UNIVERSITI PUTRA MALAYSIA

EXPERT SYSTEM
FOR
PREDICTING CADMIUM POLLUTION

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By
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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering
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Dedicated to,

My beloved parents, Mr. and Mrs. Vengidason

brother, Mr. V. Seguprakash

and

Mr. P. Shashi Kumar

For their love and support ……………..

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EXPERT SYSTEM FOR PREDICTING CADMIUM POLLUTION

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Chairman: Dr. Ir. Mohamed Daud

Faculty: Engineering

Expert System for predicting cadmium (Cd) pollution was developed using Visual Basic incorporated with CLIPS. The information was obtained from a primary data to develop this expert system. Sediment was used as an indicator of Cd pollution because of it's permanency compared to water itself and reported to be the sink for trace metals. The data obtained showed that in the dry season there was a significant change in the concentration of Cd. The Cd concentration increased from before the source to after the source of pollution. In the wet or semi-wet seasons, the overall Cd concentration reduced because the washout effect caused by the increase in the quantity of river water. As a result, the concentration of Cd before, at and after the source of pollution became about the same for the wet and the semi-wet seasons. This two points were used as a guide to come up with a theory to structure and develop the expert system. The user of the expert system is required to key in the before and after the source of pollution data and the Cd concentration in the water data, so that the system

could process these data and predict the present and future level of heavy metal (Cd) pollution. The prediction and information provided in the system enabled user to produce a good EIA report on Cd pollution in the aquatic environment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

SISTEM PAKAR UNTUK MERAMAL PENCEMARAN CADMIUM

Oleh

YOGAVAENI VENGIDASON

Februari 1998

Pengerusi: **Dr. Mohamed Daud**

Fakulti: **Kejuruteraan**

Sistem Pakar untuk meramal pencemaran Cadmium (Cd) telah diusahakan dengan menggunakan Perisian 'Visual Basic' dan CLIPS. Maklumat yang diperolehi daripada data primer telah digunakan untuk membina sistem pakar tersebut. Sedimen telah digunakan sebagai alat untuk mengukur pencemaran Cd kerana ia wujud secara lebih stabil jika dibandingkan dengan air sungai itu sendiri. Data yang diperolehi menunjukkan bahawa pada musim kering kepekatan Cd menunjukkan perubahan yang lebih jelas. Kepekatan Cd semakin bertambah dari sebelum ke selepas punca pencemaran. Pada musim tengkujuh mahupun musim hujan, kepekatan Cd secara keseluruhannya berkurangan disebabkan oleh kesan pencairan. Kepekatan Cd sebelum, pada dan selepas punca pencemaran didapati lebih kurang sama pada musim tengkujuh dan hujan. Kedua-dua fakta ini digunakan sebagai asas untuk menghasilkan teori yang digunakan dalam sistem pakar ini. Pengguna sistem pakar ini dikehendaki memasukkan

nilai-nilai Cd, sebelum, dan selepas punca pencemaran dan juga nilai Cd dalam air, supaya sistem ini dapat memproses data tersebut dan meramal tahap pencemaran Cd. Ramalan dan maklumat yang diberikan oleh sistem pakar ini membantu para pengguna membuat satu laporan EIA yang baik.

CHAPTER 1

INTRODUCTION

The last decade has seen a period of rapid industrial development all over the world. Malaysia is no exception. With human advancement, industrial wastes, domestic wastes and pollutants from transportation have become an increasingly important problem to consider in the control and maintenance of the environment.

One of the most important environmental problems is the pollution caused by heavy metals in the aquatic environment. Heavy metals are biologically non-degradable and through food chain, it might finally pass on to man. Heavy metals are regarded as potential pollutants in the aquatic ecosystems because of their adsorption in bottom sediments even at low concentrations, environmental persistence, their toxicity at low concentration, their ability to be incorporated into food chain, and concentrate in aquatic organisms (Negilski 1976). Heavy metal accumulation in sediments is postulated to be carried by sorption processes (e.g. adsorption, absorption, co-precipitation) with various geochemical phases, such as, hydrous metal oxides, clays and organic matter.

Modern research on particle-bound contaminants, for instance, heavy metals presumably originated with the idea that sediments reflect the biological, chemical and physical conditions of a waterbody (Zullig,1956). Sediments influence the current quality of the water systems and preserve the historical development of certain hydrological and pollution conditions. Contaminated sediments have come to be recognized as a significant problem contributing to degradation of environmental quality. Sediment analysis is used to estimate point sources of trace metals that upon being discharged to surface waters do not remain in solution but are rapidly adsorbed by particulate matter, thereby escaping detection by water monitoring. Thus, sediment data play an increasing role within the framework of environmental forensic investigations (Meiggs,1980), where short term or past pollution events are not detected from the water analysis.

Urban heavy metal pollutants, for example, Cadmium (Cd), originates from domestic wastes, including sewage and all substances got rid of by the inhabitants in a town. A main drain contains the wastes produced by the everyday life of the population: excrement, food leavings, discharges from hospitals or clinics and slaughterhouses, but also cleansing preparations, detergents, pesticides, toxic substances used in the households.

In vehicles, the mineral content of the fuel (petrol) is converted into an ash composed of mixed oxides. The more volatile materials, such as, oxides of lead, cd, mercury, and the radium and polycyclic aromatic hydrocarbons will be released as vapours, but will condense as, or on, fine particulates in the exhaust pipe and could be transferred to the environment.

Most fuel oils have some Cd traces in the inherent makeup. The traces are greater in the residuals than the distillates. The main problem is not with the oil itself, but with the slag that is forming in the boiler firebox which had measurable concentrations of Cd. This Cd is released into the air and gets into the water body.

However, heavy metal originates largely from metallurgical operations, non-metallic mineral production industries, inorganic chemical manufacturing, and the lead used in gasoline.

Problem Statement

The rapid development in our country has caused serious pollution to the aquatic environment. One of the pollutants which is considered to cause serious harm to organisms and human beings are heavy metals. Cd is an example of heavy metals that is proven to cause serious problems to the organisms on earth. At the moment there is no data to describe existing Cd level and to predict the future concentration of Cd in the river. So, a study has to be done to highlight the possibility of serious pollution that might have been caused by the three main sources of pollution - residential, transportation and industrial.

As sediment influences the quality of the water systems, it will be used as a tool for reporting the status of heavy metal pollution in the river system. Since the monitoring work is expensive and time consuming, an expert system will be developed to predict Cd pollution in the environment.

Objectives of Study

The objectives of this study are:

1. To demonstrate that measurement of Cd in sediment can be used as an indicator to monitor Cd pollution;

2. To produce an expert system that could be used to describe existing Cd and to predict the future level; and
3. To study the possibility of using results of Cd level in sediment as expert system rules to describe Cd level in order to reduce the effect of variations of Cd concentration in water due to variation in the rate of flow in a stream.

CHAPTER II

LITERATURE REVIEW

Cadmium Pollution

Surveillance of concentrations of heavy metals in the environment is of global interest since Cadmium (Cd) is listed as environmentally dangerous chemical substance. Estimates on the world river transport of heavy metals to oceans indicate that bulk of the metal transport in the river takes place in the particulate form (Gibbs, 1977; Martin and Meybeck, 1979; Martin and Whitfield, 1981). It is well documented that the concentrations of heavy metals in aquatic sediments are much higher than those in the water column (Forstner, 1976; Forstner & Muller, 1976).

What Is Cd

Cadmium is one of the harmful heavy metals that is found in the aquatic environment. It is a wide-spread environmental contaminant attaining considerable scientific interest and concern. Cadmium (atomic number 48; relative atomic mass 112.40) is a metallic element belonging to group IIb of the periodic table. Cadmium is a soft ductile metal, melting at 321^0C. Its usual valence is +2.

Cd is a white heavy metal, but is also found as salts or Cd oxide. Cd is very toxic to aquatic organisms, and is blacklisted in the Paris and Oslo Conventions (1978). Lethal dose is approximately 30 - 40 mg. Cd accumulates in food chains. The major emission sources now are devices for corrosive protection on offshore structures and ships.

Cd has been acknowledged as one of the most hazardous environmental pollutants. It has been hypothesized that Cd may be mobilized by human and industrial activities in amounts that rival, or exceed, the natural circulation of these elements (Simpson, 1981; Yeats and Bewers, 1983). Cd is one of the metals most commonly given special status in environmental management and regulation, largely for historical reasons associated with the incidence of Itai-itai disease in Japan.

Cd has been described as "the dissipated element" (Fulkerson and Goeller, 1973), and indeed, the element has been widely mobilized by both natural and anthropogenic processes. Natural processes, include aeolian transport of weathered rock particles, forest fires, volcanic emissions, transpiration and also possibly volatilization of Cd from soils. Anthropogenic sources include emission from vehicles, factories and urban pollutants.

Sources and Utilization Of Cd

Sources of Cd pollution mainly originates from untreated effluents that flow into the aquatic environment. Cd contamination in the terrestrial and aquatic environments has been a great concern since biological accumulation may cycle Cd into the food chain and cause a serious toxicity problems. Cd, when discharged from industrial and other sources, becomes associated with the sediment solids at the bottom of the waterways. Mechanisms that may be responsible for the retention of Cd in the solid phase are precipitation of Cd as carbonates, hydroxides and sulfides, complexation with insoluble organic material and incorporation of Cd with clay minerals.

Discharges from the electroplating battery (McCaull 1971), television tube manufacturing and aircraft industries (Lieber and Welsch 1954) have greatly augmented levels of Cd in natural waterways. Cd is found as greenockite(CdS), but it is produced commercially as a by-product of other metals (zinc, lead and copper) from sulfide ores (NIOSH 1976; Stokinger,1981)

Some compounds (especially CdS and CdSeS) are used in pigments, primarily for plastics, and as plastic heat stabilizers. A number of alloys are used for soldering, brazing, electrical contacts and for other purposes. Cd is used in Ni-Cd batteries, fungicides and other minor uses. Cd is also found in paints, enamel and fertilizers.

Cadmium plating is common inorganic corrosion preventive coating. Cadmium plating is frequently used for fasteners and other very tight tolerance parts because of the dual qualities of lubricity at minimal thickness and superior sacrificial corrosion protection.

Cadmium originates mostly from the manufacture of Cd-containing articles, followed by phosphate fertilizer manufacturing and zinc production. Various national estimates are that the per capita consumption of Cd varies from17 to 64 µg/day (USEPA 1980).

Mitigating Measures to Reduce the Sources of Cd

The toxicity of Cd and its effect to the organisms have made mitigating measures necessary to be carried out. One of the methods is to minimise the source of pollution by replacing the usage of the metal. Replacements for Cd will require similar mechanical and performance properties over the full spectrum of the applications for which they are currently used. Some of the methods that could be done are explained below:

Electroplating Waste Reduction

One of the industries that uses Cd in electroplating is the aircraft industry. There is a need to replace hazardous plating processes (cadmium) currently used on Naval aircraft, weapons platforms and ground support equipment. The Clean Air Act, as well

EPA and State Departments of Environmental Resources regulations, restricted the Cd emission from these processes.

One alternative to Cd plating is aluminum-manganese electroplating from a molten salt bath. This process differs from the traditional aqueous electrolytic plating bath. The best aluminum-manganese (Al-Mn) concentrations for naval aircraft use will be isolated through a test program, which examines the varied choices of Al-Mn systems on test coupons of various materials and sizes. This bath formulation will then be established as a full-size prototype at a selected Naval Aviation Depot (NADEP). Following full-scale tests Al-Mn will be transitioned to the fleet through specification modification and design changes. In addition, ion vapor deposited (IVD) aluminum is an another demonstrated alternative for certain applications that will be pursued for navy use. Other alternatives to hexavalent chrome plating and Cd plating include:

1. electroless nickel plating,
2. hard chrome plating,
3. tin-zinc plating,
4. zinc-nickel plating.