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METHOD FOR TREATMENT OF WATER CONTAINING LOW CONCENTRATIONS OF MERCURY

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Cleveland, Ohio 44135

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16. Abstract

A process employing magnetic filtering techniques has been devised for treating water containing concentrations on the order of 1 $\mu g/cm^3$ of atomic or ionic mercury. A laboratory-scale system has been operated and can reduce the mercury content of test solutions by as much as 90 percent.

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METHOD FOR TREATMENT OF WATER CONTAINING LOW CONCENTRATIONS OF MERCURY

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SUMMARY

A very simple process for the treatment of water containing mercury in concentrations of the order of 1 microgram per cubic centimeter has been devised and subjected to preliminary investigation. Mercury-contaminated water is circulated through a chamber containing copper-plated nickel powder, where amalgamation of the mercury and copper occurs. Any grains of the powder that are carried out of the chamber are trapped in a magnetic filter located downstream from it. Tests made in a laboratory-scale system indicate that as much as 90 percent of the mercury in a 1-microgram-per-cubic-centimeter solution of mercuric chloride in water can be removed after cycling through such a system four times.

INTRODUCTION

The purification of water containing trace amounts of mercury apparently has not, as yet, received much attention. It is conceivable, however, that in the future it may be necessary to produce large quantities of potable water from supplies contaminated by mercury concentrations on the order of a few micrograms per cubic centimeter. A treatment process will have to handle large volumes of water quickly, and must avoid the addition of other undesirable chemicals. We report here the results of a preliminary investigation of a treatment process that meets both criteria.

The proposed process makes use of the facts that mercury forms an amalgam with many metals and is low in the activity series of the elements. Hence, if a solution containing mercury ions is placed in contact with a metal of higher activity, the ionic mercury will be reduced to the atomic state. If the metal is one that amalgamates with mercury, the atoms that are formed will be bound to the metal and removed from solution. If, moreover, the mercury is already atomic rather than ionic, then whenever it

makes contact with the metal it will presumably be removed from solution. To help achieve a reasonable reaction rate for this process, the second metal should be in a form that has as large a surface area as possible, for example, a powder. Once the mercury has been trapped on the grains of the metallic powder, the final step is to remove the powder from the solution by a suitable filtering technique.

EXPERIMENTAL TECHNIQUES

A schematic representation of the test setup is shown in figure 1. A solution of mercuric chloride, at a concentration of approximately 1 microgram per cubic centimeter, was pumped into the bottom of a chamber containing a copper-plated nickel powder. The solution entered the bottom of the chamber, agitated the powder, and then left the chamber from the top. From there it flowed through a magnetic filter that removed the ferromagnetic particles that had been carried downstream. The effluent from the filter was collected for analysis. A standard laboratory type, variable speed tubing pump was used to circulate the solution so that it would not make contact with any extraneous metallic surfaces. The pumping lines were 6.35-millimeters (1/4-in.) inside diameter Tygon tubing, and the mixer, filter body, and sample reservoir were made of glass. Glass tubes in rubber stoppers were used as feed-through connectors where necessary. The electromagnet used for the filter had 10.16-centimeter (4-in.) pole faces and was capable of producing a 1.2 tesla field with a pole separation of 3.81-centimeters (1.5-in.).

Sample analysis was performed with a Perkin-Elmer model 305A atomic absorption spectrophotometer equipped with a Perkin-Elmer mercury analysis system. Because of the extreme sensitivity of the detection equipment, portions of the test samples were first diluted to the 0.01-microgram-per-cubic-centimeter range, and then a standard analysis procedure was followed (refs. 1 and 2). The estimated inaccuracy of the results of the analysis is approximately ±5 percent.

Two modes were used for running tests using the system of figure 1, closed loop and single pass. Closed-loop operation was used to test the efficiency of various mixing chamber designs and single pass operation was used to determine the efficiency of mercury removal for the same mixer with different flow rates.

No particular attention was paid to the magnetic filter, except to be certain that a sufficiently strong magnetic field was present (~ 0.5 T) so that virtually all the ferromagnetic particles entering it were trapped.

RESULTS

Figure 2 shows the two types of mixing chambers that were tested. Figure 3 shows the amount of mercury remaining in solution as a function of time during closed-loop operation with each mixer. All other operating conditions were identical for the tests. The difference in performance is clearly evident, and mixer 2 was selected for use in the single-pass tests. Figure 4 shows some typical results obtained from single-pass operation. In this mode the entire sample was run through the system and a test volume was withdrawn. The procedure was repeated three times to simulate the effect that a series of mixers might have. The data in figure 4 were obtained from different samples run at different speeds. As the curves show, more mercury was removed per pass at the slower speed than at the higher. Presumably the slower speed allows more time for the necessary interactions to occur.

DISCUSSION

The results reported here are only a beginning and are intended to indicate merely that the treatment process is feasible. Several aspects of it, however, require comment. It was decided at the outset to devise a process which employed magnetic filtering techniques, since these appear to have some advantages over simple mechanical filters (refs. 3 to 4). The filter used in the tests described above consisted simply of a glass tube, containing steel wool, situated between the pole faces of an electromagnet. One of the advantages of even this simple filter was that it could be cleaned reasonably well merely by reducing the applied magnetic field to zero and allowing the fluid flow to continue in the same direction. More carefully designed filters should improve the cleaning action so that it could be accomplished with a minimal interruption of service time.

Copper-plated nickel powder was employed as the active element of the system for several reasons. For example, none of the magnetic metals amalgamate readily with mercury. Of the four metals that do form amalgams easily (i.e., gold, silver, copper, and aluminum) only the last two are located above mercury in the activity series, and are therefore possible candidates for use. Copper was selected because it can be chemically plated onto other metallic surfaces quite easily and is slightly more soluble in mercury than aluminum.

Nickel was used as the substrate rather than iron, although it is less magnetic than the latter, because the copper did not adhere to the iron particles as well when they were agitated in the mixer. (Plating was accomplished simply by immersing the powders in a saturated copper sulfate solution.) Although the copper-plated nickel powder

appeared to work satisfactorily in the tests reported here, it is not necessarily the optimum material to use. Other magnetic materials, such as iron-copper and aluminum-nickel alloys, are promising candidates for further experimentation.

A complete discussion of all the engineering, operational, economic, and ecological aspects of this treatment process is beyond the scope of this paper. The data presented, and remarks made, are intended only to stimulate further investigation of the concept. There are admittedly many unanswered questions, particularly concerning the scale on which such a system could operate effectively, but these can be answered only by additional experimentation. The ease with which relatively large (~90 percent) reductions in low-level mercury concentrations could be effected by an unsophisticated treatment process suggests, however, that the additional experimentation might be worthwhile.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, January 30, 1973,
503-10.

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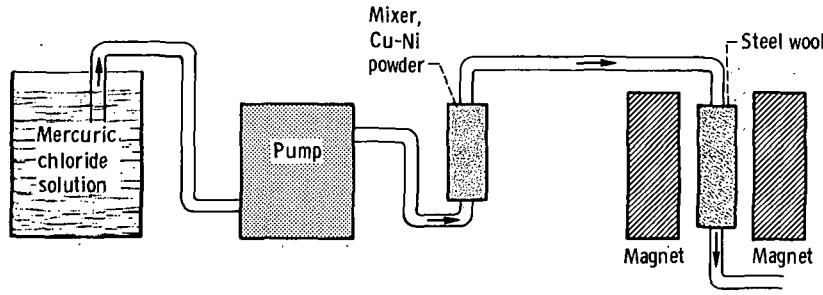
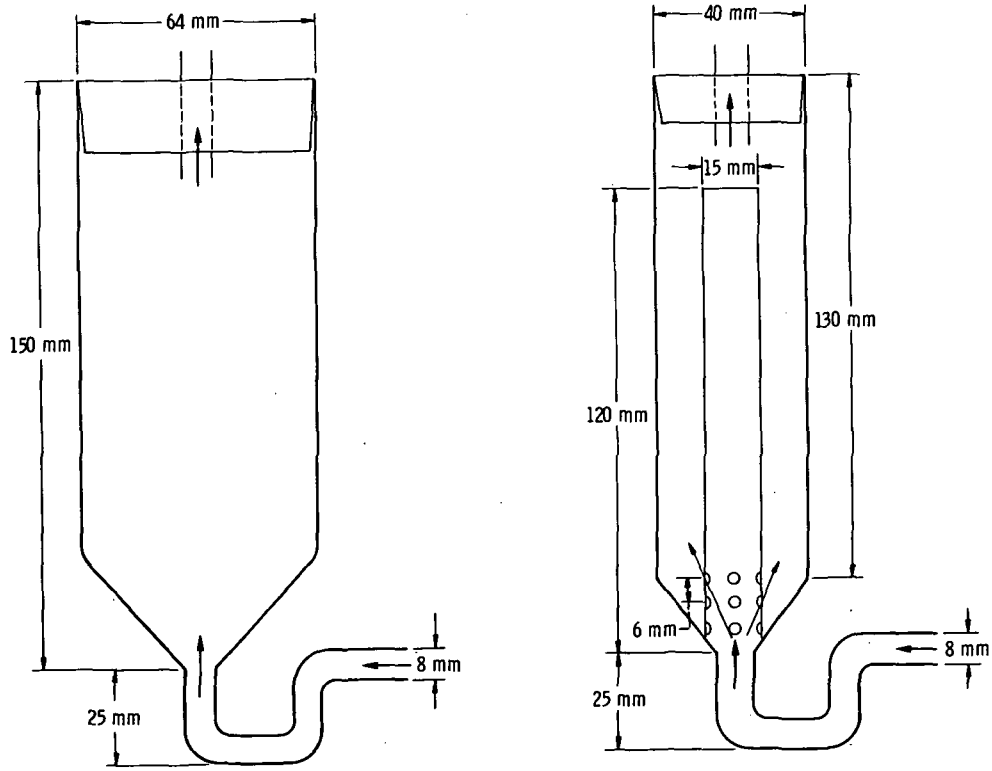


Figure 1. - Schematic diagram of experiment.



(a) Initial design.

(b) Final design.

Figure 2. - Glass mixer design.

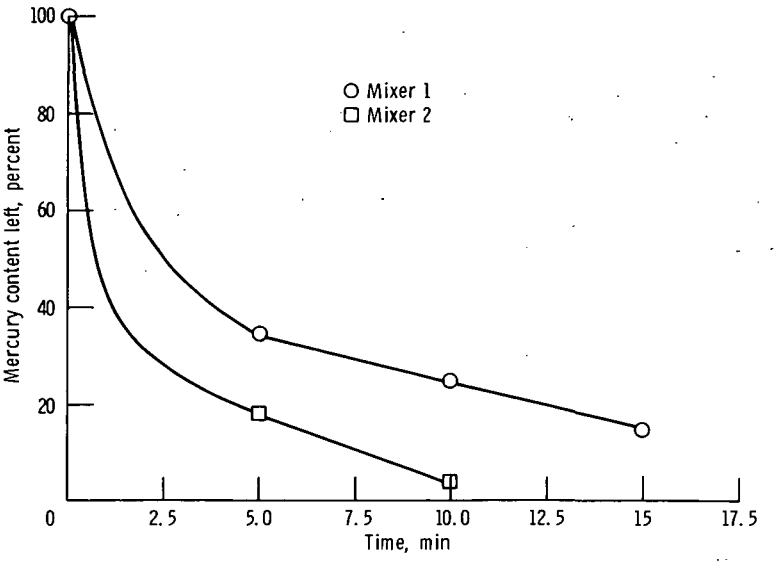


Figure 3. - Mercury levels during closed loop operation.

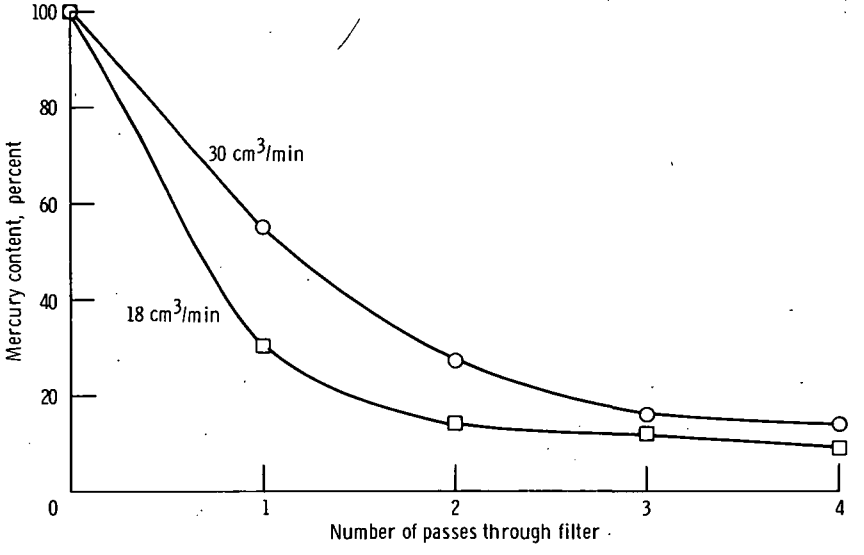


Figure 4. - Mercury levels for single-pass operation.

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