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(54) Titre : CARBONE ACTIF TRAITE AU DIOXYDE DE CARBONE ET PERMETTANT DE STABILISER LE pH D'EAUX  
TRAITEES AINSI QUE DE GERER LA TENUEUR EN ALUMINIUM DES EAUX TRAITEES  
(54) Title: AN ACTIVATED CARBON TREATED BY CARBON DIOXIDE FOR THE STABILIZATION OF TREATED  
WATER pH AND THE CONTROL OF ALUMINUM IN THE TREATED WATER

(57) **Abrégé/Abstract:**

Treatment of a wet activated carbon with carbon dioxide or with carbon dioxide followed by air results in a carbon having a reduced contact pH. The activated carbon is characterized by a modified contact pH less than about 9.0 and typically between about 7.3 and 9.0. Use of this carbon in a water treatment system eliminates the excessive effluent water pH rise which commonly occurs with activated carbon. Also, use of this carbon in a water treatment system reduces the aluminum concentration of the water when compared to an untreated carbon.

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| <b>(54) Title:</b> AN ACTIVATED CARBON TREATED BY CARBON DIOXIDE FOR THE STABILIZATION OF TREATED WATER pH<br>AND THE CONTROL OF ALUMINUM IN THE TREATED WATER<br><br><b>(57) Abstract</b><br><br>Treatment of a wet activated carbon with carbon dioxide or with carbon dioxide followed by air results in a carbon having a reduced contact pH. The activated carbon is characterized by a modified contact pH less than about 9.0 and typically between about 7.3 and 9.0. Use of this carbon in a water treatment system eliminates the excessive effluent water pH rise which commonly occurs with activated carbon. Also, use of this carbon in a water treatment system reduces the aluminum concentration of the water when compared to an untreated carbon.                                                                                                                                                                                                                                                       |           |                                                                                                                                                                                                                                                                                                                                                                    |

# **AN ACTIVATED CARBON TREATED BY CARBON DIOXIDE FOR THE STABILIZATION OF TREATED WATER pH AND THE CONTROL OF ALUMINUM IN THE TREATED WATER**

## **TECHNICAL FIELD**

The present invention relates to a process for producing an activated carbon for the stabilization of pH and for the control of the aluminum concentration in water treatment processes. More particularly, this invention relates to the production of a surface-modified, activated carbon having a reduced contact pH using carbon dioxide or using carbon dioxide with a subsequent air treatment, and the impact of this treatment on the aluminum concentration in the treated water.

## **BACKGROUND ART**

In the water treatment industry, whether municipal, industrial, or remediation, the continued use of standard carbon products causes the effluent pH to increase relative to the influent water pH and often the effluent water pH exceeds 9. This pH excursion occurs with virgin and reactivated carbon and is independent of the raw material. For example, pH excursions have been identified or associated with activated carbons that are made from bituminous coal, sub-bituminous coal, peat, wood, and coconut. The use of carbon having a reduced contact pH to stabilize the pH in water treatment has become available to assist in overcoming these problems, see, e.g., U.S. Patent Nos. 5,368,738, 5,368,739 and 5,466,378.

Work with these new modified activated carbons has shown that the carbon surface oxidizes at high temperatures with oxygen or air, at ambient temperature with oxygen or air, or with other oxidants such as hypochlorite, nitric acid, and ozone. With this oxidation, the surface of the activated carbon is changed such that the affinity or adsorption capacity for anions such as sulfate is reduced. The adsorption of these anions has been associated with pH excursions. Problems caused by the pH excursions include reduced throughput due to recycle of the high pH water, down time in operation of dialysis systems as the pH is brought into control, wasting water that is high in pH and does not meet the requirements of reverse osmosis systems for high purity water, and monetary fines for exceeding permitted pH levels in wastewater discharge. Historically, the high pH water is alleviated through excessive back washing of the carbon or neutralization of the water through the use of strong acids such as hydrochloric acid or sulfuric acid or a weaker acid such as carbonic acid. These processes are both time consuming and expensive.

Specific characteristics of pH excursions have been described in U.S. Patent Nos. 5,368,738, 5,368,739 and 5,466,378. In summary, the patents teach that a pH increase in the effluent water from an activated carbon water treatment system is triggered by the presence of anions such as chloride, nitrate, sulfate which occur naturally in water. The art also teaches that activated carbon characterized by a contact pH about 8.5 to 9.0 will exhibit pH excursions with water containing anions such as those stated above. Furthermore, the higher the carbon contact pH the greater the extent of the excursion. U.S. Patent Nos. 5,368,738 and 5,466,378 teach that the contact pH of the carbon can be reduced by oxidation at elevated temperature. U.S. Patent 5,368,739 teaches that the carbon contact pH can be reduced by oxidation at or near ambient temperature.

Also, it has been observed that the aluminum concentration in the effluent water from the carbon adsorber is higher than the influent concentration. As such, the aluminum concentration may increase to levels that exceed acceptable guidelines. In these situations, as with the pH excursions, the remediation techniques such as recycling or wasting water or strong acid treatment of the activated carbon can be both time consuming and expensive.

Accordingly, it is an object of the present invention to provide a process for producing a modified activated carbon having a contact pH between 6.0 and 9.0. It is also an object of the invention to provide a process for producing a modified activated carbon to eliminate process related problems that are associated with elevated temperature oxidation, such as reduced carbon yield, and to overcome the long treatment times or high gas volumes that are associated with oxidation at or near ambient temperature. It is a further object of the invention to provide a process for producing a modified activated carbon which is highly efficient and cost effective for use in the prevention of pH excursions in water treatment systems. Finally, it is an object of the present invention to utilize the modified activated carbon to control the aluminum concentration in water treatment systems.

### **SUMMARY OF THE INVENTION**

The present invention provides a method using carbon dioxide without the presence of oxygen for oxidation to produce a modified activated carbon especially useful in water treatment systems. The process comprises contacting a wetted activated carbon with carbon dioxide. The carbon dioxide reacts with the carbon surface and neutralizes the surface sites that normally remove anions during water treatment causing the water pH to increase. Preferably, the wetted activated carbon is contacted with the carbon dioxide at or near ambient temperatures. Alternatively, the wetted carbon is contacted with the carbon dioxide

and then air. The resulting modified carbon is highly effective at minimizing water treatment system pH fluctuation and at minimizing the water treatment system aluminum concentration fluctuation.

The treated activated carbon of an aspect of the present invention is characterized by a reduced contact pH. The contact pH is measured after contacting activated carbon with a sodium sulfate solution for 30 minutes, as described hereinafter in the Analytical section. In particular, the treated activated carbon is characterized by a contact pH less than about 9.0. The activated carbon can then be used in adsorption/filtration systems for the purification of water. The pH and aluminum concentration of the water from such a water treatment system is then controlled to levels that are acceptable to the user.

A third broad aspect of the present invention provides for the use of water treatments of a modified activated carbon having a contact pH less than about 9.0 whenever prepared by the process as described herein.

A fourth broad aspect of the present invention provides a method for treating water to control pH and reduce aluminum concentration in the treated water. The method includes contacting the water to be treated with a modified activated carbon having a contact pH less than about 9.0. The modified activated carbon was prepared by the process described herein.

## **DESCRIPTION OF THE FIGURES**

In the accompanying drawings:

Figure 1 graphically illustrates the pH profile that occurs with the volume of treated water for virgin carbon and also the carbon of the present invention. The effluent water pH profiles in Figure 1 are for a commercially-available activated carbon, an activated carbon treated with carbon dioxide by the process of an aspect of the present invention, and also for an activated carbon treated with carbon dioxide and then with air by the process of another aspect of the present invention.

Figure 2 graphically illustrates that the performance of the modified activated carbon of an aspect of the present invention is not dependent upon the influent water pH.

**AT LEAST ONE MODE FOR CARRYING OUT THE INVENTION****Experimental:**

Testing was performed with one inch inside diameter, Pyrex glass columns. The columns used for the carbon dioxide or the carbon dioxide/air contacting were 12 inches long and contained either 50 cc or 100 cc of activated carbon. Prior to contacting the carbon with carbon dioxide, the carbon was wetted by soaking in tap water in a beaker for about 16 hours. The wet carbon was then transferred to the 12 inch column, the water drained from the column, and the gas flow began. The total gas flow was measured with the use of a calibrated rotameter and stop watch. After completing the gas contact in those tests using 100 cc of activated carbon, one half of the treated carbon was tested for contact pH (Calgon Carbon Corporation Test Method TM-70) and the other half was transferred to a six-inch long column to measure the effluent water pH profile. The columns used for developing the pH profile were six inches long and contained 50 cc of activated carbon. The water passed through the six-inch column was Robinson Township Municipal Authority tap water. The flow rate was 10 cc/min for an empty bed contact time of 5 minutes. The pH of the column effluent was monitored continuously using an in line pH electrode. In those tests using 50 cc of activated carbon, only the contact pH was measured.

For the pilot scale study, ten metric tons of reactivated Filtrasorb 400 were tested using the Thames Water Utilities slow sandwich filter pilot unit. The carbon was wetted by quenching the hot carbon with water as the carbon exited the reactivation furnace. Discrete samples were taken of the water exiting the pilot filter.

Analytical:

The contact pH of the activated carbon, prior to and following treatment with carbon dioxide or carbon dioxide and then air, was determined by contacting 50 cc of the activated carbon with 100 cc of a sodium sulfate solution for thirty minutes. The sodium sulfate solution was prepared from water obtained from a Milli-Q Plus water treatment system (Millipore Corp. Bedford, MA) and Fisher Certified ACS grade sodium sulfate (Fisher Scientific Corp. Pittsburgh, PA) such that the sulfate concentration in the water was 80 mg/L. The sulfate solution was added to a beaker containing the carbon and gently stirred for 30 minutes with a magnetic stirrer. At the end of this 30 minute time period, stirring was stopped and the pH of the solution was measured.

Activated Carbons:

Tests to illustrate the present invention were performed using several different types of activated carbon. These activated carbon types included both virgin and reactivated activated carbon representing several different mesh sizes. The carbons selected were typical of those used to treat air and liquid streams. The carbons evaluated included BPL 4x6, F300 8x30, React AW 8x40, F400 12x40, and PCB 20x50 (Manufactured by Calgon Carbon Corporation, Pittsburgh, PA). All of the products tested were bituminous coal based carbons with the exception of PCB which is a coconut based carbon. Additionally, the pilot unit study was conducted using reactivated F400 that was reactivated at the Kempton Park facility operated by Chemiviron Carbon, Brussels Belgium, a subsidiary of Calgon Carbon Corporation.

Carbon Processing According to the Present Invention:

Carbons were treated with carbon dioxide ( $\text{CO}_2$ ) or  $\text{CO}_2$  and then air in a one-inch ID by 12 inch long Pyrex glass column as described in the previous Experimental section. For the treatments with  $\text{CO}_2$ , the  $\text{CO}_2$  gas volume ranged from one bed volume (approximately 100cc) to 240 bed volumes. A bed volume is defined as the gas volume equivalent to the volume of activated carbon. The volume of activated carbon is the weight of activated carbon divided by the apparent density of the activated carbon. The carbon dioxide flow rate was typically set at 100 cc/min or 1 bed volume each minute so that the total treatment time ranged from one minute to four hours. For the treatments with carbon dioxide and then air, the  $\text{CO}_2$  flow rate was set at 100 cc/min and the treatment time with carbon dioxide was set at five minutes. This treatment was followed by injecting air at a flow rate of 100 cc/min (1 bed volume each minute). The total air treatment time ranged from 5 minutes to 60 minutes.

Table 1 shows that treatment of a wet F400 activated carbon with carbon dioxide reduces the carbon contact pH to acceptable levels (less than about 8.5 to 9.0) with as little as 0.1 liters (or one bed volume) of gas for 0.1 liters of activated carbon. This reduction in contact pH is sufficient to prevent the pH excursion that occurs with untreated F400 carbon, as exhibited in Figure 1 using Robinson Township tap water as the influent water. The data in Table 1 also show that the treatment of the carbon with  $\text{CO}_2$  can be conducted either upflow or downflow as very similar carbon contact pH measurements are obtained.

Table 1 demonstrates that treatment of wetted activated carbon with carbon dioxide reduces the contact pH of that carbon to levels that are generally considered to be acceptable. In those situations where further pH reduction in the water treatment system effluent is desired, the  $\text{CO}_2$  treatment can be followed by treatment with air, to result in additional

reduction in the water treatment system effluent pH. Air is used to illustrate the effect of a gas containing oxygen. As shown in Figure 1, when carbon treated with carbon dioxide alone is first brought on line, the initial water effluent pH is about 6.2 and a maximum effluent pH of 8.5 can typically be expected. However, by following the carbon dioxide with air, the maximum effluent pH decreases, as depicted in Figure 1. This process can be utilized for systems that require a water pH closer to neutral. Table 2 also shows that the modified contact pH of the carbon treated first with carbon dioxide and then air remains in the region that is classified as a pH stable carbon, i.e., below about 8.5 to 9.0 for extended air volume treatment.

The carbon dioxide treatment or the carbon dioxide and air treatment to reduce carbon contact pH for activated carbon can be applied to many types of activated carbon. As shown in Table 3, the carbon dioxide or the carbon dioxide/air treatment can be applied to carbon of various mesh size. Also, the processes can be applied to reactivated carbon and can result in a contact pH of 7.3. Finally, the process can be applied to coconut base carbon (PCB 20x50). This is an improvement over the prior art which teaches ambient temperature oxidation (U.S. Patent No. 5,368,739) as such oxidation produced a contact pH of 9.7 for coconut based carbon.

Dilute carbon dioxide can also be used in the present invention. Table 4 shows the percentage of carbon dioxide in the contacting gas is not critical. Rather, it is the volume of carbon dioxide that contacts the activated carbon. The volume of carbon dioxide required for producing an activated carbon with a contact pH at or below about 9.0 requires between one and two bed volumes of carbon dioxide irrespective of the percentage of carbon dioxide in the treating gas. Thus it is possible to utilize off gas from other processes with lower

carbon dioxide partial pressure. For example combustion gas or flue gas could be used to contact wet activated carbon to produce the carbon of the present invention.

The carbon dioxide treatment or the carbon dioxide and air treatment to reduce the carbon contact pH for activated carbon also has the benefit of reducing the aluminum concentration in the treated water. Table 5 shows that water treated using the activated carbon without carbon dioxide or carbon dioxide and air treatment has an increase in aluminum content from 18 ug/L to 1,852 ug/L. In contrast, water treated using the activated carbon treated by carbon dioxide or carbon dioxide and air has a decrease in aluminum concentration from 18ug/L to 7 ug/L. This result shows an advantage for the pH process for control of aluminum in the water and is unlike other pH sensitive metals such as arsenic and antimony which do not show a change across the carbon filter.

The present invention expresses gas to carbon ratios as volume to volume ratios. It is equally appropriate to convert these values using well known conversion factors and equations and express the gas to carbon ratios as volume to mass, mass to volume, or mass to mass relationships.

Table 1

## Effect of Carbon Dioxide Volume on Activated Carbon pH

| Gas/Carbon<br>Contact Time, min | Total Gas Volume<br>liters | Direction of<br>Gas Flow | Carbon<br>pH |
|---------------------------------|----------------------------|--------------------------|--------------|
| 0                               | 0                          | None                     | 10.6-10.7    |
| 240                             | 24.0                       | Downflow                 | 7.8          |
| 60                              | 6.0                        | Downflow                 | 7.9          |
| 15                              | 1.5                        | Downflow<br>Upflow       | 7.8<br>7.6   |
| 10                              | 1.0                        | Downflow                 | 7.9          |
| 5                               | 0.5                        | Downflow                 | 7.9-8.0      |
| 3                               | 0.3                        | Downflow                 | 7.8          |
| 1                               | 0.1                        | Downflow                 | 8.5          |

Activated Carbon - 100 cc Filtrasorb 400 (F400)  
Carbon dioxide flow rate - 0.1 L/min

Table 2

## Effect of Carbon Dioxide Followed by Air on Activated Carbon pH

| Gas | Time<br>Minutes | Volume<br>Liters | Direction of<br>Gas flow | Carbon<br>Contact pH |
|-----|-----------------|------------------|--------------------------|----------------------|
| Air | 5               | 0.5              | Downflow                 | 7.6-7.8              |
| Air | 15              | 1.5              | Upflow                   | 8.3                  |
| Air | 60              | 6.0              | Downflow                 | 8.5                  |

Activated carbon - 100 cc of Filtrasorb 400 (F400)  
Carbon dioxide flow rate - 0.1 L/min for 5 minutes in all cases

Table 3  
Effect of Activated Carbon Particle Size

| Carbon        | Gas                  | Volume<br>Liters | Carbon<br>Contact pH |
|---------------|----------------------|------------------|----------------------|
| BPL 4x6       | CO <sub>2</sub> /Air | 0.5/0.5          | 8.7                  |
| BPL 4x6       | CO <sub>2</sub>      | 0.5              | 8.8                  |
| F300 8x30     | CO <sub>2</sub>      | 0.5              | 7.7                  |
| React AW 8x40 | CO <sub>2</sub>      | 0.3<br>0.5       | 7.3<br>7.3           |
| PCB 20x50     | CO <sub>2</sub>      | 0.5              | 8.2                  |

Gas flow rate - 0.1 L/min

Table 4  
Effect of Dilute Carbon Dioxide on Activated Carbon pH

| Percent<br>Carbon Dioxide | Total Gas<br>Volume, cc | Carbon Dioxide<br>Volume, cc | Carbon<br>Contact pH |
|---------------------------|-------------------------|------------------------------|----------------------|
| 10                        | 500                     | 50                           | 9.2                  |
| 10                        | 6000                    | 600                          | 8.4                  |
| 20                        | 200                     | 40                           | 9.6                  |
| 20                        | 400                     | 80                           | 9.0                  |
| 20                        | 800                     | 160                          | 8.4                  |
| 50                        | 100                     | 50                           | 9.5                  |
| 50                        | 200                     | 100                          | 8.7                  |
| 50                        | 500                     | 250                          | 8.3                  |

Activated Carbon - 50 cc of Filtrasorb 400

Gas Flow Rate - 0.1 L/min

Gas Composition - Carbon dioxide and Nitrogen

Table 5  
Pilot Filter Test  
Effect of Carbon Dioxide Treatment on Aluminum Concentration

| Column Dioxide Treatment        | Water Treated<br>Bed Volumes | Aluminum Concentration<br>in Filter Effluent Water<br>ug/L |
|---------------------------------|------------------------------|------------------------------------------------------------|
| None                            | 7.5                          | 1,852                                                      |
|                                 | 15.0                         | 1,500                                                      |
|                                 | 22.5                         | 164                                                        |
| 2.7 bed volumes CO <sub>2</sub> | 7.5                          | 7                                                          |
|                                 | 15.0                         | 7                                                          |
|                                 | 22.5                         | 8                                                          |

Activated Carbon - 1 metric ton of reactivated F400  
Gas Flow Rate - Approximately 1100 L/hr.  
Influent Water Analysis - 18 ug/L

While presently preferred embodiments of the invention have been described in particularity, the invention may be otherwise embodied within the scope of the appended claims.

**CLAIMS:**

1. A process for producing an activated carbon having a contact pH below about 9.0 comprising the steps of:

- a. wetting an activated carbon with water to produce a wet activated carbon;
- b. draining water from said wet activated carbons to provide drained, wetted activated carbon ;
- c. contacting said drained, wetted, activated carbon with a gas comprised substantially of carbon dioxide in the substantial absence of oxygen, wherein the amount of carbon dioxide contacted with said wet activated carbon is greater than about one bed volume of said carbon dioxide;

thereby to produce an activated carbon having a contact pH below about 9.0.

2. A process as set forth in claim 1, wherein said wetted, activated carbon is subsequently contacted with air after said contacting with carbon dioxide.

3. A modified activated carbon having a contact pH less than about 9.0, whenever prepared by the process set forth in claim 1.

4. A modified activated carbon having a contact pH less than about 9.0, whenever prepared by the process set forth in claim 2.

5. The use, for water treatments, of a modified activated carbon having a contact pH less than about 9.0;

said modified, activated carbon having been prepared by the process set forth in claim 1.

6. The use, for water treatment, of a modified activated carbon having a contact pH less than about 9.0;

said modified, activated carbon having been prepared by the process set forth in claim 2.

7. A method for treating water to control pH and reduce aluminum concentration in the treated water, said method comprising:

contacting said water to be treated with a modified activated carbon having a contact pH less than about 9.0;

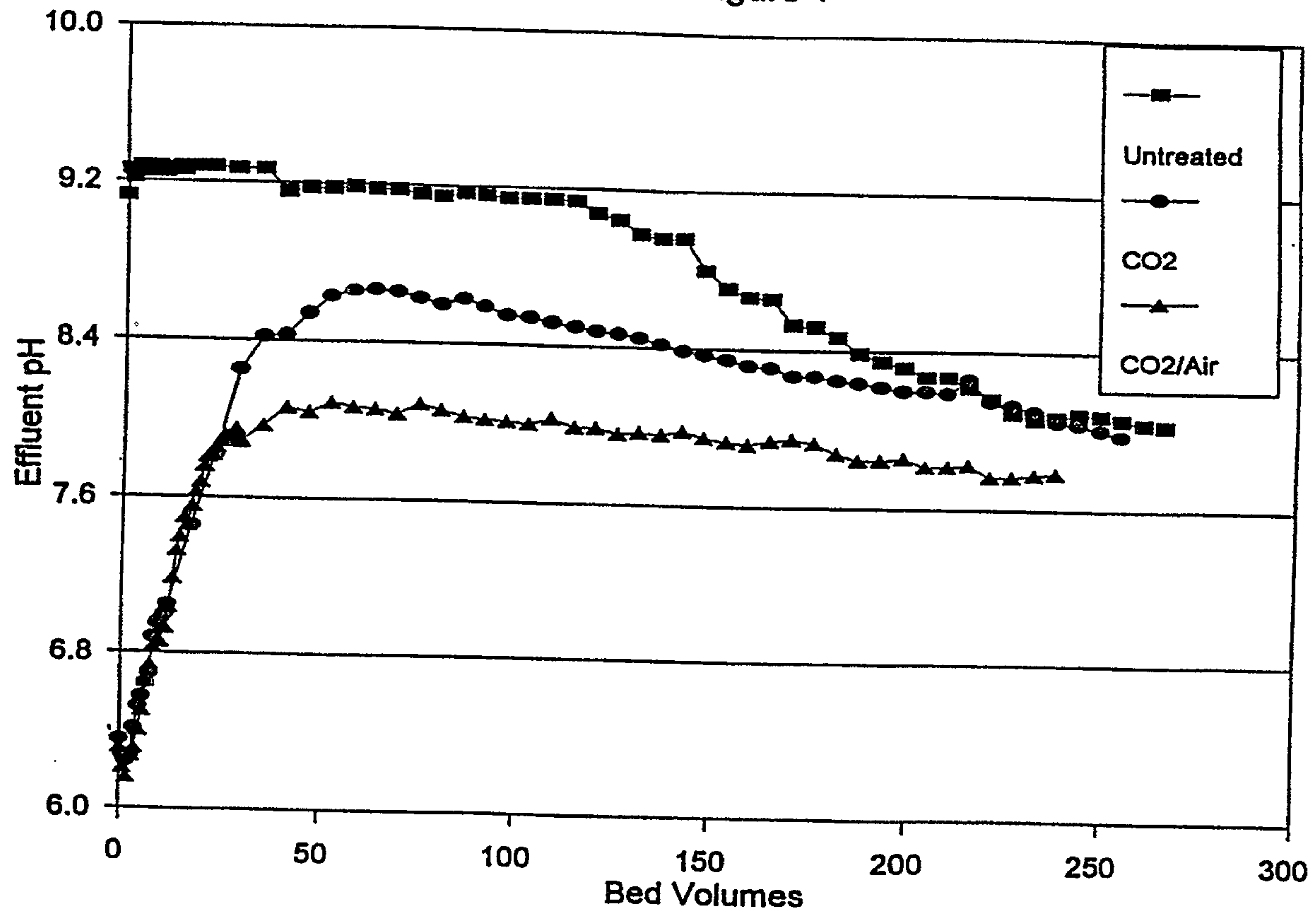
said modified activated carbon having been prepared by the process as set forth in claim 1.

8. A method for treating water to control pH and reduce aluminum concentration in the treated water, said method comprising contacting the water to be treated with a modified activated carbon having a contact pH less than about 9.0;

said modified, activated carbon having been prepared by the process as set forth in claim 2.

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Figure 1



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Figure 2

