UNIVERSITI PUTRA MALAYSIA

RECOVERY OF HEAVY METALS FROM ELETROPLATING RINSE WASTEWATER BY REVERSE OSMOSIS

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RECOVERY OF HEAVY METALS FROM ELETROPLATING RINSE WASTEWATER BY REVERSE OSMOSIS

BY

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LIST OF ABBREVIATIONS

b	Channel height
B_1	Water permeation coefficient
B_2	Solute flux coefficient
C	Solute Concentration
c_i	Molar concentration of the solute
D	Diffusion coefficient of solute
d_t	Channel diameter
J	Permeate flux
J_s	Solute flux
k_s	Mass transfer coefficient
L	Channel length
$\sum \overline{mi}$	Summation of molalities of all ionic and nonionic constituents
P	Pressure
ΔP	Pressure drop (Crossflow Pressure)
ΔP_T	Average inlet and outlet pressure
ΔP_{TM}	Transmembrane pressure
Q_f	Feed rate
Q_p	Permeate rate
R	Gas constant
$\Re$	Rejection coefficient
R_b	Boundary layer resistance
R_s	Solute deposited resistance
R_m	Membrane resistance
T	Absolute temperature
T'	Temperature
v_i	Number of ions formed if the solute dissociates
v_s	Bulk velocity
Y	Recovery
$\dot{Y}$	Shear rate
π	Osmotic pressure
$\Delta\pi$	Osmotic pressure drop
α	Osmotic pressure coefficient
μ	Viscosity
$\varnothing$	Sieving coefficient
δ	Thickness of boundary layer

DOE	Department of Environment
SIRIM	Standards and Industrial Research Institute of Malaysia

Subscripts

b	Bulk or feed
i	Inlet
m	Membrane surface
o	Outlet
p	Permeate or filtrate

Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in partial fulfilment of the requirements for the degree of Master of Science.

RECOVERY OF HEAVY METALS FROM ELECTROPLATING RINSE WASTEWATER BY REVERSE OSMOSIS

By

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December 1996

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Faculty : Faculty of Engineering

Electroplating rinse wastewater contains a number of toxic metals which are harmful to receiving waters. The Tubular B1 Module (PCI Membrane Systems) with AFC 99 polyamide membrane was used to treat the aluminium anodizing rinse water at different feedwater concentrations and different transmembrane pressures. Permeate flux was found to be directly proportional to transmembrane pressure and indirectly proportional to natural logarithms of feedwater concentrations. Aluminium concentration was reduced from 747.1 mg/l to 2.

rejection at 65 bar transmembrane pressure and 40 °C feedwater temperature.

Overall conductivity rejection was in excess of 98% at 65 bar. Rejection efficiency was increased with increasing transmembrane pressure. However, permeate quality deteriorated with increasing feedwater concentrations. High production rate was recorded with 3.3 $m^3/m^2.d$ at 7% recovery and 65 bar transmembrane pressure with a feedwater concentration of approximately 9,500 mg/l TDS (Total Dissolved Solids). Reverse osmosis permeate is suitable for reuse as rinse water in the factory. No membrane fouling was encountered during the study. Reverse osmosis was found to be an effective alternative for recovery of rinse water and heavy metals from the waste effluent compared to other conventional treatment technologies.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia untuk memenuhi sebahagian daripada syarat untuk mendapat Ijazah Master Sains.

PEMULIHAN LOGAM BERAT DARIPADA AIR SISA PENYADURAN ELEKTRIK OLEH OSMOSIS BALIKAN

Oleh

SEE BOON YAN
Desember 1996

Pengerusi : Dr. Fakhru'l-Razi Ahmadun

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Air sisa bilasan daripada penyaduran elektrik mengandungi sejumlah logam toksik yang merbahaya kepada sumber air. "Tubular B1 Module" (PCI Membrane Systems) dengan menggunakan selaput AFC 99 Poliamida telah digunakan untuk merawat air bilasan penganodan aluminium pada kepekatan air suapan dan tekanan perantaraan selaput yang berlainan. Aliran air rawatan didapati berkadar terus kepada tekanan perantaraan selaput dan berkadar songsang kepada log jati kepekatan air suapan. Kepekatan aluminium telah dapat dikurangkan daripada 747.1 mg/l kepada 2.81 mg/l dengan 99.6% penolakan pada 65 bar tekanan perantaraan selaput dan suhu air suapan pada 40°C. Penolakan konduktiviti keseluruhannya

melebihi 98% bagi tekanan perantaraan selaput 65 bar. Kecekapan penolakan meningkat dengan pertambahan tekanan perantaraan selaput. Kualiti air rawatan menjadi buruk dengan peningkatan kepekatan air suapan. Kadar pengeluaran adalah tinggi dengan mencatat 3.3 $m^3/m^2.d$ pada keadaan 7% pemulihan, 65 bar tekanan perantaraan selaput dan kepekatan air suapan lebih kurang 9,500 mg/l TDS (Jumlah Pelarutan Pejal). Air rawatan osmosis balikan adalah sesuai digunakan semula sebagai air bilasan di dalam kilang. Kerosakan selaput tidak berlaku semasa penyelidikan. Osmosis balikan merupakan satu alternatif yang berkesan daripada teknologi rawatan konvensyenal yang lain untuk penggunaan semula air dan logam berat daripada sisa efluen.

CHAPTER I

INTRODUCTION

Nowadays, society is getting more conscious and well informed of environmental problems. Environmental issues such as the green house effect, acid rain, the destruction of tropical rain forest, depletion of ozone layer and discharged of toxic heavy metals from industries into natural stream have become the main topics for discussion in many international conferences and workshops by politicians, scientists and environmental organizations in recent years. The Malaysian government has launched several environmental documentary programmes and educational campaigns through the mass media to inform and educate the public regarding the hazards of improper disposal of industrial wastes.

Industrial wastewater is the main source of heavy metals contamination in the natural environment (Department of Environment, 1993). Heavy metals are considered to be potential hazards to both the public health and natural wild life as they cause physiological and neurological disorders. In Malaysia, surveys carried out by the Department of Environment had shown that the metal finishing industry was on top of the list that generated toxic and hazardous wastes (DOE, 1985 and 1987). Metal finishing wastewater is extremely heterogeneous and dangerous because it contains high concentration of toxic metals such as cadmium, chromium, copper, zinc, nickel, etc. These metals have the potential to cause mutagenicity to humans.

Metal finishing operations generally consist of cleaning, surface treatment, electroplating, rinsing and fume or exhaust scrubbing. Each of these operations produces one or more toxic heavy metals in their waste effluent. In Malaysia, two-thirds of all metal effluents are discharged by the metal finishing industries (DOE, 1993). More than 57% of these metal finishing industries did not comply with the Environmental Quality (Sewage and Industrial Effluents) Regulations of 1979 (DOE, 1993). Small and medium scale industries contributed about 25% of the total metal waste effluent and these industries normally discharged the wastewater containing heavy metals directly into the municipal sewer without proper treatment. The main reasons for non-compliance especially in the electroplating industry were the lack of proper and efficient treatment systems. Some factories had ignored the necessity of setting up treatment facilities when the companies were established. During the process, a lot of water has been used as rinsing water. This rinsing water contained low concentrations of heavy metals compared to plating bath but rinsing water was discharged in large volume. Therefore, a huge volume of toxic metals was discharged and polluted the natural environment without proper treatment.

Electroplating industry contributed the majority of all metal effluents and almost 50% of this industry does not have efficient wastewater treatment facility. Therefore, a study on treating electroplating rinse wastewater was formulated. The study involved evaluating a membrane filtration process on heavy metals recovery from waste effluent.

The main objectives of this project were as follows:

1. To study the efficiency of heavy metals recovery from industrial waste effluent by reverse osmosis membrane filtration to facilitate reuse or disposal.
2. To conserve and recover water from waste effluent for reuse purposes.
3. To study the applicability of some membrane filtration models.

CHAPTER II

LITERATURE REVIEW

Heavy Metals Contamination in Malaysia

Metal finishing industry contributed the maximum volume of toxic and hazardous waste in Malaysia. Wastewater from this industry constitutes about two-thirds of all metal effluents. The majority of metal finishing industries in Malaysia do not exercise any pretreatment of waste effluents and discharge directly toxic wastes at concentrations far above the specifications of the Environmental Quality (Sewage and Industrial Effluents) Regulation of 1979 (Standards and Industrial Research Institute of Malaysia, 1991; Department of Environment, 1993; Rakmi and Salmijah, 1993). Only 42.5% of the metal finishing industries had complied with the Environmental Quality (Sewage and Industrial Effluents) Regulation of 1979 by the year 1993. Figure 9 (Appendix A) shows the compliance status of manufacturing industries with Environmental Quality Regulations of 1979.

In all metal finishing plants, the highest water consumption for electroplating processes is at the rinsing stage. At this stage, dissolved salts and particulates are flushed away from the plated articles. This will improve bonding of the next layer and prevent products from being discoloured and avoids contamination of succeeding baths.

In Malaysia, acid and alkaline wastes from small and medium scale metal finishing industries contribute about 25% of the total wastes effluent. Central treatment plants have been recommended to alleviate the economic constraints of the small scale operators in building their own waste treatment system. Physical and chemical processes have been recommended for the central treatment plant (Dames and Moore, 1988). The treatment fee is based on the type of wastes, for example acid and alkaline solutions with heavy metals contamination are charged at RM 27 per metric ton (Dames and Moore, 1988; Standards and Industrial Research Institute of Malaysia, 1991).

Conventional Treatment Technologies

The configuration of a conventional treatment process is relatively standard, that it consists generally of the following unit processes (Cushnie, 1985):

- Chromium reduction (if needed) of segregated chromium waste streams to reduce the chromium from its hexavalent form to trivalent state, which then can be precipitated as chromium hydroxide by alkali neutralization
- Cyanide oxidation (if needed) of segregated cyanide bearing waste streams to oxidize the toxic cyanides to harmless carbon and nitrogen compounds
- pH adjustment of the combined metal-bearing waste water and the effluent from the cyanide and chromium treatment systems to precipitate the dissolved heavy metal as metal hydroxides
- Clarification with flocculation/coagulation to promote the initial settling of the precipitated metal hydroxides