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(54) Title: WATER PURIFICATION AND ENHANCEMENT SYSTEMS

(57) Abstract: Water purification system comprising at least two filtration media sized with respect to each other to allow a first contaminate to be saturated first with a delay before a second contaminate is saturated.

WATER PURIFICATION AND ENHANCEMENT SYSTEMS

[0001] The present invention relates to a low-cost potable water purification system and a sensor to alert the user when the water is no longer safe to drink. This low-cost water purification system incorporates additional functionality that enables beneficial impurities and molecules to be added to the water.

BACKGROUND OF THE INVENTION

[0002] Water purification systems can be comprised of many different components using various mechanisms for removing impurities from water. One class of prior water purification systems is commonly referred to as 'point-of-use' (POU) water purification systems. Such POU systems are composed of components that remove water impurities on a relatively small scale, e.g. a table-top or dwelling-oriented system as opposed to a large central facility, like a municipal water treatment facility.

[0003] POU systems in general have been constructed for high-end marketplaces, i.e., markets where higher costs in POU systems can be tolerated. POU systems have not effectively penetrated large but lower-end marketplaces due to the lack of inventive design in low-cost environments.

[0004] A typical POU system may have a pre-filter to remove sediment, followed by mechanisms that ensure pathogen and sometimes inorganic material removal. One of the most important aspects of a POU system which contains consumables, such as filters, is an 'end-point' detection system that warns user or service personnel that the time to change the filter has arrived. Most POU systems use a time-based system where, after a certain amount of time has passed, a light turns on (or some other indicator) which signals that it is time to change the filter. This relatively low cost sensor is not adequate. If the water purification system is deployed in different environments, the required length of time between filter changes to avoid contamination can vary greatly, thus possibly exposing individuals to contaminated water.

[0005] The main method of determining water composition (and safety) is to periodically take samples of the water and ship these samples to a laboratory where relatively large equipment is used to analyze the water composition. This information supplies feedback to the user or service personnel of what is in the water. In addition, there are field-kits which can test for particular contaminates, e.g. chlorine. Generally, neither of these standardized test methods is either universal enough or compatible with a POU water system. Likewise, neither of these test methods is consumer friendly.

[0006] Current POU water purification systems do not add beneficial ingredients to the water. Typical systems that impart molecules or compounds into water are found in the confectionary or restaurant businesses. A soda fountain, for example, adds molecules and compounds that add flavor to carbonated water by simply mixing streams of liquids, but not ingredients beneficial to the consumer's health.

[0007] A need exists for an improved system for purifying water and/or adding beneficial ingredients to the water. The present invention seeks to satisfy this need.

SUMMARY OF THE INVENTION

[0008] In one aspect there is provided a water purification system comprising at least two filtration media sized with respect to each other to allow a first contaminate to be saturated first with a delay before a second contaminate is saturated. In another aspect, there is provided a method of purifying water comprising passing water through a system comprising at least two filtration media sized with respect to each other to allow a first contaminate in the water to be saturated first with a delay before a second contaminate is saturated.

[0009] An important aspect of the present system is to employ the user of the system as the end-point detector of pathogens or other dangerous elements. This aspect of the system allows for the ultimate in low-cost water purification and water safety. The present inventive system employs the user as a detector through the user's sight or taste. A mechanism in the water purification system releases a color element when the water filter has reached or is beginning to reach the end of its life. Additionally the system also has the ability to release a different taste in the water which also can alert the user that the filter has reached its end of life. In addition, since these detection mechanisms are introduced in a low-cost manner, the same mechanisms can be utilized to impart desired molecules or compounds into purified water, thus creating healthy beverages and/or therapeutic drinks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a schematic of a first embodiment of the present invention showing a low-cost arsenic purification system;

[0011] Figure 2 illustrates how taste removal media breaks through first and the water will possess an undesirable musty or earthy taste for some time period of delay before the water begins to be contaminated with arsenic;

[0012] Figure 3 illustrates how time release capsules can release taste substances at a constant rate which is absorbed by a downstream media and saturates the media at the right time;

[0013] Figure 4 illustrates how time release capsules are engineered into abrupt-release form which are located in this case at the end of the purification system;

[0014] Figure 5 illustrates time-release capsules designed to inject an even dose of flavor over time;

[0015] Figure 6 illustrates a time-release capsule designed so that the outer shell dissolves at a rate such that the flavor is released as abruptly as possible when the arsenic media is about to expire; and

[0016] Figures 7 and 8 show arsenic removal results of the combination AC/GFO filter on Chapala water over the lifetime of the filter.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Referring to the drawings, Figure 1 is a schematic of a first embodiment of the present invention of a low-cost arsenic purification system. The system 2 comprises a reservoir 4 for containing water to be purified connected via a valve 8 to a filter region 10 having a series of remediation medias 12,14,16. Water passing through the filter region 10 exits through nozzle 18 via valve 20 into receiving vessel 22.

[0018] The prefilter 12 is designed to eliminate large particles and sediment from the water. The pre-filter 12 is followed by a series filter medias which are designed to remove targeted atoms, molecules, or compounds from the water and/or may be employed to impart either a color or taste change to the water when the media are saturated with contaminates and the media is no longer purifying the water (i.e. the invention indicates that the water will soon be unsafe). In the particular embodiment illustrated in Figure 1, the prefilter media 12 is followed by a taste removal media 14, and an arsenic removal media 16.

[0019] Similar mechanisms can be employed to inject other beneficial compounds into the water. Beneficial compounds can be, for example, vitamins, amino acids, minerals, and/or herbal extracts. Some examples include vitamin A, vitamin C, vitamin D, and vitamin E, vitamin K, vitamin B_6, vitamin B_{12}, thiamin, riboflavin, niacin, folic acid, biotin, pantothenic acid, calcium, iron, phosphorus, iodine, magnesium, zinc, selenium, copper, manganese, chromium, molybdenum, potassium, boron, nickel, silicon, tin, vanadium, lutein, and lycopene.

[0020] The system of the invention is primarily designed for treatment of water which has been disinfected with chlorine. As noted above, one of the remediation medias 14 may be designed to remove undesirable tastes, and the other 16 may be chosen to remove arsenic.

[0021] Different geographical areas may have different water problems and, hence, may require adjustment of the media types, number of medias, or media ratios to properly remove contaminants. The filter system is designed with an appropriate empty bed contact time (EBCT) for each of the medias to allow sufficient removal of the target contaminants. Typical EBCTs are on the order of 1 to 10 minutes, and these guidelines determine water flow rates through the media filter volume.

[0022] The purification system may include additional filter stages after the remediation medias described above (not shown). For example, a filter to remove media fines (such as a fiber wound filter) and or a filter to remove microbial contaminants may be implemented after the remediation media stages. Common causes of water taste problems are algal metabolites such as geosmin, or 2 methylisoborneol (MIB) which impart musty or earthy tastes to the water. (See for example, chapter 26 in *Adsorption by Carbon*, edited by Bottani and Tascon). Although the order of the media in the present system is not critical, in the embodiment illustrated in Figure 1, the taste removal filter media 14 is positioned immediately following the prefilter media 12, followed by the arsenic removal media 16.

[0023] In other embodiments, the medias may be intermixed, alternating, or stacked. Additionally, although there are other potential media that can perform both tasks described above, activated carbon (also referred to as activated charcoal) is typically selected as the taste removal filter media 14, and one or more of granular ferric hydroxide, activated alumina, granular ferric oxide, titanium oxide, zirconium oxide, or another metal oxide or mixture of metal oxides may be selected as the arsenic removal media 16.

[0024] The design of the system of the invention is very low cost for two principal reasons. First, the system is targeted at the two primary problems arising with the water, namely the toxic arsenic concentration and the undesirable taste. Secondly, the method of end-point-detection is either time, or more importantly, taste. The system is able to employ user taste as an end-point detection mechanism by sizing the taste-removal media and the arsenic-removal media such that the taste-removal media is saturated before the arsenic-removal media is saturated. When these media volumes are sized as described, the taste removal media breaks through first, and the water will possess an undesirable musty or earthy taste for some time period of delay before the water begins to be contaminated with arsenic.

[0025] This effect is represented schematically in the graph shown in Fig. 2. The sizing of the volume media to arrive at this functional effect, in which the user is the sensor since the user is signaled to replace the media when an earthy or musty taste is sensed in the water, is accomplished in a series of steps as described below.

[0026] First, the local water is measured to determine the level of taste imparting compounds such as geosmin or MIB and the level of arsenic in the water. Secondly, the taste and arsenic removal media is tested to determine how long it will take a volume of media to be saturated with geosmin and/or MIB or arsenic. Once this second step is complete, volumes of the media in the system can b chosen to achieve the effect shown in Fig. 2.

[0027] For example, a two component POU filter can be constructed with activated carbon for taste improvement and granular ferric oxide (GFO) for arsenic removal. By appropriately sizing the medias, the taste improvement serves the function of an early warning system for the user that it is time to replace the filter. The relevant parameters are the media adsorption capacities for target contaminants, typically listed in mg contaminant adsorbed per gram of media. The adsorption capacity of MIB on activated carbon is in the range of 1 to 3 mg/g, depending on activated carbon structure (carbon containing source material, pore size distribution, and surface area), and water chemistry. (See for example, Chapter 26 in *Adsorption by Carbon*, edited by Bottani and Tascon, p.683, (2008)). Similarly, the adsorption capacity of arsenic (V) on GFO is in the range of 0.5 to 1 mg/g depending on water chemistry. (Reference, *Adsorption Treatment Technologies for Arsenic Removal* ,AWWA publishing, Chapter 6, (2005)).

[0028] A suitable activated carbon can be obtained from Calgon Carbon Corporation (http://www.calgoncarbon.com/solutions/?view=ChallengeProducts&Industry=10&Application=7&Challenge=7). Similarly GFO can be obtained from Severnt Trent Corporation.(http://severntrentservices.com/Water___Wastewater_Treatment/Arsenic_Removal_prod_52.aspx).

[0029] For example, it is assumed that, in the input water, MIB and arsenic(V) concentrations are both 0.05mg/L, and further it is assumed that the adsorption capacity of both contaminants on their respective removal medias is 1mg/g. Neither GFO nor AC has appreciable adsorption capacity for the other contaminant. Thus, to design a filter where MIB breaks through the activated carbon prior to arsenic break through in the GFO requires a GFO to carbon ratio greater than 1. Suitable ratios could be 2:1 = mass GFO:mass activated carbon. Such a ratio would result in an undesirable taste notification to the user that it is time to replace the filter prior to the user being exposed to elevated levels of arsenic. Of course, the overall media masses (and hence filter volume) must be chosen appropriately for the intended water flowrate and filter lifetime. If the concentration of geosmin or MIB is not large enough, the saturation is not abrupt enough, or another suitable taste imparting compound is not present in the water, the method described above cannot be used as an end-point-detection sensor.

[0030] If a constant rate of a taste compound is added outside the POU system, the invention has a similar design as shown in Fig.1 since the geosmin or MIB taste removal media is replaced with a media that removes the intentionally introduced taste compound. Alternatively, the taste substance or compound may be added within the POU system by employing time-release capsules.

[0031] Figure 3 shows a system similar to that shown in Figure 1 except that a region 24 is provided downstream of the taste removal media 14 containing capsules adding constant rate release of taste substances. These time release capsules can either release taste substances at a constant rate which is absorbed by a downstream media and saturates the media at the right time (as seen in Fig. 3), or the capsules may be engineered into abrupt-release form 26 which are located in this case at the end of the purification system as the last stage (see Fig. 4). In the first case (continuous), the time-release capsules (see Fig. 5) are designed to inject an even dose of flavor over time. In the capsule shown in Fig. 6, this is designed so that the outer shell dissolves at a rate such that the flavor is released as abruptly as possible when the arsenic media is about to expire.

[0032] The inventive time-release capsules used in the water purification system of the invention can also be used to release color either in addition to or instead of taste. For example, both methods described above for flavor release can be used for color release. In the first case, the constant-rate-release time capsule can be used to release a color that is absorbed by one of the media in a filter system, and the saturation is planned such that the color compound achieves saturation in the media just before a purification media becomes saturated with an undesirable atom, molecule, or compound(s) which is being removed. Thus, the water will change color when it is time to replace the purification media. A time delay is designed into this system as well, so that even though the water changes color, the water is still safe for some delay time. The delay is designed by understanding the saturation rate of the color compound concentration released by the time-release capsule as well as the saturation of the undesirable atom, molecule, or compound that is being removed.

[0033] An abrupt-time-release time capsule can be used as well to impart color in the water to indicate that it is time to replace the purification media. In this embodiment, the outer shell of the time release capsule dissolves at a rate such that color is released abruptly just before the purification media is saturated with the atom, molecule, or compound that it is removing from the water.

[0034] The time-release capsules described herein are also useful in adding desirable atoms, molecules, or compounds to the water. The constant-rate time capsules described previously are desirable for this beneficial release. The capsules are loaded into a media, or separately, located at the last stage of the water purification system (so that other media do not remove the desired beneficial atoms, molecules, or compounds). Flavors can be released by these capsules, as well as therapeutic substances such as vitamins.

[0035] A key aspect of the invention is the recognition that local water conditions must be carefully assessed in order to choose the most appropriate, lowest cost media for optimum arsenic POU removal with sufficient longevity to produce potable water in amounts suitable for a household. For example, in one particular location, testing determined that the chlorine content, arsenic valence, and pH would need to be primarily considered when choosing the most appropriate arsenic removal media. Likewise, the ratios of the media in the filtration system would have to be adjusted based on the water characteristics and desired longevity and quality of the water post-filtration. Chlorine neutralization requires activated carbon (AC), while arsenic removal requires a metal oxide media such as GFO. In the example above, GFO media was chosen because it exhibits superior As(V) removal at the elevated pHs present in the local water supply compared to other metal oxide medias such as activated alumina. (Reference, *Adsorption Treatment Technologies for Arsenic Removal* ,AWWA publishing, Chapter 6, (2005)).

[0036] To minimize plumbing connections and reduce unit assembly cost, the medias were combined in a single standard filter housing. It was estimated that 550g of GFO (1.1 dry liters) would give sufficient arsenic removal capacity under local water conditions to achieve the designed filter lifetime of 7,000 liters. The overall filter volume was fixed to that of a standard 130cc filter element in the POU device. It was determined that the element containing 1.1 L of GFO and 1.1L of AC, in a 1:1 media ratio by volume worked best for the conditions present in the example.

[0037] Following the above described process, the media ratios can be adjusted without undue experimentation once the local water characteristics have been assessed. The medias formed two distinct layers, and water flowed through the AC prior to the GFO. Figures 7 and 8 show arsenic removal results of the combination AC/GFO filter on Chapala water over the lifetime of the filter. Arsenic is maintained below the 0.01mg/L limit during the test. In addition, chlorine was not detected in the treated water, resulting in pleasing taste to local residents. Depending on the local water quality factors, POU filter size, and designed operational lifetime the ratios of GFO to AC may be adjusted as required. For small filter sizes present in POU devices, it is expected that proper ratios of GFO arsenic removal media to activated carbon would be approximately 1:1 = volume of GFO:volume AC or larger such as 2:1. These volumes should be adjusted for the arsenic removal capacities and densities of different medias appropriate for the local water conditions. Additional medias may be added to the filter elements to remove other water contaminants as required resulting in elements with 3, 4, or more media components. The individual medias may be separated (i.e., layered) as in the above example, or they may be intermixed.

[0038] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A water purification system comprising at least two filtration media sized with respect to each other to allow a first contaminate in the water to be saturated first with a delay before a second contaminate is saturated.

2. A water purification system according to claim 1, which is a point of use system.

3. A water purification system according to claim 1, wherein said at least two filtration media are located downstream of a water reservoir.

4. A water purification system according to claim 1, wherein a prefilter is provided immediately upstream of said at least two filtration media for removal of large particles and sediment from the water.

5. A water purification system according to claim 1, wherein chlorine and arsenic are contaminates.

6. A water purification system according to claim 1, wherein a first filtration media is activated carbon when the first contaminant is chlorine and a second filtration media is activated alumina, granulated ferric oxide and/or granulated ferric hydroxide when the second contaminant is arsenic.

7. A water purification system comprising:

at least two filtration media sized with respect to each other to allow a first contaminate in the water to be saturated first with a delay before a second contaminate is saturated; and

time release capsules to impart flavor to indicate end-point-detection of the filtration media.

8. A water purification system according to claim 7, wherein the

time-release capsules are continuous.

9. A water purification system according to claim 7, wherein the time release capsules are abrupt.

10. A water purification system according to claim 9, wherein the abrupt capsules are positioned as a last stage of the system.

11. A water purification system according to claim 8, wherein the continuous capsules are positioned upstream of another media that will saturate at some point, and allow entry of taste into the water.

12. A water purification system comprising:

at least two filtration media sized with respect to each other to allow a first contaminate in the water to be saturated first with a delay before a second contaminate is saturated;

color time release capsules to impart color to indicate end-point-detection of the filtration media.

13. A water purification system according to claim 12, wherein the color time-release capsules are continuous.

14. A water purification system according to claim 12, wherein the time release capsules are abrupt.

15. A water purification system according to claim 14, wherein the abrupt capsules are positioned as a last stage of the system.

16. A water purification system according to claim 13, where the continuous capsules are positioned upstream of another media that will saturate at some point, and allow entry of color into the water.

17. A water purification system comprising:

at least two filtration media sized with respect to each other to allow a first contaminate in the water to be saturated first with a delay before a second contaminate is saturated; and

time release capsules for continuously introducing flavor or a therapeutic substance into the water.

18. A water purification system according to claim 17, wherein the time release capsules are positioned such that the flavor is introduced into the water in a last stage of the system.

19. A method of purifying water comprising passing water through a system comprising at least two filtration media sized with respect to each other to allow a first contaminate in the water to be saturated first with a delay before a second contaminate is saturated.

20. A method according to claim 19, wherein the water is measured to determine a level of taste imparting compounds and the level of arsenic in the water; the filtration media is tested to determine how long it will take a volume of media to be saturated with taste imparting compounds and with arsenic; and the volumes of the media in the system are chosen to allow the taste imparting compounds in the water to be saturated first with a delay before the arsenic is saturated.

Figure 1

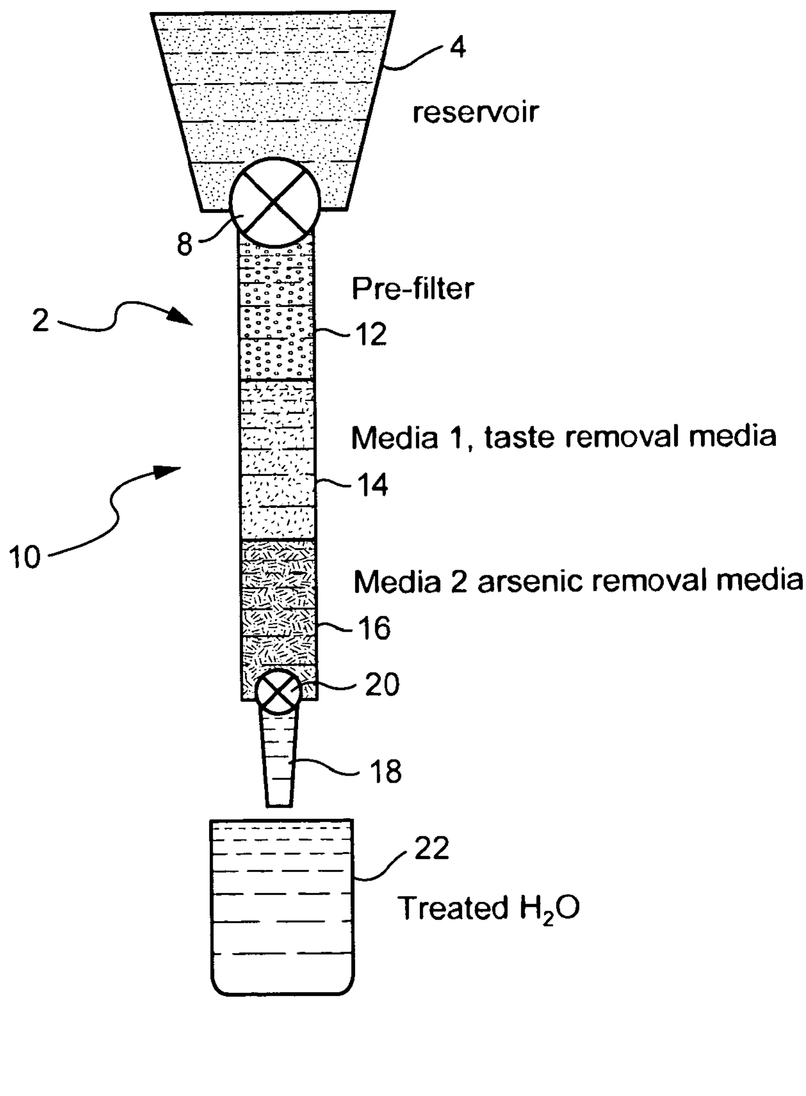
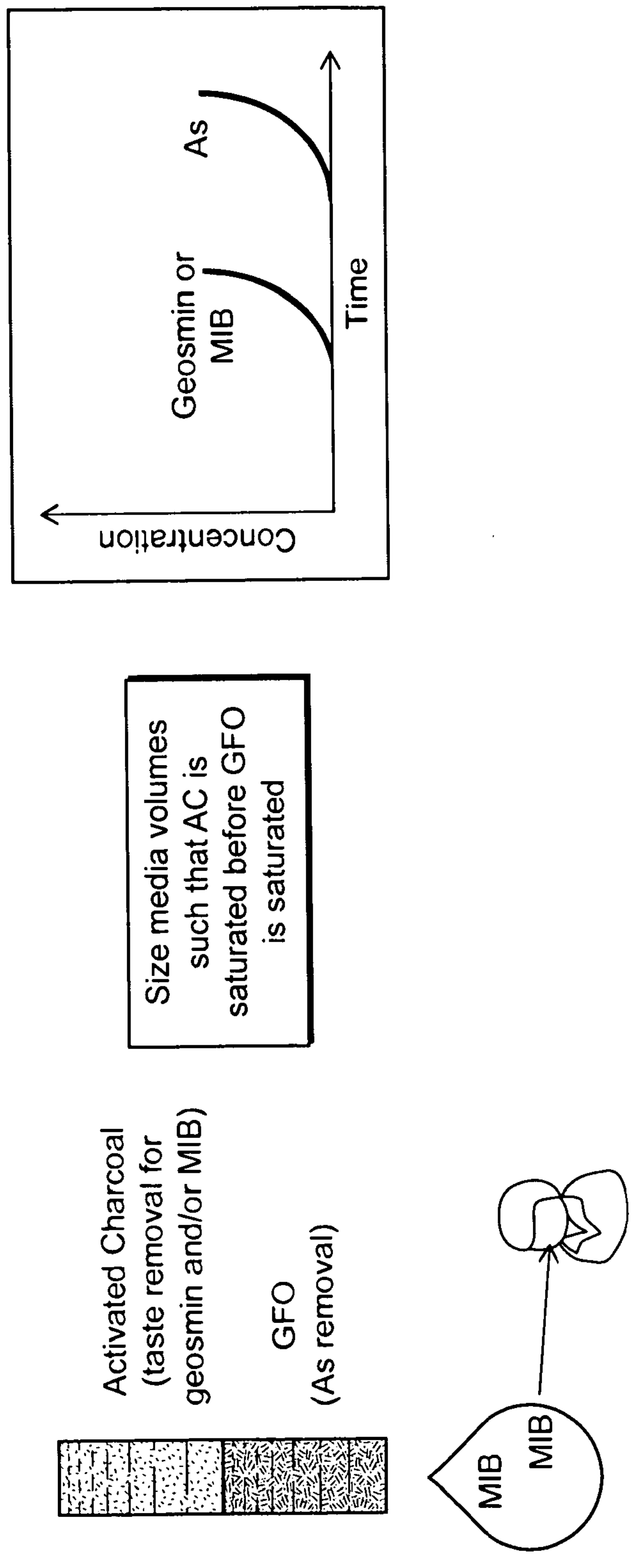

4
reservoir
8
Pre-filter
2
12
Media 1, taste removal media
14
10
Media 2 arsenic removal media
16
20
18
22
Treated H_2O

Figure 2



Concentration
Time
Geosmin or MIB
As
Size media volumes such that AC is saturated before GFO is saturated
Activated Charcoal (taste removal for geosmin and/or MIB)
GFO (As removal)
MIB
MIB

Figure 3

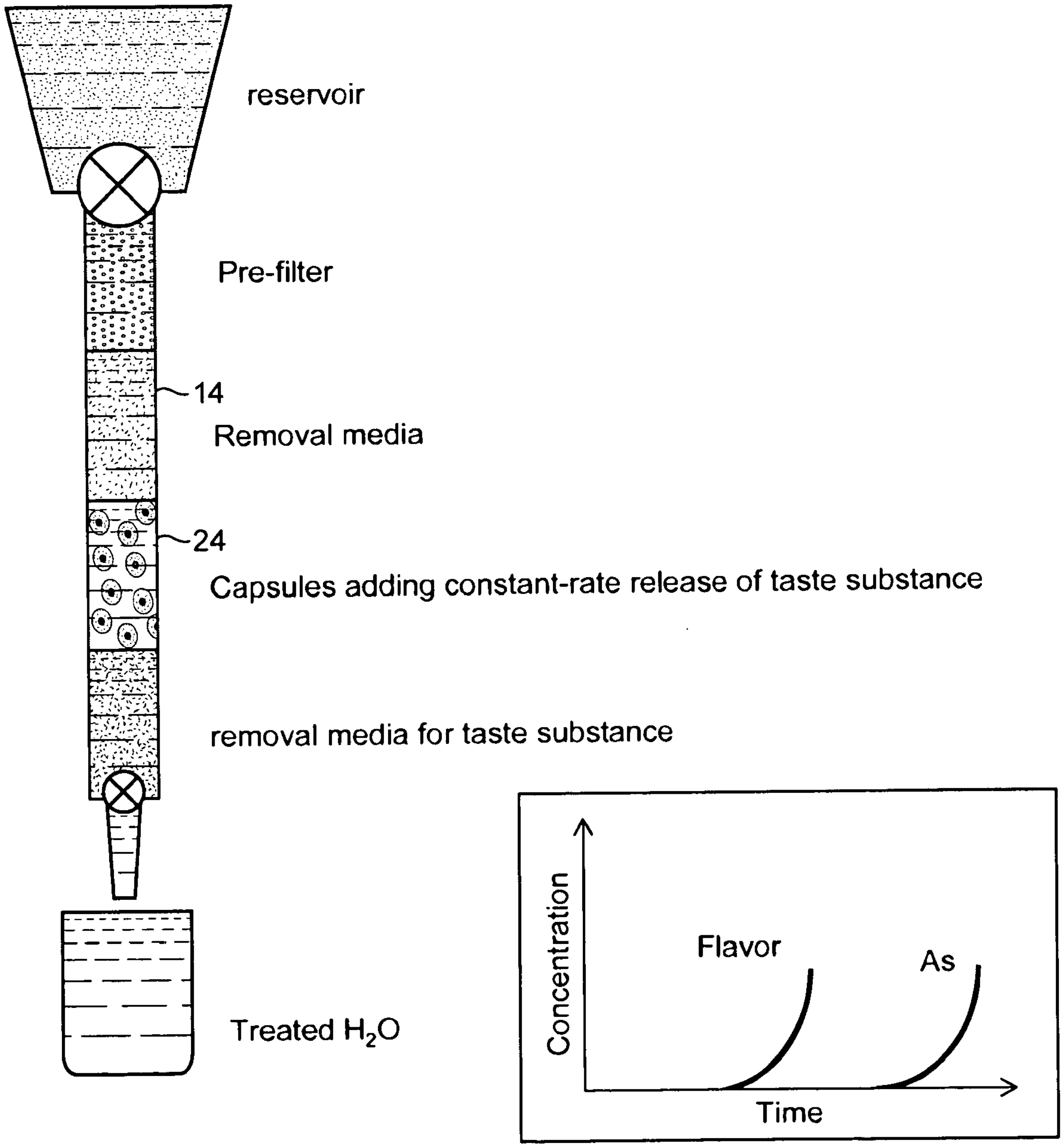

reservoir
Pre-filter
14
Removal media
24
Capsules adding constant-rate release of taste substance
removal media for taste substance
Treated H_2O
Concentration
Flavor
As
Time

Figure 4

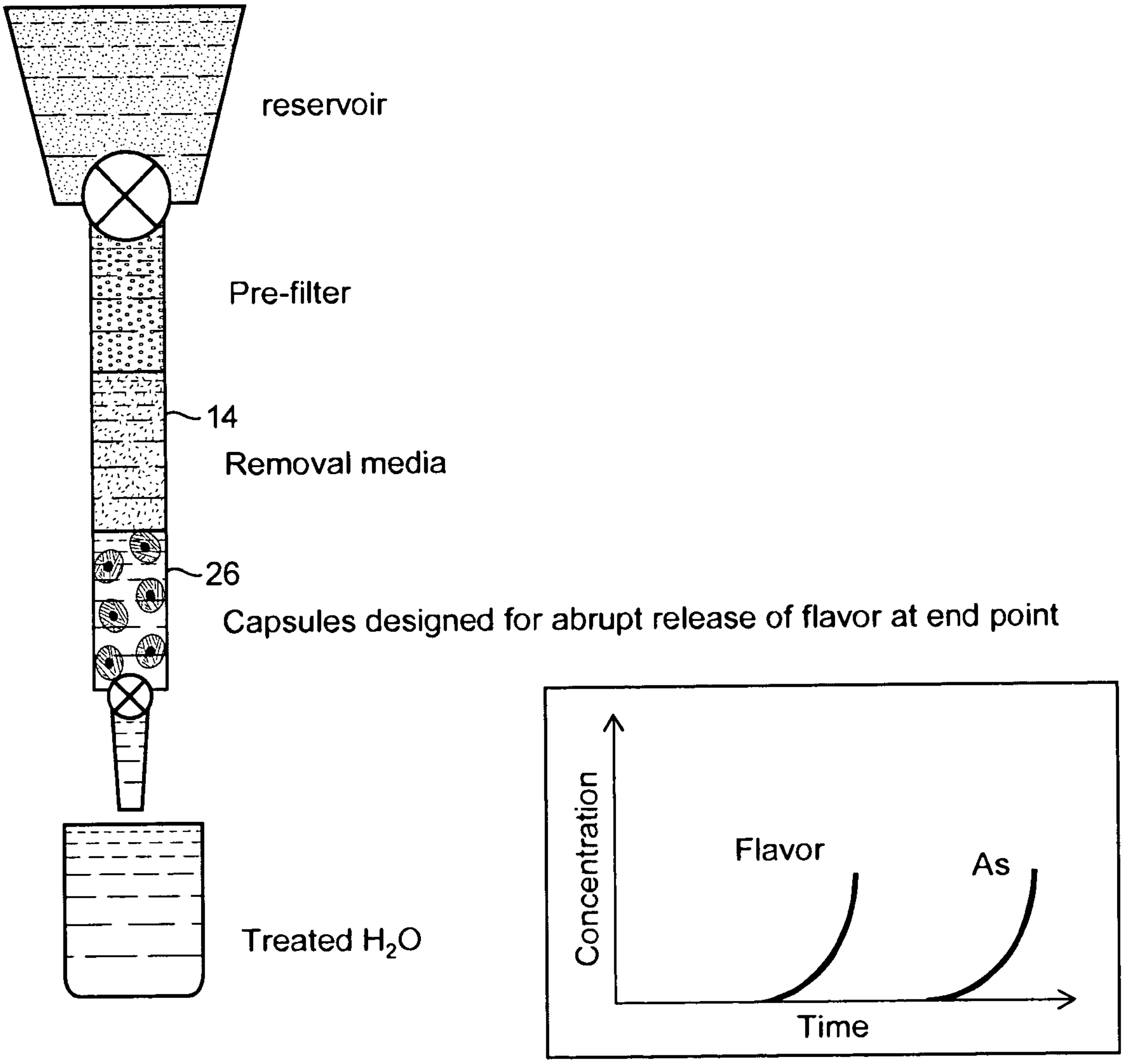

reservoir
Pre-filter
14
Removal media
26
Capsules designed for abrupt release of flavor at end point
Treated H_2O
Concentration
Flavor
As
Time

Figure 5

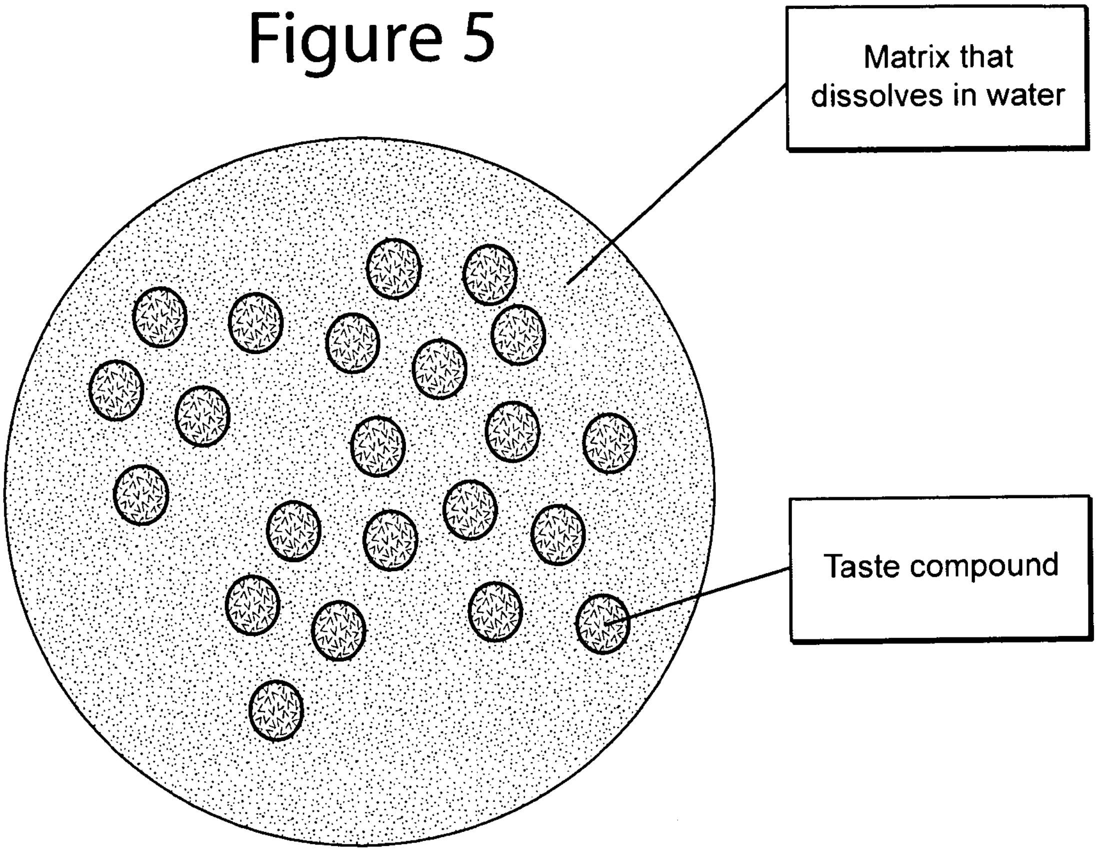


Figure 6

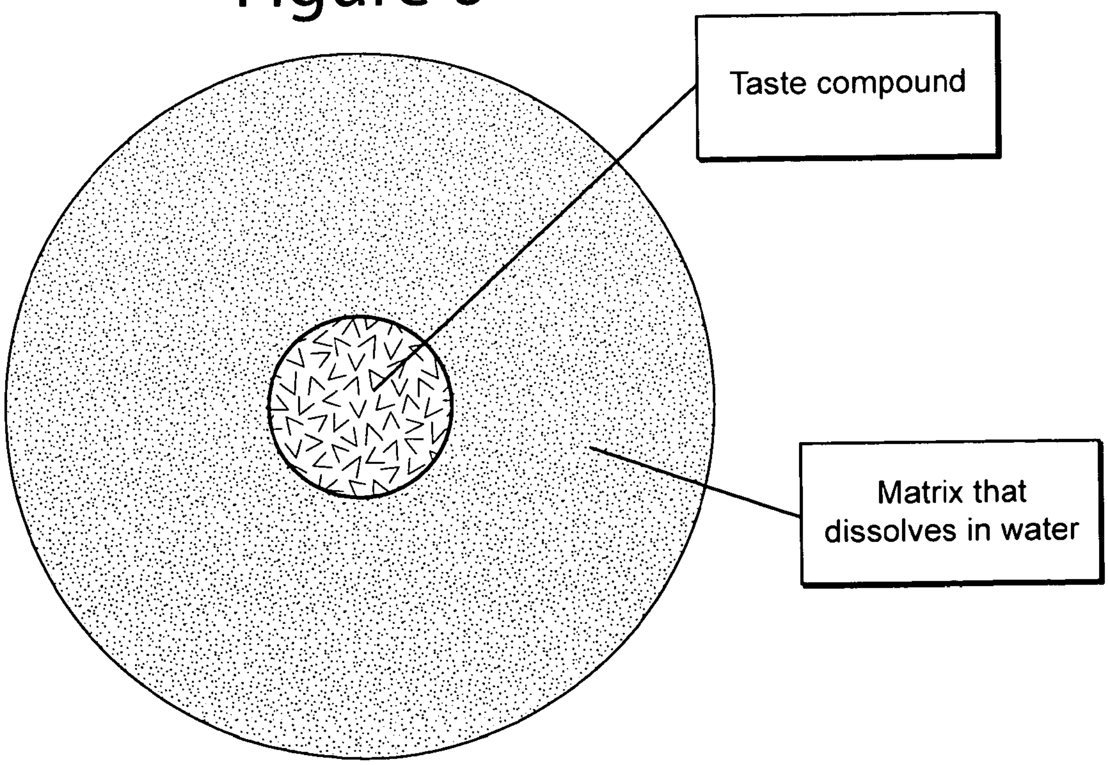


Figure 7

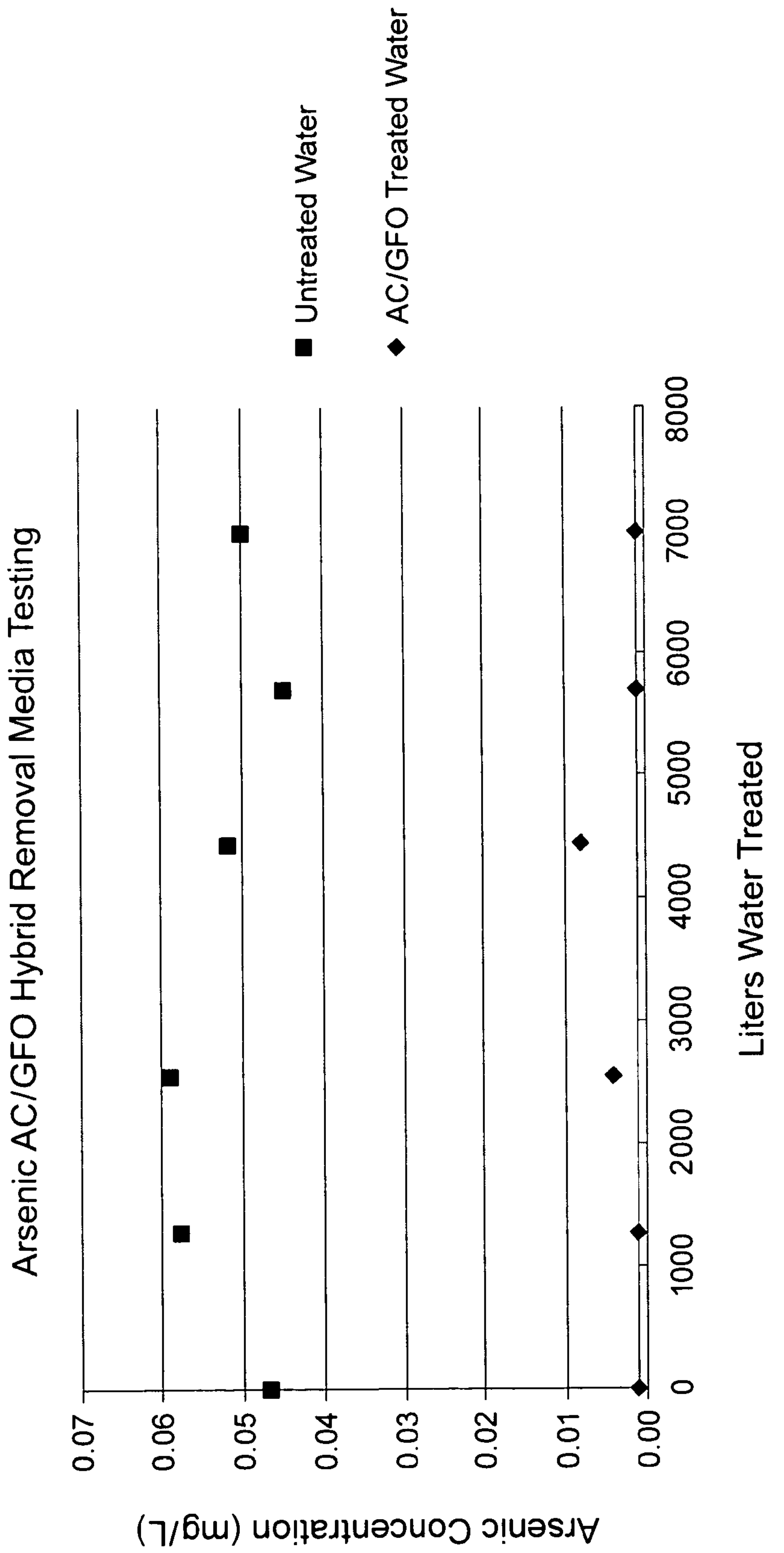

Arsenic AC/GFO Hybrid Removal Media Testing
Untreated Water
AC/GFO Treated Water
Arsenic Concentration (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Liters Water Treated
0
1000
2000
3000
4000
5000
6000
7000
8000

Figure 8

Volume of Water Treated (L)	Untreated Water Arsenic Level (mg/L)	Treated Water Arsenic Level (mg/L)
1	0.047	0.001
1267	0.058	0.001
2534	0.059	0.004
4435	0.052	0.008
5702	0.045	0.001
6970	0.05	0.001