United States
Environmental Protection
Agency

Research and Development

Industrial Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/S2-83-061 Oct. 1983

EPA

Project Summary

Activated Carbon Process for the Treatment of Cadmium(II)-Containing Wastewaters

C. P. Huang

This study deals with the removal of cadmium(II) from two synthetic cadmium plating wastewaters, namely cadmium (II)-tetrafluoroborate and cadmium(II)-cyanide solutions, by activated carbon adsorption process. Among a total of 17 different types of commercial activated carbon tested, it was found that the acidic activated carbons, namely Nuchar SA and Nuchar SN exhibited the greatest cadmium(II) removal capacity.

In batch mode experiments, the effects of pH, carbon to cadmium(II) ratio, temperature, particle size, ionic strength and mixing rate on cadmium(II) removal were studied. A suspension-polymerization technique was used to prepare activated carbon beads from powdered carbon. The cadmium(II) adsorption characteristics of the activated carbon beads were studied and compared with the original powdered carbon. Chemical regeneration with strong acids of the used activated carbon was also investigated along with wet thermal-chemical process.

Continuous flow column packed with activated carbon beads was used to treat the cadmium(II)-tetrafluoroborate wastewater with successive adsorption-regeneration runs.

The costs of activated carbon adsorption systems, i.e., continuously mixed and packed column, were also estimated and compared with several other treatment processes including insoluble sulfide precipitation, alkaline neutralization precipitation and ion exchange processes.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

It has been estimated that more than 45% of all cadmium is used in electroplating, and that 10% of total industrial cadmium use ends up in wastewater streams. The removal of cadmium(II) from wastewater stream, therefore, is of great importance, especially in the protection of human health. Although precipitation is the method most commonly used, it has some definite drawbacks. The main disadvantage is the separation of chemical precipitates. Furthermore, the presence of organic and inorganic complex forming agents in wastewater always renders precipitation and other processes, such as ion exchange, ineffective. The major objective of this research project was to investigate the treatability of activated carbon adsoprtion process for cadmium(II)-containing wastewater.

Major factors affecting the extent of cadmium(II) removal by activated carbon adsorption process, such as pH, particle size, mixing rate, carbon types, carbon-to-cadmium ratio, ionic strength, and temperature were thoroughly studied. Both batch and column reactors were used in this study. Finally, an effort was made to estimate costs of activated carbon adsorption processes; i.e., completely mixed tank with carbon separation and column packed with activated carbon beads. A similar economical analysis was made for other treatment processes; namely, alkaline-neutralization precipitation, insoluble sulfide precipitation and ion exchange.

Conclusions

Among a total of 17 different types of commercial activated carbons tested, the acidic activated carbons such as Nuchar SA and Nuchar SN appear to be most effective adsorbents for cadmium(II) removal. Figure 1 exemplifies the effect of carbon type on cadmium(II) removal. An acidic activated carbon, generally, has a low pH of zero point of change, pH_{zpc}. The extent of cadmium(II) removal depends significantly on the pH value of the wastewater. For cadmium(II)-tetrafluoroborate wastewater, the amount of cadmium(II) removal increases with pH, reaches a plateau then remains constant. Chemical precipitation apparently takes place at high pH value, i.e., >9. For cadmium(II)-cyanide wastewater the extent of cadmium(II) removal peaks at pH 6. While cadmium(II) removal by chemical precipitation mechanism is inhibited by the presence of cyanide, it is noted that the presence of cyanide also depresses cadmium(II) removal due to formation of cadmium(II)-cyanide complexes which are not as adsorbable as the uncomplexed cadmium(II) ions.

Figure 2 shows the general adsorption characteristics of cadmium(II) from synthetic cadmium(II)-tetrafluoroborate wastewater as affected by pH and various cadmium concentrations; Figure 3 demonstrates the adsorption behavior of cadmium(II) from another synthetic wastewater, cadmium(II)-cyanide.

Other factors such as carbon-to-cadmium ratio, ionic strength, and temperature can also have an effect on cadmium(II) removal. Less than a critical carbon-to-cadmium ratio, increasing temperature, and ionic strength all depress cadmium(II) removal at various significant levels.

The rate of cadmium(II) removal by activated carbon adsorption reaction is very fast, reaching equilibrium adsorption in a few minutes of reaction time. Varying parameters such as pH, carbon dose, ionic strength and temperature do not affect the rate of cadmium(II) removal. Carbon type, i.e., powdered, granular or "beaded", appears to be the most influencing variable; powdered activated carbons attain adsorption equilibrium more rapidly than the other types of activated carbons.

Since protons compete favorably with cadmium(II) ions, particularly at low pH region, the cadmium(II)-laden activated carbon can be readily regenerated by strong acids such as sulfuric, hydrochloric and perchloric acids at ambient temperature. The rate of acid regeneration is moderately fast. However, the cadmium (II) adsorption capacity of regenerated activated carbon is somewhat decreased after several times of acid regeneration.

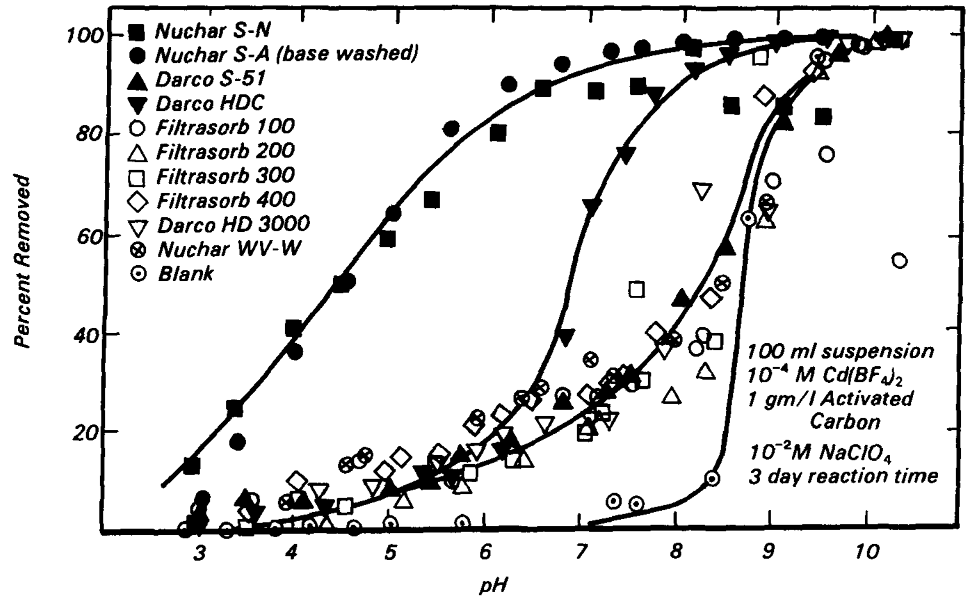

Figure 1. *Typical cadmium(II) removal capacity of different types of activated carbons as affected by pH.*

Pretreatment of the basic activated carbons, such as Filtrasorb 400 that has a pH_{zpc} of 7 by sodium methylate and carbon bisulfide, failed to improve the cadmium(II) removal capacity.

With the use of a suspension-polymerization technique, it is possible to make activated carbon beads from the powdered form. The beads, containing 70% by weight of powdered activated carbon and 30% by weight of polyvinyl alcohol and glutaraldehyde, have the same cadmium (II) adsorption capacity as the original powdered activated carbon. However, due to intraparticle diffusional resistance, the rate of cadmium(II) adsorption is slower than the original powdered carbon.

Two schemes may be proposed for the treatment of cadmium(II)-containing wastewaters, specifically cadmium(II)-tetrafluoroborate and cadmium(II)-cyanide: (1) completely mixed flow reactor (CMFR) and (2) column reactor (CR). In CMFR, powdered activated carbon is used; after adsorption reaction, the spent activated carbon can be separated then regenerated for reuse. In CR, activated carbon beads are used.

The annual costs for these two proposed treatment schemes and three other common processes; namely, alkaline neutralization precipitation (ANP), insoluble sulfide precipitation (ISP) and ion exchange were estimated. Both activated carbon adsorption processes appear economically comparable with ion exchange and alkaline neutralization precipitation methods. Figure 4 shows the estimated total annual cost for various cadmium treatment processes.

Recommendations

While the results obtained from laboratory experiments with synthetic wastewaters clearly demonstrate the technical and economical feasibility of activated carbon adsorption process for cadmium(II) removal, the chemical composition of actual wastewater may differ significantly from those synthesized in the laboratory. These differences in solution chemistry may alter the rate and the extent of cadmium(II) removal by this process. Therefore, it is necessary to fully characterize the chemical properties of each wastewater and to run separate laboratory experiments to identify the optimal treatment conditions.

In order to better analyze the costs associated with the activated carbon adsorption process, it is recommended that a full scale system be established in a small plant and operational parameters applied.

Although preliminary results show that powdered activated carbon may be applied directly without beading, it will still be beneficial to study the preparation of activated carbon beads in detail,

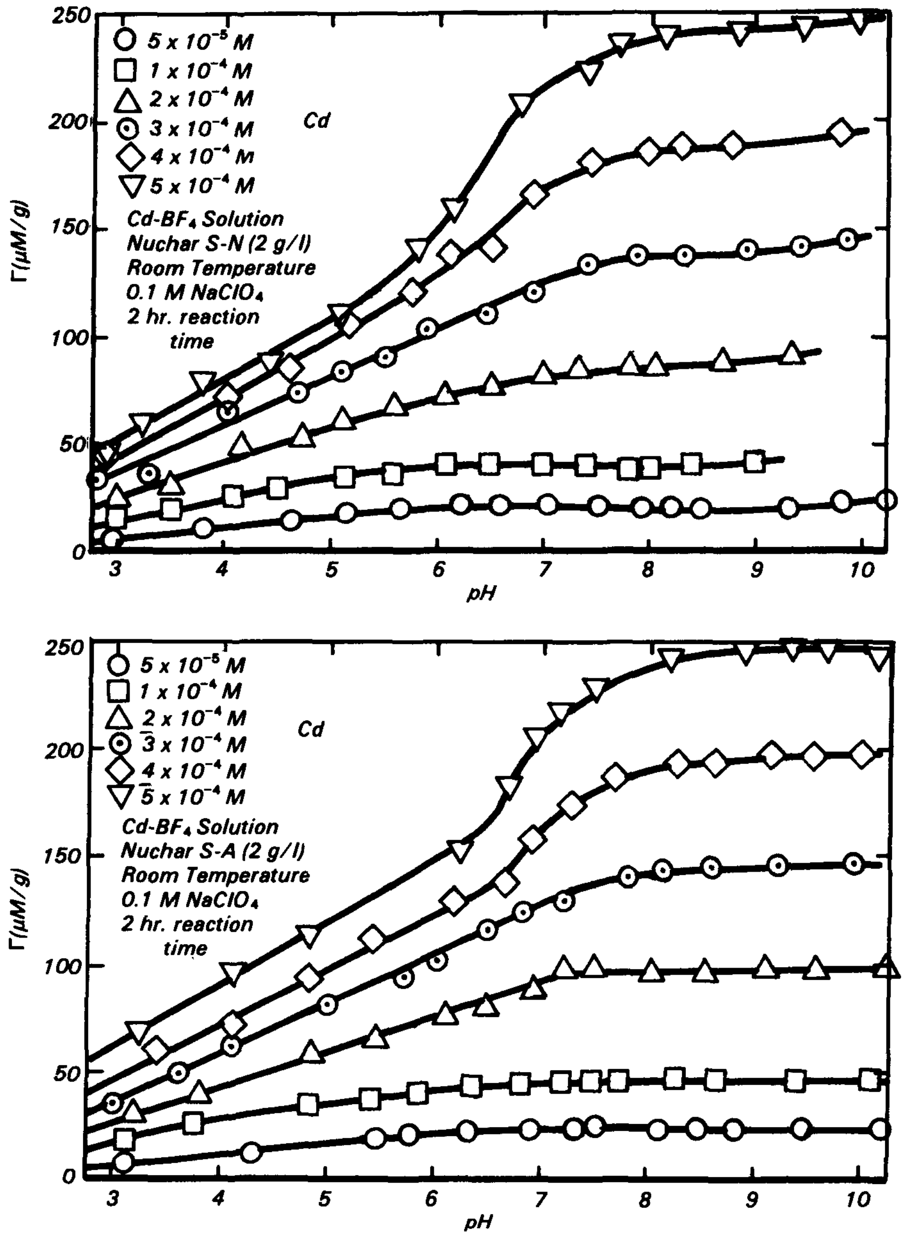

Figure 2. *The cadmium(II) removal characteristics of Nuchar SN (top) and Nuchar SA (bottom) from synthetic cadmium(II)-tetrafluoroborate wastewater.*

specifically, the optimal operational conditions and control parameters.

Further work should also be focused on the separation of powdered activated carbon from water phase and the effect of separation operation such as coagulation on the cadmium(II) retaining capacity of the activated carbon.

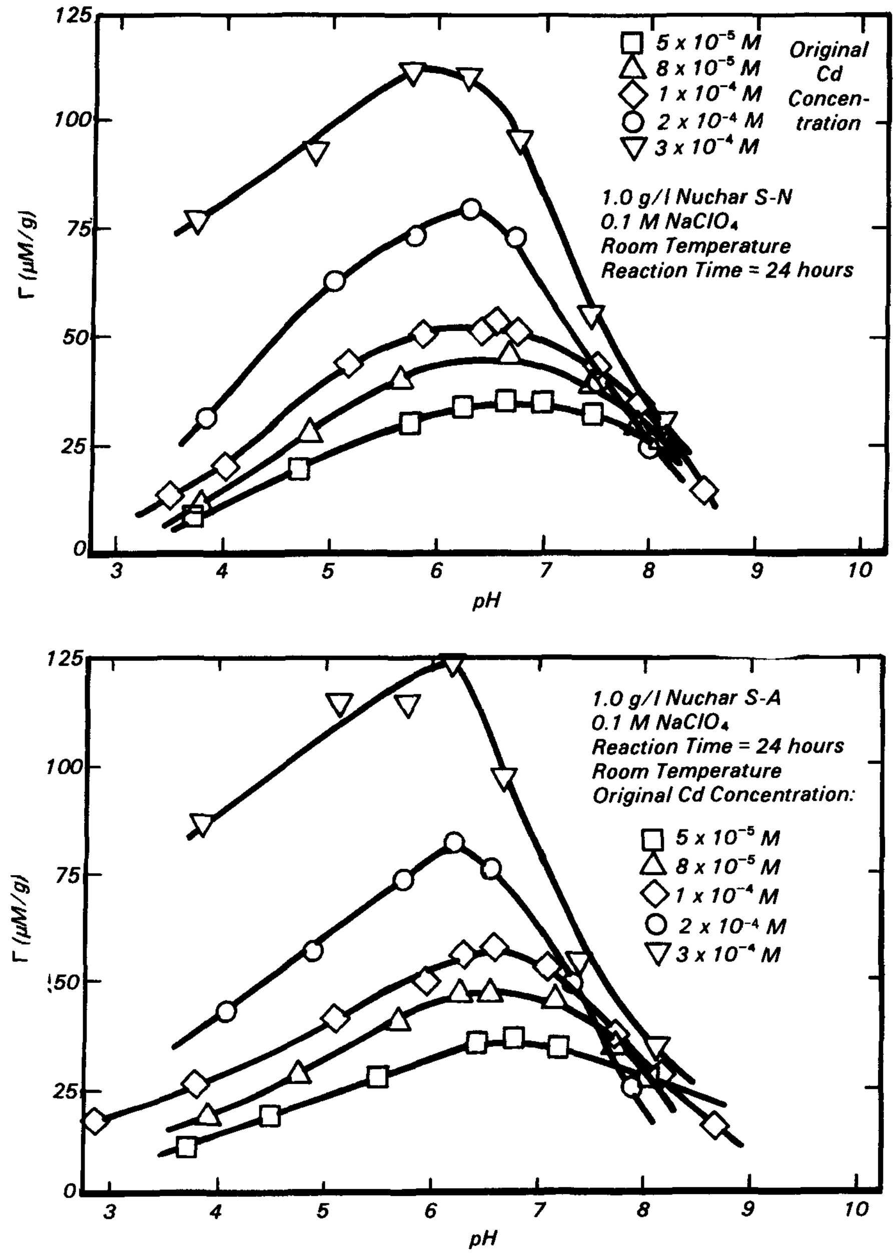

Figure 3. *The cadmium(II) removal characteristics of Nuchar SN (top) and Nuchar SA (bottom) from synthetic cadmium(II)-cyanide wastewater.*

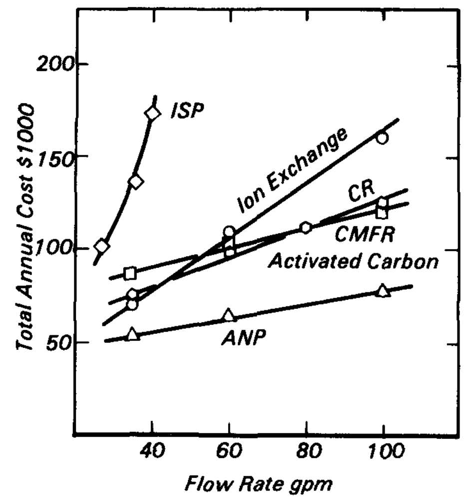

Figure 4. *Estimated total costs of various cadmium(II) treatment processes.*

C. P. Huang is with University of Delaware, Newark, DE 19711.
***Mary Stinson** is the EPA Project Officer (see below).*
The complete report, entitled "Activated Carbon Process for the Treatment of Cadmium(II)-Containing Wastewaters," (Order No. PB 83-247 155; Cost: $13.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

BULK RATE
U.S. POSTAGE
PAID
Cincinnati, Ohio
Permit No. G35

Official Business
Penalty for Private Use $300

U.S. GOVERNMENT PRINTING OFFICE: 1983-759-102/076