45018	2	7.9	224	488	456	48	11	1147	7.9	153	252	49	4	1224	8	110	248	92	67	0.4	1238	8	15	36	17	82	0	1217	28	64	91	86	86	93	93	96	100
D-1/4/90	40552	2	7.9	200	395	178	72	3.5	1038	7.8	190	156	72	3.5	1063	7.7	127	281	102	73	0.7	1023	7.6	17	75	19	90	0	1148	33	35	80	87	73	92	81	89	99
D-2/4/90	53210	5	7.8	87	241	236	38	4	1179	8	97	248	34	3.5	1231	8	78	190	70	57	0	902	7.7	10	79	16	78	0	899	20	72	100	87	58	89	67	93	100
D-3/4/90	53530	1.5	8.1	132	336	330	37	6	1234	8	161	264	38	5.5	1327	7.9	126	316	80	75	0.7	1257	7.7	13	68	13	69	0	1229	22	70	88	90	79	90	80	96	100
D-4/4/90	46659	2	7.7	175	321	176	58	3.5	1335	7.8	198	192	58	4	1418	7.7	141	281	76	79	0.3	1316	7.5	12	67	11	100	0	1308	29	60	93	92	76	93	79	94	100
D-5/4/90	45772	2	7.9	162	348	156	64	3.1	1340	7.9	228	252	65	5.9	1398	7.9	135	329	110	78	0.7	1377	7.7	17	127	14	93	0	1423	41	56	88	87	61	90	64	91	100
D-6/4/90	52933	1.8	7.9	135	317	180	54	3.5	1362	7.9	181	268	60	4.6	1417	7.6	114	285	104	71	0.5	1459	7.8	14	91	22	86	0	1555	37	61	89	88	68	90	71	88	100
D-8/4/90	36510	1.5	7.9	91	325	122	77	3.5	1026	7.9	109	124	94	3.7	1063	7.8	81	227	64	97	0.4	983	7.7	15	74	11	100	0	1039	26	48	89	82	67	84	77	91	100
D-9/4/90	34299	3	7.8	210	725	350	42	5	1265	7.8	238	428	42	7.5	1262	7.8	136	306	106	47	0.4	1287	7.6	21	94	18	67	0	1309	43	75	95	85	69	90	87	95	100
D-10/4/90	41073	0.8	8.1	166	422	184	63	3	1450	8	118	280	66	3.5	1429	8.1	119	323	114	70	0.4	1419	7.8	26	81	22	76	0	1357	40	59	89	78	75	84	81	88	99
D-11/4/90	43536	2.5	7.8	267	342	202	58	2	1327	7.7	254	172	70	2	1306	7.8	130	349	120	67	0.4	1450	7.7	12	77	16	88	0	1454	49	30	80	91	78	96	78	92	100
D-13/4/90	34667	6	7.2	165	315	170	65	4.5	1125	7.3	219	180	68	4.5	1151	7.3	121	235	86	81	0.3	1204	7.4	11	53	19	74	0	1306	45	52	93	91	77	93	83	89	100
D-16/4/90	29624	1.4	7.5	184	219	148	62	3	1530	7.5	189	146	60	2	1553	7.5	92	192	78	77	0.3	1560	7.5	18	37	22	73	0	1100	51	47	85	80	81	90	83	85	99
D-17/4/90	34069	1.2	7.5	89	298	116	69	2	1119	7.7	89	120	70	2.3	1103	7.7	79	250	74	81	0.2	1188	7.6	16	42	22	84	0	1149	11	38	91	80	83	82	86	81	99
D-18/4/90	37782	1.2	8.1	155	382	174	67	7	1205	7.9	295	212	74	5.5	1319	7.8	147	312	90	76	0.3	1246	7.6	18	87	24	77	0.1	1244	50	58	95	88	72	88	77	86	99
D-19/4/90	42109	0.7	7.8	159	350	150	69	3	1304	7.8	192	160	75	2.5	1206	7.7	166	312	82	76	0.2	1276	7.7	41	152	41	79	0	1341	14	49	94	75	51	74	57	73	99
D-20/4/90	40871	0.7	7.7	193	298	120	60	3	1068	7.8	160	200	38	2.5	1167	7.8	135	222	90	75	0.3	1211	7.8	16	69	19	81	0	1199	16	60	88	88	69	92	77	91	99
D-22/4/90	36088	15	7.5	75	133	142	39	2	860	7.6	127	172	47	1.8	838	7.6	73	124	62	68	0.3	871	7.3	9	32	12	80	0	889	43	64	86	88	74	88	76	92	100
D-23/4/90	47255	0.6	7.7	181	264	124	61	2.6	1087	7.8	148	150	52	3	1047	7.8	122	232	68	62	0.3	1103	7.7	19	72	28	64	0.1	1008	18	55	92	84	69	90	73	77	96
D-24/4/90	55300	1.5	7.9	254	356	206	56	4	1300	7.9	207	222	53	3.5	1347	7.9	91	184	66	70	0.3	1188	7.6	18	100	20	76	0	1202	56	70	91	80	46	93	72	90	100
D-25/4/90	37646	1	7.8	355	556	184	50	3.3	1278	7.8	308	194	52	3	1376	7.8	122	216	78	72	0.2	1395	7.7	42	124	48	74	0.1	1310	60	60	93	66	43	88	78	74	99
D-26/4/90	34528	1	7.9	262	444	324	48	6.5	1319	7.9	279	380	43	6	1362	7.9	161	347	90	78	0.4	1476	7.6	31	174	67	74	0.5	1398	42	76	94	81	50	88	61	79	92
D-27/4/90	31417	3	7.8	237	549	236	71	4	1397	7.9	286	280	67	8	1368	7.8	176	416	112	70	0.4	1469	7.7	39	287	84	82	0.2	1480	39	60	96	78	31	84	48	64	95
D-29/4/90	27333	2	7.6	238	348	174	64	3.5	1110	7.6	372	124	76	2.5	1105	7.4	172	364	104	79	1	1171	7.4	44	210	73	81	1.5	1256	54	16	60	74	42	82	40	58	57
D-1/7/90	30201	1	7.3	137	398	188	57	4	1179	7.3	164	204	59	4.3	1164	7.3	81	204	62	65	0.1	1165	7.4	9	66	10	70	0	1264	51	70	98	89	68	93	83	95	100
D-2/7/90	39445	0.8	8.1	187	488	216	56	6.5	2440	8	191	252	49	5	2340	7.9	130	304	66	73	0.2	2230	8	28	80	21	71	0	2190	32	74	96	79	74	85	84	90	100
D-3/7/90	37252	3.5	7.6	131	436	476	28	4.5	1603	7.8	151	416	29	5	1479	7.8	114	269	78	56	0.1	1591	7.9	13	90	16	69	0	1625	25	81	98	89	67	90	79	97	100
D-4/7/90	37643	1.3	7.7	145	382	168	55	3.5	1814	7.9	180	184	57	3	1820	8.1	113	271	70	66	0.2	1893	8.1	15	88	15	73	0	1879	37	62	95	87	68	90	77	91	100
D-5/7/90	36389	0.9	7.7	156	391	156	54	3.5	1358	7.8	161	172	58	3	1412	7.9	116	285	66	73	0.3	1460	7.9	11	86	14	50	0	1425	28	62	92	91	70	93	78	91	100
D-6/7/90	33020	0.8	7.7	176	422	176	61	4	2200	7.7	176	196	59	3.5	2180	7.7	120	274	72	64	0.3	2230	7.8	14	82	16	69	0	2140	32	63	91	88	70	92	81	91	100
D-8/7/90	36095	4.5	7.5	112	341	256	47	4.2	2070	7.4	101	238	48	3	2430	7.5	95	251	82	76	0.2	1930	7.6	18	114	27	74	0	2700	5.9	66	93	81	55	84	67	90	100
D-9/7/90	39590	5	7.8	144	361	220	54	4.5	1790	7.8	112	236	54	3.3	1760	7.8	53	239	78	64	0.2	1710	7.6	14	74	20	70	0	1660	53	67	94	74	69	90	80	91	100
D-10/7/90	42859	13	7.8	161	326	268	45	4.5	1570	7.9	152	208	55	5	1640	7.9	76	173	74	65	0.2	1690	7.8	23	111	26	77	0	1720	50	64	97	70	36	86	66	90	100
D-11/7/90	36325	2.5	7.7	135	304	222	47	3.5	1087	7.7	135	250	55	3.5	1143	7.8	107	260	96	73	0.2	1162	7.9	14	96	18	69	0	1169	21	62	94	87	63	90	68	92	100
D-12/7/90	33522	2.5	7.7	189	416	248	58	5.5	1330	7.7	194	252	64	4.5	1931	7.8	114	304	104	71	0.2	1426	7.8	27	108	26	77	0	1416	41	59	96	76	65	86	74	90	100
D-13/7/90	33680	1.8	7.6	215	532	282	64	5.3	1444	7.6	253	296	62	5	1437	7.8	120	320	90	76	0.2	1418	7.8	17	92	15	75	0	1433	53	70	96	86	71	92	83	95	100
D-15/7/90	31293	1	7.7	150	337	182	64	3	1189	7.7	117	190	68	2.5	1199	7.7	108	256	62	75	0.5	1282	7.8	18	85	20	76	0	1378	7.7	67	80	83	67	88	75	89	100
D-16/7/90	36010	1	7.9	189	424	264	55	4	2270	7.8	190	318	55	5.5	2310	8	119	250	90	67	0.4	2130	8	16	68	21	78	0	1848	37	72	94	87	73	92	84	92	100
D-17/7/90	35445	2.5	7.9	182	388	272	43	3.5	1704	7.9	166	262	48	4	1731	7.9	110	274	82	51	0.2	1734	8	18	71	18	53	0	1788	34	69	96	84	74	90	82	93	100
D-18/7/90	32540	1	7.7	290	566	352	53	8	2540	7.7	314	358	54	8	2730	7.7	122	304	78	90	0.2	2750	7.9	18	116	15	93	0	2580	61	78	98	85	62	94	80	96	100
D-19/7/90	32929	1.2	7.8	246	641	376	56	6	1683	7.8	265	378	58	8	1724	7.9	132	338	170	64	1.7	1710	7.9	31	100	34	79	0	1742	50	55	79	77	70	87	84	91	100
D-20/7/90	32575	2	7.7	244	607	380	54	6	2160	7.8	242	436	54	8	2220	7.9	139	353	164	46	1.8	2120	8	18	104	26	72	0	2270	43	62	78	87	71	93	83	93	100
D-22/7/90	30019	4.5	7.6	175	416	224	52	4.5	1463	7.7	183	214	57	3.5	2120	7.7	105	274	104	63	0.8	2250	7.9	18	84	21	67	0.1	2610	43	51	77	83	70	90	79	91	99
D-23/7/90	27711	1.5	7.4	342	400	232	65	4.5	1858	7.6	259	284	61	6	1907	7.6	133	278	86	72	0.2	1835	7.6	23	106	38	77	0	1511	49	70	97	83	62	93	74	84	100
D-24/7/90	33999	1.5	7.5	191	488	506	36	6.3	2590	7.4	172	580	41	7.8	2530	7.6	102	267	84	71	0.2	2670	7.7	22	110	33	75	0.1	2850	41	86	97	78	59	89	78	94	99
D-25/7/90	33959	2	7.7	235	614	692	30	8	1589	7.7	242	716	32	9.5	1632	7.7	94	246	244	24	0.2	1588	7.9	16	90	52	29	0	1625	61	66	98	83	63	93	85	93	100

D-26/7/90	33290	1	7.7	128	392	236	59	3.2	2100	7.6	130	176	57	4	2200	7.7	118	272	88	59	0.2	2010	7.8	18	164	49	67	0.1	2070	9.2	50	95	85	40	90	58	79	98
D-27/7/90	33877	1.5	7.6	166	452	320	46	4.5	1160	7.7	221	388	47	5.5	1137	7.7	87	216	76	74	0.2	1147	7.8	19	56	28	75	0.1	1148	61	80	97	78	74	89	88	91	98
D-29/7/90	26871	2	7.3	139	369	284	49	4	991	7.5	161	312	45	4	986	7.3	87	198	90	62	0.1	978	7.5	19	116	34	73	0	1070	46	71	98	78	41	86	69	88	100
D-30/7/90	37634	2	8.1	151	400	268	48	3.5	1732	8	160	248	60	3	1803	8	85	274	84	69	0.2	1721	8.2	12	84	17	78	0	1643	47	66	93	86	70	92	79	94	100
D-31/7/90	32909	0.4	7.5	221	391	260	46	4.3	2140	7.5	173	244	53	4.5	2090	7.5	112	261	74	78	0.2	2000	7.6	17	127	20	78	0	1950	35	70	97	85	51	92	68	92	100
D-2/9/90	44601	1.7	7.5	140	231	360	64	4	806	7.5	146	328	63	3.5	811	7.5	79	145	64	75	0.2	834	7.6	12	39	11	81	0	905	46	81	94	85	73	91	83	97	100
D-3/9/90	43614	6.5	7.8	143	400	472	64	6.5	2230	7.8	95	226	63	4	2160	7.8	97	235	74	75	0.3	2170	7.8	14	82	12	81	0	1910	40	67	94	86	65	90	80	98	100
D-4/9/90	40529	4.5	7.7	192	253	186	64	5	1818	7.6	250	194	63	4.5	1745	7.5	108	197	80	75	0.3	1625	7.5	14	48	13	81	0	1726	57	59	94	87	76	93	81	93	100
D-5/9/90	38231	0.8	7.7	124	234	120	64	1.8	1550	7.9	123	220	63	4	1651	7.8	87	156	76	75	0.2	1586	7.9	18	84	74	81	0.2	1661	29	66	95	79	46	86	64	38	89
D-6/9/90	36909	1.3	7.6	172	394	226	51	5.5	1324	7.6	197	302	47	4	1306	7.7	119	257	92	65	0.2	1368	7.8	14	74	13	71	0	1418	40	70	96	88	71	92	81	94	100
D-7/9/90	37002	1.7	7.6	268	324	226	53	4	1390	7.6	265	236	53	4.5	1389	7.6	110	179	98	69	0.2	1352	7.7	13	97	15	69	0	1358	59	59	96	88	46	95	70	93	100
D-9/9/90	43377	6.5	7.6	176	200	176	50	3	859	7.6	149	172	51	2	860	7.6	90	178	76	66	0.2	926	7.7	13	45	18	69	0	1020	40	56	90	86	75	93	78	90	99
D-11/9/90	37862	5	7.6	146	243	164	57	3.2	1095	7.6	193	208	56	3	1089	7.6	68	165	86	77	0.3	1095	7.7	6	59	14	83	0	1095	65	59	92	91	64	96	76	92	100
D-12/9/90	35809	5	7.8	139	380	256	53	5.5	2040	7.8	201	340	48	8.5	2000	7.9	131	278	104	73	0.2	1950	7.9	11	51	8	58	0	1690	35	69	98	92	82	92	87	97	100
D-13/9/90	35729	2.5	7.9	205	529	264	61	6.5	2750	7.9	220	324	61	6	2850	7.8	111	325	90	73	0.3	2550	7.8	11	84	9	62	0	2500	50	72	95	90	70	95	79	97	100
D-14/9/90	41206	3.3	7.8	117	366	500	27	4.2	3230	7.8	135	620	32	7	3170	7.7	81	181	106	49	0.2	3690	7.8	12	67	12	75	0	3950	40	83	97	85	63	90	82	98	100
D-16/9/90	15519	3.6	7.6	148	400	564	32	7	1554	7.6	235	798	29	11	1515	7.6	49	151	120	48	0.4	1259	7.7	11	54	9	80	0	1267	79	85	97	78	64	93	87	98	100
D-17/9/90	49986	2.7	7.8	158	256	194	47	3	1831	7.8	218	240	47	4	1860	7.8	94	198	98	59	0.3	1862	7.7	10	66	9	76	0	1813	57	59	93	89	67	94	74	95	100
D-18/9/90	51575	2.4	7.7	123	246	186	40	2.5	1288	7.7	241	300	25	4.5	1328	7.7	101	202	86	37	0.2	1287	7.7	12	70	15	56	0	1317	58	71	96	88	65	90	72	92	99
D-19/9/90	44869	0.9	7.7	133	410	204	63	4.5	1490	7.7	161	256	58	4.5	1421	7.7	69	251	88	68	0.3	1386	7.7	8	144	11	80	0	1361	57	66	94	88	43	94	65	95	100
D-20/9/90	43491	1	7.5	237	388	178	57	4	1620	7.6	300	240	53	4.5	1571	7.7	113	243	84	69	0.2	1631	7.8	12	76	12	87	0	1590	62	65	96	89	69	95	80	93	100
D-21/9/90	45453	1.6	7.7	203	357	222	59	3	1828	7.6	215	208	73	5	1817	7.6	98	169	86	65	0.2	1890	7.6	9	73	13	81	0	1868	54	59	96	91	57	96	80	94	100
D-23/9/90	37190	1.1	7.8	199	380	244	56	5	1453	7.8	110	196	60	3.5	1430	7.8	104	204	116	72	1.5	1436	7.9	13	43	15	75	0	1458	5.5	41	57	88	79	94	89	94	100
D-24/9/90	40067	3.4	7.8	214	941	304	53	6.5	1454	7.8	396	320	58	7	1528	7.8	107	243	106	68	0.2	1456	7.9	11	55	14	74	0	1324	73	67	98	90	77	95	94	95	100
D-25/9/90	57606	5.4	7.7	208	298	260	38	4	1236	7.8	245	284	47	5	1285	7.8	90	220	124	48	0.3	1416	7.9	19	84	14	83	0	1611	63	56	94	79	70	91	79	95	100
D-26/9/90	46791	2.2	7.9	206	305	188	56	4	1200	7.9	197	272	50	6	1228	7.9	113	210	88	66	0.2	1237	7.9	14	55	10	92	0	1084	40	68	98	88	74	93	82	95	100
D-27/9/90	46852	1.5	7.7	247	361	286	51	4.5	1180	7.7	146	212	56	2.5	1251	7.7	135	248	134	52	0.6	1144	7.9	11	56	10	78	0	1222	7.5	37	76	92	77	96	85	97	100
D-28/9/90	38761	4	7.5	438	681	370	57	6	1396	7.6	212	348	64	6	1446	7.6	148	350	88	77	0.2	1356	7.6	15	120	11	71	0	1311	30	75	97	90	66	97	82	97	100
D-30/9/90	42046	2	7.8	255	282	166	68	2	950	7.8	284	172	65	2	965	7.8	164	259	112	77	0.5	971	7.9	13	56	20	80	0	1093	42	35	75	92	78	95	80	88	99
D-1/8/90	33322	0.4	7.6	217	315	400	59	3.5	2080	7.5	225	376	65	4	2090	7.4	131	215	67	78	0.1	2190	7.5	22	81	28	71	0.1	2170	42	82	98	83	62	90	74	93	99
D-2/8/90	10050	0.4	7.6	208	556	210	52	4	2340	7.5	244	148	66	2.5	2080	7.4	95	205	73	75	0.1	2070	7.6	18	75	34	72	0	2080	61	51	96	81	63	91	87	84	100
D-3/8/90	55930	1.2	7.8	223	459	364	46	5.5	2220	8	220	346	41	4.5	2300	7.9	85	199	63	75	0.1	2240	8	19	56	23	78	0.1	2350	61	82	98	78	72	92	88	94	99
D-5/8/90	52851	0.3	8.1	64	161	172	41	2	1350	8	59	146	45	1.1	1315	7.9	44	114	63	64	0.1	292	8.1	8	31	14	80	0	1400	25	57	91	82	73	88	81	92	100
D-6/8/90	40585	0.4	8	66	152	364	20	1.6	1403	8.1	86	412	20	2.5	1383	8	49	114	80	46	0.2	1407	8	11	24	12	77	0	1433	43	81	92	78	79	83	84	97	100
D-7/8/90	45027	2.5	7.7	48	156	242	26	1.4	1400	7.9	63	266	25	1.9	1403	7.8	37	112	84	48	0.2	1363	8	5	60	12	83	0	1407	41	68	90	87	46	90	62	95	100
D-8/8/90	47338	2	8.1	69	126	138	39	1.4	882	8.1	150	180	39	1.9	902	8.2	53	100	62	60	0.1	920	8	8	52	9	89	0	902	65	66	95	85	48	88	59	94	100
D-9/8/90	44207	1.2	7.8	70	188	112	48	1.3	1031	7.9	125	194	41	2.8	1074	7.9	44	101	54	61	0.2	1064	8	12	53	16	63	0	1056	65	72	95	73	48	83	72	86	100
D-10/8/90	43563	1	7.8	95	206	132	44	1.5	828	7.8	74	112	57	1.2	856	7.9	47	158	62	65	0.1	85	7.9	21	99	39	67	0.1	891	37	45	92	55	37	78	52	71	97
D-12/8/90	47718	0.7	7.8	31	81	208	20	0.8	715	7.8	32	246	25	1.5	714	7.8	119	80	233	20	0.7	712	7.9	3	25	12	73	0	831	40	5.3	53	85	69	90	69	94	100
D-13/8/90	42587	2	7.8	77	256	248	31	2.5	910	7.9	71	270	29	3	931	7.9	26	120	71	45	0.3	917	8	7	62	9	93	0	919	63	74	90	73	48	91	76	96	100
D-15/8/90	35098	0.8	7.8	100	256	234	38	2.5	993	7.8	97	168	50	1.3	953	7.8	119	140	95	53	0.4	1034	8	11	58	10	76	0	985	40	44	68	85	59	89	77	96	100
D-16/8/90	38052	0.8	7.6	94	409	194	58	2.5	997	7.6	197	192	54	2.5	996	7.7	119	194	103	57	0.7	988	7.9	14	65	11	69	0	990	40	46	72	85	67	85	84	94	99
D-17/8/90	31404	0.8	8	183	321	160	68	2.5	1096	7.9	197	164	61	2.5	1136	7.9	119	179	85	66	0.3	1082	8.1	11	98	15	67	0	1061	40	48	88	85	45	90	70	91	100
D-19/8/90	38905	0.3	7.7	58	197	130	65	2	1135	7.7	85	146	62	2.5	1169	7.8	44	123	54	80	0.2	1141	7.9	20	42	16	68	0	1143	48	63	94	55	66	66	79	88	99
D-20/8/90	38620	0.7	7.5	95	302	176	59	3	1120	7.6	94	152	59	2.5	1145	7.6	48	316	107	65	1.2	1155	7.7	19	59	15	77	0.1	1040	49	30	52	60	81	80	81	92	98
D-21/8/90	34352	0.3	7.4	112	470	172	65	4.5	1207	7.4	100	192	65	4	1208	7.4	74	213	69	73	0.2	1175	7.6	14	97	15	72	0	1162	26	64	95	81	55	88	79	91	100
D-22/8/90	34785	1	7.5	126	397	188	67	5	1950	7.5	121	190	63	3.5	1760	7.6	75	190	68	72	0.2	1720	7.7	16	101	15	61	0	1570	38	64	96	79	47	87	75	92	100
D-23/8/90	27109	0.4	7.6	158	276	142	65	1.5	1939	7.6	205	278	56	7.5	1878	7.6	102	269	123	66	1	1920	7.7	24	77	21	59	0	1959	50	56	87	77	71	85	72	85	98
D-24/8/90	32802	0.7	7.3	203	405	212	68	4.5	1922	7.3	197	320	61	8.5	1874	7.4	97	225	74	78	0.3	1820	7.4	22	114	24	71	0.1	1796	40	77	97	77	49	89	72	89	98
D-25/8/90	35876	0.5	7.9	81	448	296	64	4.5	1315	7.7	128	380	63	4.5	1355	7.8	65	319	70	75	0.3	1401	7.9	27	123	33	81	0	1525	49	82	93	59	61	67	73	89	100
D-27/8/90	41410	0.6	7.9	85	269	110	64	1.5	1342	7.8	139	198	63	4	1325	7.8	65	168	65	75	0.2	1362	7.9	15	84	23	81	0	1375	53	67	95	77	70	82	79	79	100
D-28/8/90	40933	1.5	7.8	120	303	290	64	4.5	1818	7.8	125	250	63	4	1800	7.8	78	192	68	75	0.2	1846	7.9	10	76	10	81	0	1723	38	73	95	87	60	92	75	97	100
D-29/8/90	34764	0.9	7.5	127	284	188	64	2.8	2260	7.6	143	222	63	3.5	2500	7.6	114	192	92	75	0.4	2140	7.7	18	62	14	81	0	2100	20	59	90	85	68	90	78	93	100
D-30/8/90	39489	0.9	7.8	131	320	166	64	2.5	1680	7.8	135	196	63	2.5	1690	7.8	90	214	88	75	0.2	1551	7.8	15	74	14	81	0	1672	33	55	92	83	65	89	77	92	99
D-31/8/90	42230	0.7	8.1	132	288	144	64	1.3	1581	8.3	143	196	63	3	1705	8.3	80	184	74	75	0.2	1717	8.3	11	64	13	81	0	1720	44	62	93	86	65	92	78	91	100
D-2/12/90	29388	0.8	8.2	339	713	356	73	10	2170	8	334	584	84	8.5	2110	7.9	223	372	116	85	1.3	2140	7.6	17	83	12	72	0	2330	33	80	85	92	78	95	88	97	100
D-3/12/90	30935	2	8.1	255	550	214	69	5.5	1919	8.2	227	246	68	8	1917	8.1	161	372	100	78	0.2	1815	7.8	18	87	22	82	0	1690	29	59	98	89	77	93	84	90	100
D-4/12/90	26348	1	8.1	253	473	212	79	7	1990	8.1	250	246	75	6	1950	8.1	202	384	112	82	0.2	2220	7.7	23	105	22	89	0	2130	19	55	97	89	73	91	78	90	100
D-6/12/90	28680	1.7	8.1	256	539	188	75	4.7	1803	8.1	337	218	75	5.2	1732	8.1	186	365	102	84	0.5	1804	7.8	27	116	23	87	0	1932	45	53	90	86	68	90	79	88	100

D-7/12/90	32799	5.9	8.4	215	440	190	70	4.5	1380	8.3	228	228	68	4.5	1408	8.1	113	213	78	77	0.3	1362	7.8	9	60	13	77	0	1379	50	66	93	92	72	96	86	93	100
D-9/12/90	33545	1.3	8.2	145	747	310	56	6	1059	8.2	181	264	53	4.7	1056	8.1	118	353	110	66	1	1082	7.7	15	100	18	78	0	1210	35	58	79	87	72	90	87	94	100
D-10/12/90	28791	1.1	8.7	354	539	232	68	5.5	1620	8.4	197	178	71	2.5	1677	8.4	114	356	130	79	1.5	1529	7.9	14	67	17	82	0	1359	40	27	40	88	81	96	88	93	100
D-11/12/90	27219	1.5	8.3	302	566	212	70	5.7	2270	8.3	319	216	69	6.3	2240	8.1	119	475	144	74	1.7	2200	7.7	18	84	19	81	0	1432	40	33	73	85	70	90	79	91	100
D-12/12/90	31849	5.5	8	330	511	184	79	4	2110	8	372	212	75	5	2100	8.1	204	396	128	78	1	2050	7.7	34	119	33	81	0	2270	45	40	80	83	70	90	77	82	100
D-13/12/90	30352	5.9	8.2	324	539	196	78	4.5	2090	8.2	282	190	73	4.5	2180	8.1	203	396	110	86	1	2130	7.8	21	89	19	90	0	2210	28	42	78	90	78	94	84	90	100
D-14/12/90	32009	2.9	8.1	288	459	216	73	4.5	1755	8	399	258	71	4.5	1690	7.9	183	364	104	77	0.3	1729	7.6	18	75	18	84	0	1750	54	60	93	90	79	94	84	92	100
D-16/12/90	34492	0.4	7.9	253	354	162	77	3.5	1443	8	232	202	71	4	1455	8.2	162	287	96	81	0.5	1520	7.9	16	69	12	90	0	1689	30	53	88	90	76	94	81	93	100
D-17/12/90	36452	0.5	8.2	154	310	128	72	3	1520	8.2	164	148	70	3	1350	8.1	126	237	82	81	0.2	1403	7.7	15	50	11	91	0	1280	23	45	93	88	79	90	84	91	100
D-18/12/90	34361	1.2	8.2	172	345	152	74	4.3	1552	8.2	286	156	74	3.5	1500	8.2	140	310	74	84	0.2	1736	7.8	16	85	14	94	0	1679	51	53	94	89	73	91	75	91	100
D-19/12/90	36432	18	8.1	168	334	196	65	7	2230	8.1	188	188	66	4.5	2110	8.2	133	210	74	78	0.2	2190	7.8	20	74	20	85	0	2320	29	61	96	85	65	88	78	90	100
D-20/12/90	37009	1.5	8.3	181	348	184	85	4.5	1337	8.3	278	200	78	5.5	1479	8.3	124	264	76	90	0.2	1544	7.8	21	48	19	91	0	1605	55	62	96	83	82	88	86	90	100
D-21/12/90	37281	1.5	8.1	287	484	308	77	5.8	1653	8.1	392	308	75	5.5	1640	8.1	155	332	118	83	0.3	1777	7.8	22	80	16	93	0.1	1880	61	62	95	86	76	92	84	95	99
D-23/12/90	28437	1	7.9	176	387	162	75	3.8	1344	7.9	178	156	80	3	1331	7.9	155	312	100	84	0.6	1420	7.7	17	51	14	71	0	1468	13	36	80	89	84	90	87	91	100
D-24/12/90	29955	0.9	7.6	203	301	146	69	4.5	1299	7.8	229	176	65	4.5	1319	7.9	135	242	108	72	0.3	1375	7.6	18	51	32	79	0	1430	41	39	93	85	79	90	83	78	100
D-26/12/90	35263	0.3	8	201	434	118	73	5	1727	8.1	300	214	73	4.5	1700	8.1	131	317	114	67	0.9	1749	7.7	12	55	18	67	0	1750	56	47	80	91	83	94	87	85	100
D-27/12/90	34319	0.5	8.1	236	448	178	76	5	1325	8	241	180	77	4.5	1259	7.9	150	226	90	78	0.5	1344	7.8	16	79	17	85	0	1276	38	50	89	89	65	93	82	90	100
D-28/12/90	32730	1	7.8	290	376	146	84	4.5	1441	7.8	222	154	86	4.5	1460	7.7	150	242	72	83	0.3	1446	7.5	18	89	19	93	0	1491	32	53	93	85	63	90	76	87	100
D-30/12/90	30164	0.5	7.9	232	503	194	78	6	1200	7.9	407	220	80	5.5	1222	8	149	297	112	80	0.4	1167	7.8	18	84	14	94	0	1399	63	49	94	85	70	90	79	93	100
D-1/11/90	45006	5.2	8	183	182	134	61	2.5	1007	8	197	190	51	3	1041	8	119	137	76	84	0.2	1106	7.8	18	42	11	76	0	1117	40	60	93	85	69	90	77	92	100
D-2/11/90	44158	8.1	8	124	463	230	48	4.5	1599	7.9	123	230	49	3	1586	7.9	94	251	88	64	0.3	1631	7.6	27	90	20	70	0	1554	24	62	93	71	64	78	81	91	100
D-4/11/90	39223	1.8	8.1	151	294	186	57	4	1006	8	148	154	61	2.8	1000	7.9	94	204	90	71	0.2	988	7.8	9	39	11	87	0	1038	37	42	93	90	81	94	87	94	100
D-5/11/90	42394	1.5	8.2	241	688	270	53	4.5	1566	8.2	331	244	56	4.2	1571	8.2	125	294	108	61	0.2	1550	7.8	26	84	21	65	0	1409	62	56	95	79	70	89	79	92	100
D-6/11/90	44364	2.5	8	182	364	154	69	3	1672	8.1	156	224	49	3.5	1750	8	136	261	86	65	0.2	1694	7.8	20	83	17	78	0	1683	13	62	94	85	68	89	77	89	100
D-7/11/90	44235	1.9	7.9	195	428	210	70	6.5	1835	8.2	194	250	57	3.5	1873	8.2	121	289	104	67	0.2	1855	8	15	75	22	73	0	1820	38	58	94	88	74	92	83	90	100
D-8/11/90	45151	1.7	8.3	185	457	184	70	4	1944	8.3	161	228	61	5.5	2050	8.1	109	325	98	76	0.4	2090	7.8	18	98	17	75	0.1	1824	32	57	93	84	70	90	79	91	99
D-9/11/90	47032	1.5	8.2	139	294	256	41	3	1456	8.1	140	260	39	2.5	1361	8	81	172	90	56	0.2	1504	7.7	11	55	14	71	0	1751	42	65	92	86	68	92	81	95	100
D-11/11/90	41372	1.6	7.8	119	220	128	63	1.5	1444	7.9	117	138	55	1.2	1493	7.9	91	161	76	68	0.3	1391	7.9	7	45	9	84	0	1431	22	45	75	92	72	94	80	93	99
D-12/11/90	45729	4.5	8.2	139	263	144	61	1.5	1665	8.3	159	204	51	2.5	1717	8	85	208	80	83	0.2	1807	7.8	9	51	10	90	0	1698	47	61	92	89	76	94	81	93	99
D-13/11/90	49314	2.3	8.1	166	318	118	56	2.5	1820	8	198	134	63	2	1779	8.1	95	213	60	70	0.2	1768	7.9	15	74	12	77	0	1810	52	55	90	84	65	91	77	90	100
D-14/11/90	44038	0.4	8	138	304	136	66	2.5	2050	8.1	144	168	61	3	2000	8.2	107	243	68	88	0.2	1852	7.8	17	106	20	85	0	1854	26	60	93	84	56	88	65	85	100
D-15/11/90	29816	0.5	8.5	251	447	152	66	3.3	1770	8.4	312	204	63	3.8	2880	8.2	192	439	108	72	0.9	2490	7.9	26	158	30	83	0	2240	39	47	76	87	64	90	65	80	100
D-16/11/90	29448	0.1	8.2	192	357	286	79	4.5	2950	7.9	127	230	70	4.5	2980	7.7	158	304	92	89	0.3	2780	7.6	27	77	31	88	0	2790	40	60	93	83	75	86	78	89	100
D-18/11/90	35825	1.4	8	111	371	142	73	4.5	1440	8	157	154	71	4	1437	7.9	109	197	80	90	0.2	1560	7.7	14	131	24	83	0	1757	31	48	96	87	34	87	65	83	100
D-19/11/90	47384	0.8	8.2	147	224	146	66	4	1758	8.2	118	138	67	1.4	1740	8	85	106	74	70	0.2	1712	7.7	15	23	18	82	0	1707	28	46	86	82	78	90	90	88	100
D-20/11/90	47306	0.1	8.2	206	324	166	64	3.5	1782	8	261	146	69	3	1830	8	105	220	84	71	0.2	1879	7.8	12	66	23	66	0.1	1833	60	43	93	89	70	94	80	86	99
D-21/11/90	40127	7.9	8.1	233	456	214	67	6	1586	8.1	268	238	70	4.5	1672	8	114	260	74	81	0.2	1784	7.9	33	140	32	78	0	1839	58	69	96	71	46	86	69	85	100
D-22/11/90	28005	3.5	8.2	226	419	178	71	4.5	2210	8.3	197	218	71	4	2150	8.2	141	318	100	80	0.4	2170	7.8	19	100	28	76	0	1914	28	54	91	87	69	92	76	84	99
D-23/11/90	28819	2.2	8.4	195	392	188	70	4	2790	8.2	218	210	67	4	2680	8	130	267	82	78	0.3	2550	7.9	18	86	19	79	0	2520	40	61	94	86	68	91	78	90	100
D-25/11/90	27098	2.1	8.2	197	497	254	73	6.5	1685	8.2	197	274	66	7	1681	8.2	130	307	132	73	1.3	1697	7.7	10	70	19	74	0	1894	40	52	82	92	77	95	86	93	100
D-26/11/90	42667	2.7	8.3	173	427	208	71	5.5	1979	8.4	221	204	71	5	1955	8.3	113	291	82	83	0.2	1862	7.7	16	105	20	86	0	1789	49	60	97	86	64	91	75	90	100
D-27/11/90	47222	2.2	8.1	148	321	142	73	3	1681	8.1	194	242	67	7	1704	8	130	274	104	75	0.8	1653	7.8	12	78	14	83	0	1705	33	57	89	91	72	92	76	90	100
D-28/11/90	32157	0.6	8.1	243	572	200	78	4.5	2280	8.2	289	240	74	6.5	2340	8	166	372	98	82	0.2	2320	7.8	13	86	13	89	0	2230	43	59	98	92	77	95	85	94	100
D-29/11/90	25687	1.2	8.2	316	743	280	72	6.5	2390	7.8	363	260	71	7	2460	8.1	169	408	112	77	0.3	2380	7.7	16	98	16	78	0	2210	53	57	96	91	76	95	87	94	100
D-30/11/90	26040	2.1	8.1	302	702	244	75	8.5	2480	8	357	304	71	12	2250	8	194	412	114	83	0.2	2640	7.8	19	118	18	83	0	2590	46	63	98	90	71	94	83	93	100
D-1/10/90	47623	3.4	7.7	283	310	170	61	2.5	1065	7.8	235	270	51	5.5	1100	7.8	110	227	108	67	0.5	1090	7.9	16	85	20	80	0	993	53	60	92	86	63	94	73	88	99
D-2/10/90	54578	3.6	7.9	313	341	512	34	6	915	7.9	205	520	34	7.5	976	7.9	107	200	106	64	0.2	1002	7.9	13	74	16	80	0	1021	48	80	97	88	63	96	78	97	100
D-3/10/90	36911	6	7.7	300	610	452	45	8	1313	7.7	375	556	44	10	1312	7.7	150	323	212	49	2.5	1238	7.7	21	116	14	86	0	1133	60	62	75	86	64	93	81	97	100
D-4/10/90	35244	6	7.8	177	412	196	69	4.5	2190	7.8	330	476	52	7.5	2330	7.8	151	274	124	61	0.3	2350	7.7	8	90	17	77	0	2220	54	74	97	95	67	96	78	91	100
D-5/10/90	39566	5.8	7.7	192	416	236	58	4.5	1447	7.6	296	384	54	7	1445	7.7	148	270	108	67	0.4	1380	7.8	13	78	14	71	0	1408	50	72	94	91	71	93	81	94	100
D-7/10/90	45469	2	7.3	129	237	234	39	1.5	1190	7.4	123	228	42	2	1202	7.4	73	175	110	35	0.2	1309	7.5	7	66	19	63	0	1631	41	52	90	90	62	95	72	92	99
D-8/10/90	46240	2.7	7.9	122	287	168	50	2	1906	7.8	157	188	53	2	2130	7.8	99	198	92	59	0.2	810	7.8	12	43	16	78	0.1	1425	37	51	93	88	78	90	85	91	98
D-9/10/90	45903	1.3	8	90	271	144	67	4.5	1221	8	110	164	71	3	1209	7.8	78	179	74	73	0.2	1266	7.7	10	41	14	74	0.1	1283	29	55	95	87	77	89	85	90	99
D-10/10/90	44343	1.3	8	169	327	126	68	2.5	1940	8.1	172	180	78	2.5	1950	7.8	106	272	78	80	0.2	1886	7.9	15	93	17	73	0	1891	38	57	92	86	66	91	72	87	99
D-12/10/90	39343	4.8	8	140	555	282	45	6.5	850	8	134	208	48	3.5	890	7.9	44	160	76	61	0.2	906	7.8	7	75	10	72	0	882	67	64	94	84	53	95	87	97	100
D-14/10/90	34347	0.8	7.9	155	243	210	48	2.5	848	7.9	170	138	52	1.5	858	8	89	133	74	76	0.3	902	8	9	35	12	58	0	898	48	46	83	90	74	94	86	94	99
D-15/10/90	53012	3.5	8.2	157	361	208	51	5	1015	8.2	197	188	53	4	931	8.1	93	204	86	61	0.3	1019	7.9	12	51	17	59	0	967	53	54	94	87	75	92	86	92	100
D-16/10/90	52258	1.5	8.4	195	246	172	61	3.5	1631	8.3	184	156	69	3.8	1564	8.2	92	165	86	72	0.4	1626	8	11	42	18	78	0	1635	50	45	89	88	75	94	83	90	100
D-17/10/90	49493	3.7	8.1	102	269	156	53	2.5	1082	7.9	177	152	53	2.5	1180	8	68	165	76	71	0.2	1041	7.8	10	54	13	83	0	1079	62	50	92	85	67	90	80	92	99

D-18/10/90	46200	2.5	8.3	192	294	172	56	3.5	1983	8.3	157	150	61	2	1934	8.1	107	207	104	62	0.4	1886	7.9	15	69	20	84	0	1880	32	31	83	86	67	92	77	88	99
D-19/10/90	46069	6	8.2	185	334	156	60	4	1987	8.3	217	162	64	4	2100	8.2	121	299	114	65	0.5	2050	7.9	16	65	11	80	0	2040	44	30	88	87	78	91	81	93	99
D-21/10/90	44324	1.6	7.8	174	173	134	69	2.5	967	7.8	165	114	68	2	980	7.8	104	202	100	70	0.3	1013	7.8	21	81	28	76	0.1	1105	37	12	88	80	60	88	53	79	96
D-22/10/90	48950	2.5	8.1	109	211	880	13	5.5	1745	7.9	154	1108	14	7	1534	8	46	111	118	44	0.4	1556	7.9	7	35	13	77	0	1495	70	89	95	85	69	94	83	99	100
D-23/10/90	60017	3.5	7.9	120	284	518	18	4	1048	7.9	115	460	20	4	1046	8	92	215	134	43	0.5	1135	8	11	88	20	54	0	1171	20	71	89	88	59	91	69	96	100
D-24/10/90	41569	3.3	7.9	115	357	334	34	3.5	1760	8	186	464	38	6	1858	8	92	230	110	55	0.5	1785	7.9	8	61	18	58	0	1595	51	76	93	91	74	93	83	95	99
D-25/10/90	40915	2	8	244	400	194	51	3.2	1885	8	197	284	42	2.8	2080	7.9	141	251	140	53	0.6	2020	8	13	63	16	63	0	2030	40	51	79	91	75	95	79	92	99
D-26/10/90	44858	1.4	8.1	380	318	194	56	2.7	1970	8.1	137	188	55	1.8	2080	8	99	239	104	64	0.4	2130	7.9	16	71	22	59	0	2190	28	45	78	84	70	96	78	89	99
D-28/10/90	47576	6	8.1	183	188	128	67	2	1465	8.1	197	158	56	2	1489	7.9	119	176	80	80	0.3	1435	7.8	18	59	24	73	0	1566	40	49	85	85	67	90	69	81	99
D-29/10/90	47501	1	8.2	183	384	180	64	3.5	1567	8.2	197	224	55	2.5	1512	8.1	119	270	110	64	0.3	1570	7.8	18	122	22	68	0	1463	40	51	88	85	55	90	68	88	100
D-30/10/90	47506	0.5	8	183	307	196	60	4	1557	8	197	228	49	5	1575	8	119	233	96	63	0.3	1620	7.9	18	74	26	60	0	1639	40	58	94	85	68	90	76	87	100
D-1/3/91	26343	2.1	7.7	275	553	528	44	7	1105	7.8	166	516	45	8.5	1174	7.9	84	265	158	60	1.4	1422	7.7	24	87	29	83	0.1	1782	49	69	84	71	67	91	84	95	99
D-3/3/91	32884	0.8	7.8	169	337	132	76	2.5	1568	7.9	192	204	69	4.5	1526	7.9	137	332	126	78	1.8	1516	7.7	14	71	14	94	0	1450	29	38	60	90	79	92	79	89	99
D-4/3/91	40745	1.5	7.7	156	547	166	66	6	1667	7.9	135	174	68	4	1730	7.9	118	333	100	74	1	1619	7.7	15	120	17	82	0	1576	13	43	75	87	64	90	78	90	100
D-5/3/91	39804	4.9	7.9	209	416	196	68	5	1711	7.9	277	250	70	7	1774	7.9	138	348	110	78	0.6	1845	7.7	16	107	19	78	0	1813	50	56	91	88	69	92	74	90	100
D-6/3/91	45804	2.2	7.9	170	380	146	80	4.5	1949	7.9	236	160	76	4.5	1957	7.9	161	328	82	90	0.6	2110	7.8	23	127	21	93	0	2130	32	49	87	86	61	87	67	86	100
D-7/3/91	42289	3.3	7.7	150	289	182	74	2.5	1698	8	130	134	69	2	1718	8	76	202	68	74	0.5	1604	7.7	25	87	21	84	0	1694	42	49	75	67	57	83	70	89	100
D-8/3/91	44548	1.4	7.9	218	272	216	41	4.5	1360	7.9	261	236	44	4.5	1328	7.8	154	213	100	64	0.3	1427	7.7	16	101	18	84	0	1514	41	58	93	90	53	93	63	92	100
D-10/3/91	36792	0.7	7.9	168	303	148	66	2.5	1069	8	158	158	66	3	1070	7.9	92	248	74	87	0.4	1150	7.7	16	78	12	83	0	1244	42	53	88	83	69	91	74	92	100
D-11/3/91	36410	1.6	8	173	396	242	57	6.8	1879	8.1	253	210	64	6.3	1916	7.9	85	341	108	67	0.7	1761	7.7	21	70	18	89	0	1605	66	49	89	75	80	88	82	93	100
D-12/3/91	33988	2.5	7.8	161	391	148	73	4.5	1551	7.9	183	170	69	4	1505	7.9	151	313	86	86	0.9	1512	7.8	19	94	14	97	0	1439	18	49	78	87	70	88	76	91	100
D-13/3/91	36479	3.8	8.1	192	422	176	68	4.5	2080	8	202	220	64	5.7	2100	7.9	132	367	118	80	1.2	2140	7.8	20	152	16	88	0	2290	35	46	79	85	59	90	64	91	100
D-14/3/91	31592	4.7	8	217	549	248	68	7	1370	8.1	255	224	68	5	1483	8.1	154	406	102	80	0.6	1410	7.8	15	74	13	86	0	1406	40	55	88	90	82	93	87	95	100
D-15/3/91	31789	2.1	7.9	215	549	234	72	5.5	2370	7.9	328	272	72	5	2410	7.9	204	428	112	79	1	2360	7.8	18	101	18	89	0	2300	38	59	80	91	76	92	82	92	100
D-17/3/91	27968	1.6	8	202	471	242	64	5.5	1158	8	278	340	61	6.5	1160	7.9	118	277	106	74	0.4	1205	7.7	25	83	21	76	0	1285	58	69	95	79	70	88	82	91	100
D-18/3/91	30853	1.2	8	179	455	168	70	4.3	1410	8	179	166	70	3	1347	7.9	119	376	104	79	0.1	1371	7.6	24	99	22	86	0	1203	40	37	97	85	74	87	78	87	100
D-19/3/91	29815	1	8	224	400	160	69	4.5	2230	8.2	244	178	64	5	2270	8	168	392	96	77	0.6	1763	7.7	20	94	22	84	0	1754	31	46	88	88	76	91	77	86	100
D-20/3/91	32578	2.5	7.8	223	443	184	70	4	1553	7.9	214	186	71	3.5	1670	7.9	181	345	86	84	0.1	1643	7.8	29	86	22	91	0	1665	15	54	97	84	75	87	81	88	100
D-21/3/91	33784	1	7.9	166	392	186	65	7.5	2510	8	213	198	65	5	2470	8	149	357	110	75	1.2	2390	7.8	20	94	20	80	0	2420	30	44	76	87	74	88	76	89	100
D-22/3/91	33029	3.4	7.9	226	624	264	75	4.5	2150	7.8	336	226	75	4.5	2070	7.7	164	348	82	95	0.3	2240	7.6	27	60	22	86	0	2210	51	64	93	84	83	88	90	92	100
D-24/3/91	48657	1.7	7.7	72	180	122	49	2.5	990	7.7	98	122	46	1.8	986	7.6	61	180	70	63	0.2	923	7.6	21	72	18	83	0	1109	38	43	89	66	60	71	60	85	100
D-25/3/91	45512	2.6	7.9	89	176	166	36	1.2	1059	8	97	218	32	1.9	1145	8	72	161	86	49	0.2	1060	7.7	15	84	14	86	0	1046	26	61	92	79	70	83	79	92	100
D-26/3/91	44085	4.2	7.4	183	325	228	47	3.5	1229	7.7	125	218	51	3	1254	7.8	97	368	136	57	1.3	1343	7.7	15	94	18	78	0	1382	22	38	57	85	75	92	71	92	100
D-27/3/91	40578	3.3	7.9	174	400	160	68	3.1	1433	7.9	203	146	66	3	1388	7.9	133	274	82	81	0.2	1472	7.8	17	84	18	80	0	1459	35	44	93	87	70	90	79	89	100
D-29/3/91	34917	8.5	7.5	156	311	226	67	4.5	1075	7.5	256	204	65	4.5	1116	7.5	112	182	92	76	0.3	1141	7.4	12	29	15	80	0	1170	56	55	93	89	84	92	91	93	100
D-31/3/91	32217	2	7.7	365	370	172	63	4.5	928	7.6	296	196	55	4.5	936	7.7	93	135	80	78	0.3	940	7.6	13	70	16	88	0	940	69	59	93	86	48	96	81	91	100
D-1/2/91	38105	1.6	8.4	230	517	218	75	5	1645	8.5	269	212	74	4.5	1676	8.3	154	349	102	80	0.4	1658	8	16	82	13	92	0	1658	43	52	91	90	77	93	84	94	100
D-3/2/91	30701	0.6	8.1	136	447	196	60	4.5	1105	8.3	159	188	61	3.5	1120	7.8	114	247	74	78	0.4	1155	7.6	29	106	27	85	0	1312	28	61	89	75	57	79	76	86	100
D-4/2/91	34290	3	8.1	194	435	166	72	4	1770	8.1	213	260	70	5.5	1930	8.1	64	345	100	76	0.8	1880	7.7	14	51	13	85	0	1722	70	62	86	78	85	93	88	92	100
D-5/2/91	35338	3.2	8	195	574	166	70	4.9	1563	8	156	188	68	4	1580	8	131	337	76	79	0.5	1695	7.7	17	83	16	88	0	1736	16	60	88	87	75	91	86	90	100
D-6/2/91	37120	2.6	8	212	546	184	73	4.5	2240	8	312	182	75	4.3	2160	8	169	329	94	75	0.5	1940	7.8	16	91	14	93	0	1860	46	48	89	91	72	93	83	92	100
D-7/2/91	35190	10	8.1	227	812	350	59	0.7	1512	8.1	323	358	60	7.3	1592	8.1	175	412	150	71	1.2	1524	7.8	21	91	20	90	0.1	1565	46	58	83	88	78	91	89	94	86
D-8/2/91	33714	2.7	8.4	228	473	200	74	4.5	1542	8.3	224	280	69	4.5	1546	8.1	146	335	106	81	0.3	1658	7.7	31	117	22	91	0	1645	35	62	93	79	65	86	75	89	100
D-10/2/91	29660	2	8	223	521	208	74	5.3	1585	8	230	200	75	5	1555	7.9	158	327	120	75	1.1	1597	9.7	21	84	17	88	0	1708	31	40	78	87	70	91	79	92	100
D-11/2/91	31749	11	8.1	247	525	264	71	6.3	1606	8.2	230	262	68	7	1598	8.1	148	339	126	75	0.8	1564	7.8	24	84	21	86	0.1	1455	36	52	89	84	70	90	79	92	99
D-12/2/91	32736	5.3	8.2	257	629	312	72	7.5	1823	8.2	259	264	72	6.3	1767	8.2	199	374	104	79	0.6	1871	7.8	28	108	22	91	0	1850	23	61	90	86	71	89	83	93	100
D-13/2/91	34441	8.2	8.1	199	486	240	68	9	1605	8.1	259	352	68	13	1684	8.1	168	394	116	76	0.4	1679	7.7	31	147	28	86	0	1770	35	67	97	82	63	84	70	88	100
D-14/2/91	32888	6.3	8.1	185	401	156	80	4	1513	8.2	170	224	73	5.5	1593	8.1	149	296	86	91	0.4	1653	7.8	24	97	22	91	0	1682	12	62	93	84	67	87	76	86	100
D-15/2/91	34461	6.2	8.1	222	662	252	68	6.5	1734	8.2	250	310	7.1	7.3	1733	8.2	175	346	104	79	0.6	1789	7.8	24	86	25	96	0.1	1821	30	67	92	86	75	89	87	90	99
D-17/2/91	34045	1.3	8	129	506	178	63	4	1180	8	109	186	62	3.8	1148	7.9	126	269	90	78	0.4	1255	7.6	22	54	19	90	0	1406	40	52	91	83	80	83	89	89	100
D-18/2/91	36421	3	8.2	240	507	356	61	9	1672	8.2	225	300	61	8	1663	8.1	135	293	94	77	0.4	1622	7.7	22	78	20	86	0	1454	40	69	95	84	73	91	85	94	100
D-19/2/91	37662	2.6	8.1	238	490	170	71	5	1652	8.2	305	244	67	5.5	1643	8.2	135	371	102	71	1	1772	8	23	95	20	85	0	1800	56	58	82	83	74	90	81	88	100
D-21/2/91	29990	7.6	7.9	204	469	212	76	5	1145	7.9	252	246	71	6.5	1186	8.1	154	257	90	84	0.3	1172	7.8	18	20	14	89	0	1249	39	63	96	88	92	91	96	93	100
D-22/2/91	37561	13	7.5	183	400	196	73	4.5	1245	7.6	370	194	75	4.5	1185	7.7	212	230	110	75	0.3	1163	7.6	15	99	14	91	0	1207	43	43	93	93	57	90	79	93	100
D-24/2/91	27340	4.2	7.7	254	411	174	74	4.5	1339	7.9	375	292	67	8	1350	7.9	121	319	102	78	0.5	1423	7.7	17	96	19	86	0	1431	68	65	94	86	70	93	77	89	100
D-25/2/91	30055	5.7	7.8	230	422	222	71	5	1733	7.9	379	400	65	10	1790	8	194	346	122	82	0.9	1743	7.7	27	106	24	85	0	1629	49	70	91	86	69	88	75	89	100
D-26/2/91	31494	2.5	8	290	459	228	72	7.5	1684	8	449	298	71	9	1746	8	187	352	112	91	0.6	1828	7.8	28	57	22	87	0	1740	58	62	93	85	84	90	88	90	100
D-27/2/91	31765	2	7.9	240	887	314	76	7	2120	7.9	158	292	74	7.2	2200	7.9	167	511	136	75	0.7	2190	7.7	26	95	23	92	0	2170	40	53	91	84	81	89	89	93	100
D-28/2/91	25342	2	8.3	275	494	212	78	4.5	2070	8.3	411	322	73	10	2200	8.2	167	371	118	88	0.5	2240	7.8	18	138	22	81	0	2230	40	60	93	85	70	90	79	91	100

D-1/1/91	32441	0.8	8.1	198	351	134	76	2.5	1341	8.1	264	142	73	2.5	1300	8.1	138	234	98	84	0.3	1355	7.9	15	77	17	85	0	1394	48	31	88	89	67	92	78	87	100
D-2/1/91	40740	1.2	8.2	127	444	172	73	3	1658	8.2	117	184	72	4	1629	8.1	66	315	94	83	0.5	1644	7.8	15	85	15	90	0	1491	44	49	88	77	73	88	81	91	100
D-3/1/91	34637	3.5	8.1	231	368	162	77	4	1854	8.1	273	158	75	4.5	1846	8.1	158	308	76	87	0.4	1822	7.8	18	92	15	83	0	1734	42	52	92	89	70	92	75	91	100
D-4/1/91	34322	3	8.4	249	600	216	78	5	1566	8.3	220	204	75	5.3	1583	8.2	161	328	86	77	0.4	1643	7.7	18	88	12	83	0.1	1655	27	58	92	89	73	93	85	94	99
D-6/1/91	35111	0.5	7.9	228	461	126	75	2.5	1113	8.1	243	142	76	2.5	1104	8	122	279	92	78	0.5	1061	7.8	14	89	13	65	0	1142	50	35	80	89	68	94	81	90	99
D-7/1/91	40585	0.8	8.3	230	524	158	71	5	1178	8.2	285	186	67	5.5	1217	8.1	117	304	82	71	0.3	1178	7.8	13	92	13	73	0	1114	59	56	95	89	70	94	82	92	100
D-8/1/91	37735	1.7	7.9	203	487	168	77	3.5	1353	8.1	231	196	70	5.5	1338	8.1	107	341	60	87	0.2	1250	7.8	17	166	15	90	0	1268	54	69	96	84	51	92	66	91	100
D-9/1/91	34277	1.5	8.2	133	531	220	74	7	1514	8.2	207	288	65	11	1535	8	92	257	72	72	0.4	1476	7.7	11	83	17	74	0	1429	56	75	97	88	68	92	84	92	100
D-10/1/91	41451	0.5	8	131	384	154	74	4.5	1260	8.1	189	298	75	6.5	1300	8	114	273	80	80	0.3	1367	7.8	18	95	19	84	0	1443	40	73	96	84	65	86	75	88	100
D-11/1/91	45183	0.4	7.8	205	347	142	68	4.5	1373	7.7	339	148	69	4.5	1312	7.8	101	219	72	82	0.3	1409	7.7	19	100	19	85	0	1473	70	51	93	81	54	91	71	87	100
D-13/1/91	27415	0.9	7.7	241	332	158	66	4	1133	7.8	182	194	67	3.3	1148	7.9	118	256	90	80	0.3	1190	7.7	12	156	11	71	0.1	1236	35	54	91	90	39	95	53	93	99
D-14/1/91	42614	0.4	8.3	113	347	120	72	2.5	1385	8.2	106	134	75	2.5	1377	8.1	98	279	68	88	0.4	1380	7.8	7	84	11	91	0	1355	7.5	49	84	93	70	94	76	91	100
D-15/1/91	48914	0.4	8.1	203	434	128	70	4	1496	8.3	222	114	72	2.5	1533	8.2	134	271	84	71	1	1489	7.7	13	60	11	76	0	1520	40	26	60	90	78	94	86	91	100
D-16/1/91	49174	0.7	7.9	188	434	126	67	2.5	2450	8.1	159	156	68	3	2680	8.2	139	422	90	71	1	2950	7.8	22	155	28	79	0.1	2740	13	42	67	84	63	88	64	78	98
D-17/1/91	45151	0.5	8.2	166	307	118	80	4	1697	8.2	214	130	80	3.5	1661	8.2	148	295	96	77	1.2	1624	7.7	19	116	27	88	0	1821	31	26	66	87	61	89	62	77	100
D-18/1/91	37143	0.7	8.2	222	493	162	75	5.3	1620	8.3	211	162	73	4	1746	8.2	140	330	86	84	0.6	1834	7.7	16	105	11	82	0	1734	34	47	85	89	68	93	79	93	100
D-20/1/91	30244	0.9	7.6	224	337	146	70	3.5	1146	7.8	240	168	71	4	1144	7.9	134	302	92	78	0.4	1205	7.7	17	78	8	80	0	1283	44	45	90	87	74	92	77	95	100
D-21/1/91	34032	1	8.2	223	470	166	72	5.5	1343	8.3	273	196	76	5	1362	8.2	161	337	92	74	0.5	1419	7.8	16	86	13	39	0	1311	41	53	90	90	75	93	82	92	100
D-22/1/91	34904	1.2	8	272	665	188	73	6	2200	8.1	293	192	74	5	2200	8	164	304	96	88	0.6	2130	7.7	20	76	15	80	0	2150	44	50	88	88	75	93	89	92	100
D-23/1/91	36063	1	8.2	346	350	144	72	5	1233	8.3	257	152	75	4	1230	8.1	174	300	86	98	0.6	1266	7.8	20	61	10	70	0	1297	32	43	85	89	80	94	83	93	100
D-24/1/91	35500	2.7	8.2	148	545	188	77	5.3	1329	8.2	221	230	74	5	1354	8.2	152	337	94	81	0.4	1407	7.7	14	71	11	86	0	1387	31	59	92	91	79	91	87	94	100
D-25/1/91	37730	0.7	8	427	815	204	71	4.5	1455	7.9	517	186	73	4.5	1558	7.9	119	423	118	78	0.3	1602	7.4	23	101	20	88	0	1590	40	37	93	85	76	95	88	90	100
D-27/1/91	28209	1.2	7.9	319	532	250	71	6.5	1379	8	331	254	69	6	1453	8	150	299	92	74	0.4	1431	7.7	15	60	14	86	0	1508	55	64	93	90	80	95	89	94	100
D-28/1/91	32680	2.6	8.2	334	594	256	67	7	1380	8.3	268	238	67	5.5	1400	8.2	180	372	118	66	0.9	1352	7.9	20	62	11	80	0	1167	33	50	84	89	83	94	90	96	100
D-29/1/91	32974	2.6	8.1	311	420	208	69	6.5	1474	8.2	258	198	73	3.3	1559	8.1	189	309	152	71	3	1402	7.8	18	41	12	83	0	1466	27	23	7.7	91	87	94	90	94	100
D-30/1/91	33189	1	8.1	238	591	202	84	6	1380	8	282	210	80	5.5	1372	8.2	153	290	106	91	0.5	1413	7.9	16	63	17	94	0	1417	46	50	91	90	78	93	89	92	100
D-31/1/91	34579	2.5	8.3	261	592	216	71	7.5	1663	8.4	244	256	73	8	1685	8.2	163	400	170	78	3.5	1680	7.8	24	47	13	93	0	1848	33	34	56	85	88	91	92	94	100
D-1/5/91	46126	1.3	7.5	122	289	114	74	2.5	1103	7.6	122	146	64	2	1060	7.6	97	242	70	77	0.3	1094	7.6	12	99	10	96	0	1131	21	52	88	88	59	90	66	91	100
D-2/5/91	43445	4.1	7.8	133	295	158	56	3	1436	7.9	140	158	54	2.5	1448	7.9	92	206	74	73	0.3	1370	7.7	14	66	12	75	0	1203	34	53	88	85	68	90	78	92	100
D-3/5/91	35990	1.7	7.9	142	272	160	56	2	1543	7.9	154	174	58	3	1485	7.8	114	295	86	74	0.3	1560	7.6	18	74	14	86	0	1565	26	51	90	84	75	87	73	91	100
D-5/5/91	36976	0.9	7.9	152	510	136	68	3	1235	7.7	145	148	66	2.5	1266	7.7	75	204	72	69	0.3	1247	7.6	16	65	11	91	0	1279	48	51	88	79	68	90	87	92	99
D-6/5/91	33085	0.8	7.7	185	518	202	66	3	2350	7.8	345	210	68	3.5	2120	7.7	156	355	98	84	0.5	2080	7.7	14	65	13	92	0	1568	55	53	87	91	82	92	88	94	99
D-7/5/91	34150	3.1	7.9	228	486	184	70	4.5	1912	8	209	214	69	4	1867	8	145	297	100	78	0.5	1889	7.8	24	86	16	81	0	1888	31	53	89	83	71	90	82	91	100
D-8/5/91	60081	3.5	7.6	100	212	280	34	3.5	651	7.6	121	288	36	3	646	7.5	73	149	98	45	0.5	697	7.4	15	59	14	86	0	937	40	66	83	80	60	85	72	95	100
D-9/5/91	57629	3.7	7.3	80	204	180	32	1.8	940	7.4	84	198	34	1.5	912	7.5	45	125	74	46	0.3	863	7.4	10	51	10	80	0	683	46	63	80	78	59	88	75	94	100
D-10/5/91	48110	1	7.7	179	340	150	53	4.5	1509	7.7	168	198	49	4.5	1517	7.6	108	163	60	67	0.3	1568	7.2	14	96	10	72	0	1548	36	70	93	87	41	92	72	93	100
D-12/5/91	59184	0.6	7.5	94	189	120	57	1.5	1200	7.5	122	144	51	1.3	1206	7.6	71	203	54	67	0.2	1260	7.5	13	33	10	68	0	1353	42	63	84	82	84	86	83	92	100
D-13/5/91	47489	0.2	7.6	135	297	164	57	2.5	1000	7.7	175	196	53	2.5	1040	7.8	99	250	98	59	0.5	968	7.7	20	43	18	83	0	906	43	50	80	80	83	85	86	89	99
D-14/5/91	35374	4.4	7.9	175	566	292	58	7.5	1268	8	196	406	50	9.2	1358	7.9	139	327	110	73	0.5	1385	7.8	20	80	16	88	0.1	1234	29	73	95	86	76	89	86	95	99
D-15/5/91	33434	3.2	7.9	223	538	284	63	7.5	1425	8	218	256	63	6.5	1441	7.9	153	355	112	79	0.5	1403	7.9	18	104	19	84	0	1391	30	56	92	88	71	92	81	93	100
D-16/5/91	31967	3.3	7.9	222	516	456	47	8.5	1335	7.9	302	374	53	9	1393	7.8	161	352	110	75	0.4	1450	7.7	21	96	19	82	0	1493	47	71	96	87	73	91	81	96	100
D-17/5/91	32835	1.7	7.8	159	516	248	61	5	1405	7.7	201	314	55	5	1340	7.8	127	314	104	71	0.4	1381	7.7	17	72	15	87	0	1390	37	67	92	87	77	89	86	94	100
D-19/5/91	33000	1.5	7.7	153	404	238	56	4.5	1049	7.7	138	184	63	2.7	1073	7.7	114	265	116	69	0.5	1061	7.7	33	111	41	81	0	1126	17	37	82	71	58	78	73	83	99
D-20/5/91	47243	0.8	7.7	168	376	272	46	5.3	1052	7.8	136	296	45	5.6	1063	7.7	97	242	80	73	0.2	1083	7.7	14	87	15	100	0	1070	29	73	96	86	64	92	77	95	100
D-21/5/91	40295	0.9	7.7	238	327	194	61	5.9	1725	7.8	210	252	55	6.3	1724	7.8	101	233	82	68	0.3	1736	7.7	12	79	14	91	0	1673	52	68	95	88	66	95	76	93	100
D-22/5/91	38792	1.9	7.7	250	431	196	64	5.5	1219	7.9	399	238	62	6	1232	7.9	133	310	86	74	0.2	1212	7.7	15	90	17	77	0.1	1197	67	64	97	89	71	94	79	91	99
D-23/5/91	36162	2.5	7.4	224	421	204	69	5	1328	7.7	293	248	65	6.5	1341	7.7	119	282	94	72	0.2	1331	7.7	18	98	20	80	0.1	1265	59	62	97	85	65	92	77	90	98
D-24/5/91	36495	0.1	7.7	213	627	2008	18	4.5	1257	7.6	308	1692	18	4.5	1335	7.5	97	226	66	70	0.3	1255	7.6	16	119	13	77	0	1289	69	96	93	84	47	93	81	99	100
D-26/5/91	36922	0.5	7.6	122	338	174	62	5	1035	7.7	135	216	57	5.5	1030	7.7	108	244	68	79	0.2	1099	7.6	14	44	12	82	0	1140	20	69	97	87	82	89	87	93	100
D-27/5/91	43497	2.1	7.8	134	323	190	61	4.5	2070	7.8	126	206	54	3	2050	7.9	85	229	118	61	0.3	1784	7.7	15	56	13	85	0	1680	33	43	90	82	76	89	83	93	100
D-28/5/91	38809	0.8	7.6	179	432	1228	23	36	1889	7.6	174	1692	21	46	1906	7.7	99	227	90	67	0.5	1962	7.6	18	71	17	82	0	1932	43	95	99	82	69	90	84	99	100
D-29/5/91	34301	3.9	7.9	243	459	286	55	6.5	1174	7.9	216	342	46	7.5	1202	7.9	123	253	90	58	0.3	1190	7.8	15	103	14	86	0	1167	43	74	96	88	59	94	78	95	100
D-30/5/91	33968	1.5	7.7	198	546	308	62	13	1869	7.8	239	420	53	19	1893	7.9	81	222	76	84	0.4	1804	7.7	17	79	27	78	0.1	1792	66	82	98	79	64	91	86	91	100
D-31/5/91	34094	1	7.8	156	483	964	24	18	2120	7.8	196	764	30	17	2110	7.8	97	170	92	61	0.4	1930	7.6	15	84	20	75	0	1966	51	88	98	85	70	90	79	98	100
D-1/4/91	34573	0.7	7.7	156	276	146	71	3.3	1265	7.7	166	206	66	4.5	1270	7.7	114	176	124	73	0.9	1260	7.7	30	43	44	80	0.5	1270	31	40	80	74	76	81	84	70	85
D-2/4/91	35395	0.6	7.8	273	473	210	73	4.5	1232	7.9	213	224	69	6	1257	7.9	170	310	116	79	0.1	1214	7.7	22	85	22	79	0	1116	20	48	98	87	73	92	82	90	100
D-3/4/91	34525	0.8	7.8	312	576	224	68	5.5	1300	7.9	324	268	72	5.5	1280	7.9	157	306	92	74	0.4	1248	7.8	23	74	23	81	0	1251	52	66	93	85	76	93	87	90	100
D-4/4/91	35861	0.8	8.1	242	492	176	75	5.5	1530	8.2	397	238	68	5	1612	8.1	148	312	88	75	0.1	1589	7.9	20	84	19	78	0	1566	63	63	98	87	73	92	83	89	100
D-5/4/91	43082	0.7	7.8	173	496	178	66	4.5	1329	7.9	365	212	63	5	1303	7.9	124	304	100	78	0.4	1338	7.7	23	88	23	87	0.1	1408	66	53	92	82	71	87	82	87	99

D-7/4/91	27931	2.2	7.5	296	455	278	78	4.3	1439	7.6	255	182	69	3.9	1436	7.6	131	318	84	83	0.3	1421	7.6	15	106	13	96	0	1423	49	54	92	89	67	95	77	95	100
D-8/4/91	32954	0.7	7.7	269	423	192	68	6	1164	7.9	360	266	59	7	1170	7.9	145	314	94	70	0.6	1222	7.7	16	110	15	98	0	1149	60	65	91	89	65	94	74	92	100
D-9/4/91	33773	4.1	7.9	233	506	222	72	4.5	1410	7.9	328	242	69	5.8	1366	7.9	201	388	102	84	0.4	1589	7.7	18	90	16	94	0	1461	39	58	94	91	77	92	82	93	100
D-10/4/91	33666	2.7	7.6	237	494	204	72	5.5	1187	7.7	241	224	65	5	1248	7.6	164	341	102	84	0.7	1350	7.6	24	71	57	88	0.1	1312	32	55	86	85	79	90	86	72	99
D-11/4/91	39715	0.6	7.8	241	539	212	71	5.5	1338	7.9	232	218	67	5.5	1403	7.9	160	353	92	80	0.2	1427	7.8	20	81	13	92	0	1364	31	58	96	88	77	92	85	94	100
D-12/4/91	28923	0.7	7.2	133	467	186	66	4.5	1398	7.4	141	216	65	4.5	1425	7.5	130	393	76	84	0.3	1586	7.5	20	147	31	84	0	1543	7.8	65	93	85	63	85	69	83	100
D-14/4/91	32317	0.7	7.5	166	393	242	55	5.3	958	7.7	206	256	55	5.5	982	7.7	135	260	96	79	0.4	1038	7.6	13	27	10	90	0	1082	35	63	94	90	90	92	93	96	100
D-15/4/91	33090	0.4	7.9	205	453	198	71	5	1479	7.9	199	214	70	5.5	1530	7.9	130	301	92	76	0.3	1401	7.8	15	70	22	64	0	1233	35	57	95	89	77	93	85	89	100
D-16/4/91	33371	0.8	7.8	290	448	218	67	5.5	1842	8	254	200	62	5	1829	7.9	137	312	90	76	0.3	1856	7.8	19	92	22	80	0.1	1843	46	55	94	86	71	93	80	90	99
D-17/4/91	33813	2.9	7.7	212	468	224	66	4.5	1475	7.8	337	260	62	6	1506	7.9	149	320	114	75	0.3	1612	7.8	18	92	14	86	0	1654	56	56	96	88	71	92	80	94	100
D-18/4/91	35456	6.4	8.1	184	412	216	62	5	1800	8.1	194	234	62	5	1770	8	116	276	106	66	0.5	1817	7.7	14	84	12	92	0	1760	40	55	90	88	70	92	80	94	100
D-19/4/91	38045	9.6	8.1	177	428	220	62	4.5	1372	8	160	244	56	5.3	1335	7.9	138	372	90	73	0.4	1340	7.7	20	104	18	89	0	1323	14	63	93	86	72	89	76	92	100
D-21/4/91	31191	2	7.9	270	321	168	67	4	1026	7.9	226	200	63	3.5	971	7.8	100	226	82	81	0.3	1009	7.7	14	51	16	83	0	1086	56	59	91	86	77	95	84	91	100
D-22/4/91	36215	6.5	7.5	161	392	266	48	6	1156	7.8	252	208	47	3.5	1105	7.9	110	238	82	78	0.4	1108	7.7	15	59	13	83	0	1035	56	61	89	86	75	91	85	95	100
D-23/4/91	34719	9	7.7	173	388	322	50	5.5	1196	7.7	167	210	62	4.5	1171	7.8	149	319	110	76	0.7	1234	7.6	20	108	24	79	0	1250	11	48	84	87	66	88	72	93	100
D-24/4/91	35729	2.9	7.7	334	841	616	60	14	1285	7.8	357	572	56	16	1378	7.9	170	274	102	80	0.4	1420	7.8	23	100	20	97	0	1433	52	82	97	87	70	93	88	97	100
D-25/4/91	36395	6.5	7.7	183	449	380	53	6.5	1306	7.8	258	464	51	7.5	1410	7.9	125	292	88	77	0.3	1498	7.7	23	54	19	90	0	1512	52	81	96	82	82	87	88	95	100
D-26/4/91	41503	8.7	7.5	133	346	274	46	4.5	1186	7.3	125	146	59	4.5	1203	7.1	113	196	74	73	0.3	1229	7	17	65	18	83	0	1272	9.6	49	93	85	67	87	81	93	100
D-28/4/91	27642	1.8	7.5	69	170	180	40	1.4	810	7.5	130	310	40	3	827	7.5	83	124	80	65	0.3	866	7.5	13	39	14	93	0	949	36	74	90	84	69	81	77	92	99
D-29/4/91	35760	1.8	7.6	115	295	182	52	25	1400	7.7	125	166	55	19	1418	7.8	98	225	84	81	1	1396	7.7	19	58	19	84	0.1	1316	22	49	95	81	74	84	80	90	100
D-1/7/91	33416	1.7	7.4	167	333	242	66	4.5	1960	7.6	211	202	67	4.5	2090	7.7	106	274	80	88	0.1	1942	7.7	12	73	14	79	0	1788	50	60	98	89	73	93	78	94	100
D-2/7/91	35518	4.2	7.8	133	105	208	55	3.5	1293	7.8	138	236	53	4.5	1347	7.8	91	125	58	83	0.1	1323	7.7	16	20	16	94	0	1318	34	75	98	82	84	88	81	92	100
D-3/7/91	35623	4.4	7.6	151	404	204	68	3.5	1565	7.6	137	232	63	4	1629	7.6	88	277	80	70	0.1	1575	7.4	12	84	13	92	0	1467	36	66	98	86	70	92	79	94	100
D-4/7/91	32815	6.6	7.8	151	485	198	72	3.5	1535	7.7	140	156	62	4	1528	7.7	102	283	78	77	0.1	1571	7.6	13	101	14	77	0	1605	27	50	98	87	64	91	79	93	100
D-5/7/91	32454	3.4	7.4	148	545	202	72	4.5	1337	7.4	138	272	63	4.5	1334	7.4	67	200	76	89	0.3	1283	7.4	11	163	11	91	0	1365	51	72	93	84	19	93	70	95	100
D-7/7/91	26590	2.9	7.5	134	351	108	82	3	1135	7.5	154	182	65	3	1115	7.5	123	351	124	76	0.9	1117	7.4	12	107	15	79	0	1220	20	32	70	90	70	91	70	86	100
D-8/7/91	33636	34	7.5	166	481	368	51	6.3	1355	7.6	155	302	54	5.5	1359	7.9	110	283	96	75	0.3	1283	8	29	113	19	81	0	1240	29	68	95	74	60	83	77	91	100
D-9/7/91	32334	19	7.6	179	461	298	56	5	1340	7.6	225	212	63	5.5	1395	7.5	111	307	84	76	0.2	1292	7.4	20	125	24	78	0	1300	51	60	96	82	59	89	73	92	100
D-10/7/91	35178	3.7	7.7	159	396	154	69	3	1440	7.8	159	184	67	3.1	1520	7.8	105	295	82	83	0.2	1415	7.7	23	109	30	87	0	1479	34	55	94	78	63	86	73	81	100
D-11/7/91	35990	6.3	7.7	146	375	244	57	4	1413	7.8	158	280	56	6.5	1486	7.7	116	282	96	81	0.7	1449	7.6	23	112	32	83	0	1410	27	66	89	80	60	84	70	87	100
D-12/7/91	35990	2.6	7.8	198	604	288	58	4.7	1235	7.8	229	222	60	4.5	1330	7.7	144	391	104	73	0.9	1320	7.7	31	159	41	83	0	1399	37	53	80	79	59	84	74	86	100
D-14/7/91	35990	0.8	7.6	177	388	170	69	4	1147	7.7	166	198	67	3	1126	7.6	89	208	68	82	0.2	1105	7.7	14	74	16	88	0	1170	46	66	93	84	64	92	81	91	100
D-15/7/91	35990	5.7	7.7	197	545	254	60	6	1202	7.7	182	248	61	4	1218	7.7	120	325	124	77	0.6	1168	7.6	20	216	18	100	0	1205	34	50	85	83	34	90	60	93	100
D-16/7/91	35990	1.1	7.6	149	412	208	58	4.3	1593	7.7	127	194	61	4	1710	7.7	96	298	128	66	0.7	1606	7.8	17	110	22	84	0	1602	24	34	83	82	63	89	73	89	100
D-17/7/91	35990	0.7	7.6	149	359	242	61	4	1315	7.7	221	280	63	7	1240	7.7	121	294	138	62	0.7	1250	7.8	105	290	104	87	0	1434	45	51	90	13	1.4	30	19	57	100
D-18/7/91	35990	1	7.6	186	495	222	66	5.5	1518	7.6	168	222	64	4.5	1496	7.6	110	274	112	70	1	1505	7.6	101	292	74	84	0.3	1642	35	50	78	8.2	70	46	41	67	96
D-19/7/91	35990	1.6	6.9	233	472	242	65	5	1183	7.3	192	236	59	4.5	1165	7.3	124	357	116	66	1.4	1253	7.5	101	236	78	74	0	1374	35	51	69	19	34	57	50	68	100
D-21/7/91	35990	0.9	7.3	185	395	216	62	3	1367	7.4	238	232	60	3	1383	7.5	93	263	102	59	0.3	1356	7.6	31	117	39	72	0	1444	61	56	90	67	56	83	70	82	100
D-22/7/91	35990	4	7.5	182	605	208	75	5	1672	7.5	155	230	62	5	1734	7.5	129	308	82	76	0.1	1693	7.6	26	86	21	71	0	1603	17	64	98	80	72	86	86	90	100
D-23/7/91	35990	1.8	7.6	198	432	224	64	4	2150	7.7	195	208	67	3.5	2100	7.6	106	290	92	74	0.2	2140	7.6	19	90	33	82	0	2240	46	56	96	82	69	90	79	85	100
D-24/7/91	35990	1.5	8.1	129	318	140	67	3	1319	8	124	136	69	2	1320	7.6	101	277	70	86	0.1	1270	7.5	15	86	22	86	0	1289	19	49	95	85	69	88	73	84	100
D-25/7/91	35990	5.7	7.7	115	408	290	51	4	2150	7.7	139	198	68	2.5	2050	7.6	96	290	98	76	0.1	1924	7.5	20	118	46	76	0	2060	31	51	96	79	59	83	71	84	100
D-26/7/91	35990	2.4	7.6	132	253	200	49	2.8	2110	7.6	129	256	50	2.5	2060	7.6	106	245	94	83	0.1	1974	7.6	15	90	28	86	0	1959	18	63	96	86	63	89	64	86	99
D-28/7/91	35990	1.4	7.5	188	263	148	68	2	1645	7.5	148	134	78	1.7	1668	7.6	98	198	56	89	0.1	1671	7.7	14	85	21	86	0	1760	34	58	94	86	57	93	68	86	100
D-29/7/91	35990	0.2	7.8	114	273	138	74	3.8	1870	7.8	128	172	76	3.5	1929	7.8	80	192	68	82	0.2	1835	7.5	14	73	14	89	0	1809	38	61	96	83	62	88	73	90	100
D-30/7/91	35990	0.6	7.4	159	394	170	69	3	1450	7.4	155	196	60	3	1556	7.4	111	274	78	72	0.1	1690	7.6	16	110	26	79	0	1693	28	60	98	86	70	90	72	85	100
D-31/7/91	35990	1.6	7.5	170	336	168	69	2.6	1531	7.5	192	200	67	3	1485	7.6	101	265	80	80	0.1	1642	7.7	19	99	34	79	0	1648	47	60	98	81	63	89	71	80	99
D-2/6/91	32308	1.8	7.7	118	295	178	63	3	1459	7.7	137	236	53	4	1442	7.7	103	231	104	67	0.3	1474	7.6	12	72	11	82	0	1607	25	56	93	88	69	90	76	94	99
D-3/6/91	31114	1	7.8	181	462	216	62	5.5	1315	7.8	197	354	54	8	1377	7.8	124	307	118	64	0.3	1270	7.7	22	68	20	75	0.1	1142	37	67	96	82	78	88	85	91	99
D-4/6/91	31205	0.6	7.7	214	467	242	61	4.5	1171	7.8	218	318	55	6	1205	7.7	132	300	116	67	0.2	1312	7.7	22	86	22	82	0.1	1333	39	64	97	83	71	90	82	91	99
D-5/6/91	35509	1.1	7.8	181	358	228	64	4.3	1224	7.9	243	456	50	9.5	1263	7.9	107	272	112	67	0.3	1265	7.8	16	105	16	75	0	1268	56	75	97	85	61	91	71	93	100
D-6/6/91	34903	2.2	7.7	227	416	218	62	5.4	1335	7.7	257	416	50	8	1350	7.7	156	311	134	60	0.5	1368	7.7	25	86	16	75	0	1379	39	68	94	84	72	89	79	93	100
D-7/6/91	34294	5.9	7.6	146	438	174	68	4.5	1102	7.6	182	332	55	4.5	1093	7.5	123	340	112	64	0.3	1239	7.5	23	78	16	88	0	1213	32	66	93	81	77	84	82	91	100
D-9/6/91	30614	0.9	7.7	146	313	168	64	4.3	1019	7.7	173	246	59	5.9	1020	7.7	116	183	124	65	0.2	1034	7.6	16	59	15	80	0	1056	33	50	97	86	68	89	81	91	100
D-10/6/91	33239	2.5	7.8	217	591	264	67	7.5	1234	7.7	227	500	53	8.5	1219	7.8	135	338	132	67	0.3	1294	7.7	17	84	27	78	0	1247	41	74	97	87	75	92	86	90	100
D-12/6/91	32100	1.5	7.5	277	523	324	68	7	1817	7.6	315	348	56	9	1816	7.8	154	297	84	67	0.2	1829	7.7	21	53	19	78	0	1819	51	76	98	86	82	92	90	94	100
D-13/6/91	32538	1	7.6	219	511	286	58	6.5	1326	7.8	243	382	57	7	1420	7.8	142	323	106	72	0.2	1359	7.7	22	98	21	74	0	1361	42	72	97	85	70	90	81	93	100
D-14/6/91	35571	1.8	7.2	166	549	138	64	4.5	1769	7.4	197	426	50	4.5	1882	7.5	111	287	74	70	0.3	2100	7.6	15	85	9	89	0	2030	44	83	93	87	70	91	85	94	100
D-16/6/91	33210	1.3	7.5	164	353	218	62	4.5	1535	7.6	185	244	58	5	1489	7.7	107	229	80	75	0.2	1573	7.6	15	59	14	71	0	1679	42	67	97	86	74	91	83	94	100

D-17/6/91	34097	0.7	7.8	192	330	190	58	5.5	1775	7.8	206	218	55	5.5	1782	7.8	117	275	82	73	0.2	1716	7.7	10	70	19	67	0	1605	43	62	96	92	75	95	79	90	100
D-18/6/91	31224	0.7	7.8	231	473	222	62	4.5	1309	7.8	279	268	58	6	1368	7.9	118	299	82	78	0.2	1529	7.7	27	136	29	76	0	1523	58	69	98	77	55	88	71	87	100
D-19/6/91	35389	0.4	7.6	157	392	232	53	5	1565	7.7	163	274	54	6	1517	7.8	103	250	76	82	0.2	1630	7.6	18	65	22	82	0	1610	37	72	98	83	74	89	83	91	100
D-20/6/91	36708	3.9	7.8	196	403	200	66	5	1592	7.8	301	236	70	4.5	1478	7.7	130	288	74	84	0.2	1469	7.6	12	54	14	86	0	1483	57	69	96	91	81	94	87	93	100
D-21/6/91	33064	1.2	7.7	266	438	200	62	4.5	1396	7.9	217	214	63	4.5	1423	7.9	137	269	74	76	0.2	1471	7.8	13	104	16	78	0	1441	37	65	96	91	61	95	76	92	100
D-24/6/91	31949	3.3	7.3	133	310	208	57	3.5	1134	7.5	137	168	64	2.5	1133	7.6	104	212	64	81	0.2	1143	7.6	6	90	12	83	0	1226	24	62	92	94	58	96	71	94	100
D-25/6/91	35195	3.2	7.6	134	404	190	58	5.5	1305	7.7	207	212	59	5.5	1341	7.8	109	325	64	81	0.2	1286	7.6	17	95	26	73	0	1190	47	70	97	84	71	87	77	86	100
D-26/6/91	34886	0.9	7.6	178	310	198	67	5.5	1560	7.7	156	178	66	3	1549	7.7	100	248	74	89	0.1	1590	7.7	13	62	22	82	0	1635	36	58	97	87	75	93	80	89	100
D-27/6/91	33708	0.5	7.8	171	380	164	83	4.5	1565	7.8	216	190	80	4.5	1589	7.8	119	279	52	100	0.1	1571	7.7	12	74	13	83	0	1560	45	73	98	90	74	93	81	92	100
D-28/6/91	32253	1.9	7.7	140	380	178	65	4.5	1668	7.7	147	182	68	3.5	1789	7.8	110	272	66	85	0.2	1898	7.8	15	92	22	77	0	1883	25	64	96	86	66	89	76	88	100
D-30/6/91	29793	2.4	7.6	137	372	170	72	4	1704	7.7	143	172	63	3.3	1616	7.7	100	290	76	82	0.5	1705	7.8	10	78	10	100	0	1817	30	56	85	90	73	93	79	94	100
D-1/10/91	32208	0.5	7.6	145	258	194	59	2.5	985	7.6	161	204	56	2.8	991	7.7	94	196	82	71	0.2	1050	7.8	19	55	20	88	0	1124	42	60	93	80	72	87	79	90	100
D-2/10/91	33649	1.4	7.5	147	351	230	47	3.5	1395	7.7	169	264	48	4.2	1390	7.8	99	253	86	77	0.3	1160	7.8	24	89	17	85	0	1068	41	67	93	76	65	84	79	93	100
D-3/10/91	34536	0.5	7.6	133	316	188	62	2.5	1273	7.5	219	218	60	3.5	1322	7.6	69	264	92	72	0.2	1373	7.7	20	104	22	76	0	1371	69	58	94	71	61	85	67	88	100
D-4/10/91	33178	1.4	7.6	155	392	182	65	4.5	1198	7.7	197	180	67	4	1264	7.8	34	356	78	80	0.4	1245	7.8	12	68	15	72	0	1248	40	57	90	65	81	92	83	92	100
D-5/10/91	33695	1.1	7.3	133	520	196	85	3.3	1258	7.6	155	128	80	3	1251	7.7	87	194	90	75	0.2	1130	7.8	16	44	19	81	0	1165	44	60	93	82	77	88	92	91	100
D-6/10/91	30442	4.5	7.8	152	318	204	56	3.5	1615	7.9	135	236	57	4.5	1595	7.9	103	198	74	76	0.3	1630	7.9	13	62	13	86	0	1534	24	69	93	87	69	91	81	94	100
D-8/10/91	29448	3	7.6	115	272	266	38	2.5	1418	7.7	117	290	40	3.5	1385	7.7	75	248	84	69	0.2	1446	7.6	18	52	18	69	0	1498	36	71	96	76	79	84	81	93	99
D-9/10/91	33623	0.5	7.8	135	366	240	49	4.5	1344	7.7	149	354	46	7	1274	7.7	112	220	110	60	0.2	1182	7.8	29	84	23	82	0	1144	25	69	97	74	62	79	77	90	100
D-11/10/91	30927	0.4	7.8	184	424	366	52	6.5	1365	7.7	167	304	51	6	1384	7.8	75	212	88	73	0.2	1353	7.7	13	64	15	80	0	1374	55	71	97	83	70	93	85	96	100
D-12/10/91	34823	0.3	7.9	170	332	226	65	5.4	1219	7.9	163	272	59	5.5	1223	7.9	94	192	78	77	0.2	1134	7.8	21	24	18	83	0	1105	42	71	96	78	88	88	93	92	100
D-13/10/91	34018	0.9	7.6	153	464	274	56	5.5	1149	7.7	142	284	54	6	1165	7.7	82	228	74	76	0.2	1157	7.7	21	92	18	82	0.1	1180	42	74	97	74	60	86	80	93	98
D-15/10/91	42876	0.2	7.8	133	349	310	48	6.5	875	7.8	128	356	41	6	870	7.8	67	172	64	78	0.2	887	7.8	16	55	19	78	0	976	48	82	98	76	68	88	84	94	100
D-16/10/91	34820	0.3	8.1	185	439	256	56	7.5	2210	7.9	180	316	53	7	2070	7.9	121	247	102	73	0.3	1770	7.8	33	47	21	80	0	1539	33	68	96	73	81	82	89	92	100
D-17/10/91	31780	0.1	7.7	175	457	262	60	4.5	1700	7.7	197	356	60	7.5	1698	7.8	119	251	98	82	0.3	1659	7.8	25	64	24	88	0.1	1631	40	73	96	85	75	86	86	91	98
D-18/10/91	33370	0.1	7.8	223	511	202	63	4.7	1473	7.8	228	276	59	5.5	1584	7.7	122	273	86	72	0.2	1510	7.8	22	81	22	82	0	1504	47	69	96	82	70	90	84	89	100
D-19/10/91	34408	0.3	8	174	442	268	58	5.7	1306	7.9	180	302	64	7.2	1316	7.9	121	275	96	71	0.4	1219	7.9	20	54	18	78	0	1241	33	68	94	84	80	89	88	93	100
D-20/10/91	32720	1.6	7.8	235	489	252	65	4.5	2110	7.8	244	268	64	5	2100	7.9	135	303	88	68	0.2	2120	7.9	27	140	24	71	0.2	2080	45	67	96	80	54	89	71	91	96
D-22/10/91	28707	0.4	7.8	117	296	142	72	3	1494	7.8	108	158	67	3	1516	7.8	96	250	68	91	0.2	1564	7.8	23	77	19	80	0.1	1680	11	57	93	76	69	80	74	87	97
D-23/10/91	36182	1.5	7.7	195	380	216	67	4.5	1542	7.8	170	240	67	3.5	1311	7.8	119	238	82	81	0.2	1443	7.9	37	100	18	89	0.1	1365	30	66	94	69	58	81	74	92	99
D-24/10/91	34364	1.2	7.9	191	400	184	74	6.5	1384	7.8	192	164	67	5	1461	7.8	114	274	66	97	0.4	1480	7.8	12	84	15	93	0.1	1463	41	60	92	90	70	94	79	92	99
D-25/10/91	35400	0.7	7.6	156	364	194	64	5.5	1680	7.6	169	222	56	5	1637	7.6	89	274	86	61	0.3	1537	7.7	21	64	18	78	0	1840	47	61	94	76	70	87	82	91	100
D-26/10/91	30964	3.3	7.7	220	540	184	62	3.5	1445	7.7	197	140	59	3	1414	7.6	119	207	86	81	0.2	1428	7.9	16	27	15	71	0.2	1337	40	39	93	85	87	93	95	92	96
D-27/10/91	35573	7.3	7.6	176	333	178	64	3.5	1627	7.7	170	178	67	3	1684	7.6	119	247	106	77	0.2	1720	7.6	16	67	23	80	0.1	1799	40	40	95	85	73	91	80	91	99
D-29/10/91	29801	1.6	7.7	172	400	136	70	1.5	1402	7.7	182	178	65	2.5	1417	7.8	123	263	106	70	0.3	1421	7.7	15	59	22	82	0.1	1468	32	40	88	88	78	91	85	84	97
D-30/10/91	31524	1.6	7.9	183	478	204	65	6	1798	7.9	197	214	66	7.2	1814	7.9	119	365	120	70	2.5	1713	7.8	18	90	21	86	0.1	1568	40	44	65	85	75	90	81	90	99
D-1/8/91	29834	3	7.4	160	348	194	62	3	1720	7.5	148	172	65	2.5	1729	7.6	105	265	80	83	0.2	1780	7.7	15	95	28	77	0	1772	29	54	92	86	64	91	73	86	99
D-2/8/91	28492	2.6	7.5	124	281	172	66	3	1520	7.5	117	172	65	2	1479	7.6	77	221	90	69	0	1535	7.8	12	75	20	86	0	1549	34	48	99	84	66	90	73	88	99
D-4/8/91	24978	0.5	7.3	146	288	124	68	2	1210	7.4	145	109	69	1.3	1164	7.4	81	200	52	67	0.1	1202	7.5	20	84	29	83	0	1259	40	52	92	75	70	86	79	77	99
D-5/8/91	29719	0.2	7.6	133	284	186	71	5	1114	7.6	136	194	68	2.5	1095	7.6	61	160	52	94	0.1	1076	7.8	11	60	21	91	0	1100	55	73	96	82	63	92	79	89	100
D-6/8/91	29741	0.5	7.9	151	316	196	64	2.5	948	7.8	163	200	69	3	904	7.9	90	220	71	82	0.2	929	8	16	44	22	86	0	951	45	65	95	82	80	89	86	89	100
D-7/8/91	29027	0.4	7.6	136	328	186	68	3	899	7.6	132	170	72	2.5	921	7.6	73	192	61	84	0.2	872	7.8	11	76	23	77	0	898	40	64	94	85	60	92	77	88	99
D-8/8/91	30211	0.5	7.6	114	521	506	44	7.5	866	7.5	113	498	44	8	882	7.6	58	137	65	79	0.1	880	7.9	11	44	20	78	0	884	49	87	99	81	68	90	92	96	100
D-9/8/91	30848	0.2	7.7	142	376	144	71	3	940	7.6	129	164	70	7.5	918	7.6	119	255	86	79	0.2	933	7.8	9	57	14	83	0	947	40	48	97	85	78	94	85	90	99
D-11/8/91	17527	0.6	7.5	150	171	172	37	1.4	732	7.5	113	220	38	1	731	7.5	42	113	49	67	0.1	691	7.6	11	39	16	85	0	728	63	78	90	74	66	93	77	91	99
D-12/8/91	33331	0.2	7.6	92	233	234	38	1.4	829	7.6	103	172	57	1.5	852	7.6	65	167	97	59	0.2	879	7.7	8	47	18	78	0	929	37	44	87	88	72	91	80	92	99
D-13/8/91	27998	0.6	7.5	138	268	154	66	1.7	890	7.5	105	166	64	1.5	880	7.7	65	157	97	65	0.2	827	7.8	8	33	13	85	0	858	38	42	87	88	79	94	88	92	99
D-14/8/91	32845	0.2	7.6	84	251	98	71	2	866	7.6	110	104	67	1.5	877	7.6	54	161	66	70	0.3	840	7.6	7	49	17	87	0	879	51	37	80	87	70	92	81	83	99
D-16/8/91	27933	0.2	7.6	158	375	178	61	3.5	1049	7.7	153	168	60	3	992	7.7	49	177	56	71	0.1	910	7.9	9	103	30	64	0.1	828	68	67	97	82	42	94	73	83	99
D-18/8/91	27527	0.2	7.3	191	240	166	74	3	1072	7.4	130	156	76	2.5	1023	7.4	80	274	71	78	0.3	990	7.5	8	44	11	100	0	999	39	55	88	90	70	96	82	93	99
D-19/8/91	32363	0.1	7.6	159	310	146	69	1.6	1096	7.6	131	166	71	1.7	1083	7.7	98	169	64	84	0.2	1112	7.9	21	59	16	70	0	1083	25	61	91	79	65	87	81	89	99
D-20/8/91	31437	0.5	7.6	132	304	148	65	2	939	7.7	147	156	62	1.8	974	7.8	80	155	62	77	0.1	1008	7.9	14	42	13	83	0	1012	46	60	94	83	73	89	86	91	100
D-21/8/91	31914	2	7.7	127	274	144	72	2	1031	7.6	124	162	69	3	1048	7.6	80	157	69	83	0.2	1020	7.8	9	35	16	83	0	1053	40	60	93	85	78	90	79	91	100
D-22/8/91	28088	0.2	7.5	153	307	124	82	2.5	1044	7.6	163	136	71	2.5	1039	7.7	97	188	62	92	0.2	1045	7.9	10	46	12	90	0	1038	41	54	94	90	76	94	85	90	100
D-23/8/91	27838	0.1	7.6	179	265	128	72	1.8	992	7.6	102	120	85	2	1012	7.7	88	188	66	85	0.1	1036	7.9	11	54	14	83	0	1044	14	45	95	88	71	94	80	89	100
D-25/8/91	29271	0.4	7.5	99	585	140	71	4.5	962	7.6	103	194	62	4.5	966	7.6	61	129	55	84	0.3	993	7.7	25	95	26	77	0	968	41	72	93	59	26	75	84	81	100
D-26/8/91	32723	0.2	7.7	93	252	176	57	2.3	894	7.7	108	146	66	3	873	7.7	63	224	55	78	0.2	915	7.9	19	54	6	100	0	942	40	62	93	70	76	80	79	97	100
D-27/8/91	33535	0.3	7.8	192	346	172	69	4	988	7.8	210	192	69	4.5	991	7.7	100	215	80	74	0.1	966	7.9	17	88	16	90	0	950	40	58	98	83	59	91	75	91	100
D-28/8/91	32922	0.3	7.4	139	367	180	64	3	1060	7.5	163	200	63	3.5	1040	7.6	105	250	70	86	0.1	1152	7.7	25	84	20	84	0	1136	40	65	97	76	66	82	77	89	99

D-29/8/91	32190	0.3	7.3	200	545	258	65	4	1260	7.4	191	226	67	3.5	1198	7.5	115	244	77	77	0.1	1351	7.7	21	71	27	71	0	1326	40	66	97	82	71	90	87	90	100
D-30/8/91	30488	0.2	7.5	152	300	132	70	4.5	1073	7.4	150	210	60	4.5	1081	7.4	93	233	64	84	0.3	1188	7.3	17	55	18	80	0	1224	40	70	93	82	76	90	82	86	100