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(54) **PROCESS AND RADIATOR DEVICE FOR WORT STERILIZATION BY RADIATION FOR ETHANOL PRODUCTION**

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(57) **ABSTRACT**

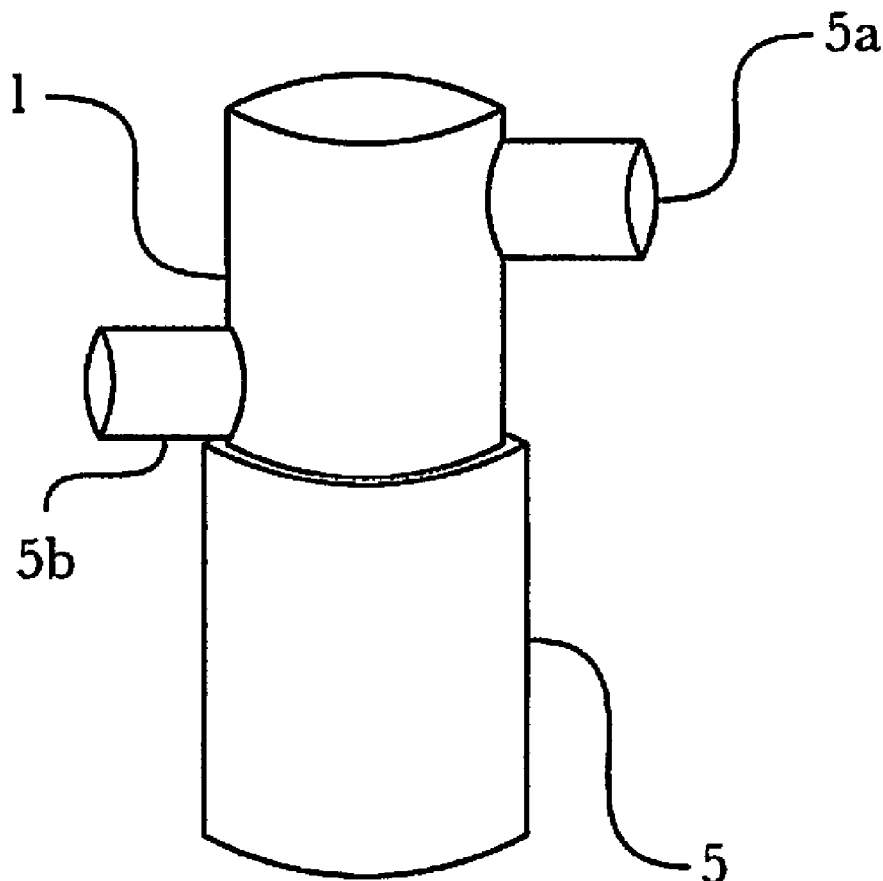
A method and irradiator apparatus used for wort sterilization by radiation for production of ethanol from sugar cane, comprising a modular irradiation drum, radioactive source, ducts for transmission of a fluid through an apparatus for irradiation, and application of radiation to a fluid within an apparatus for sterilization of such fluid.

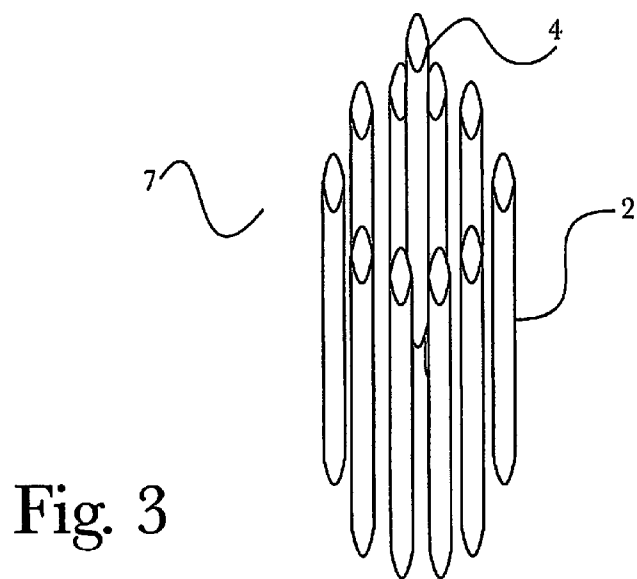
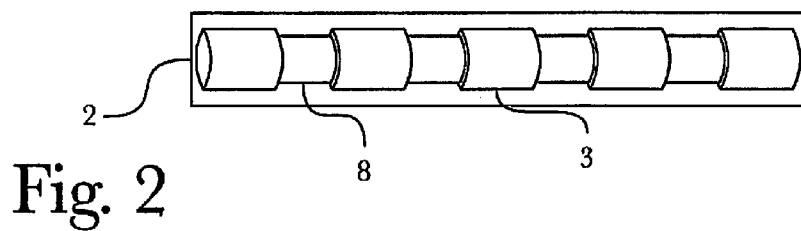
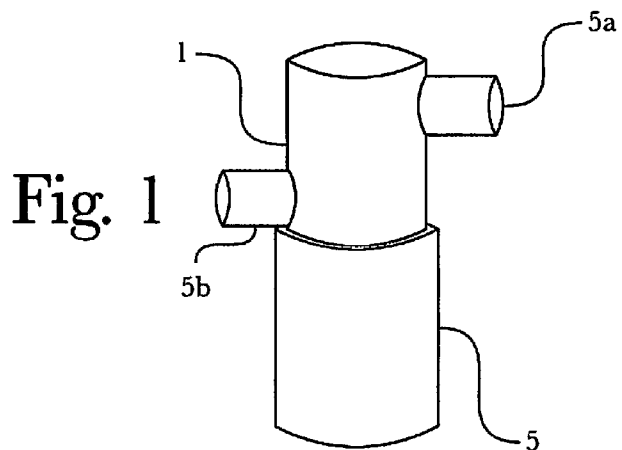
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**Related U.S. Application Data**

(63) Continuation of application No. 13/938,219, filed on Jul. 9, 2013.





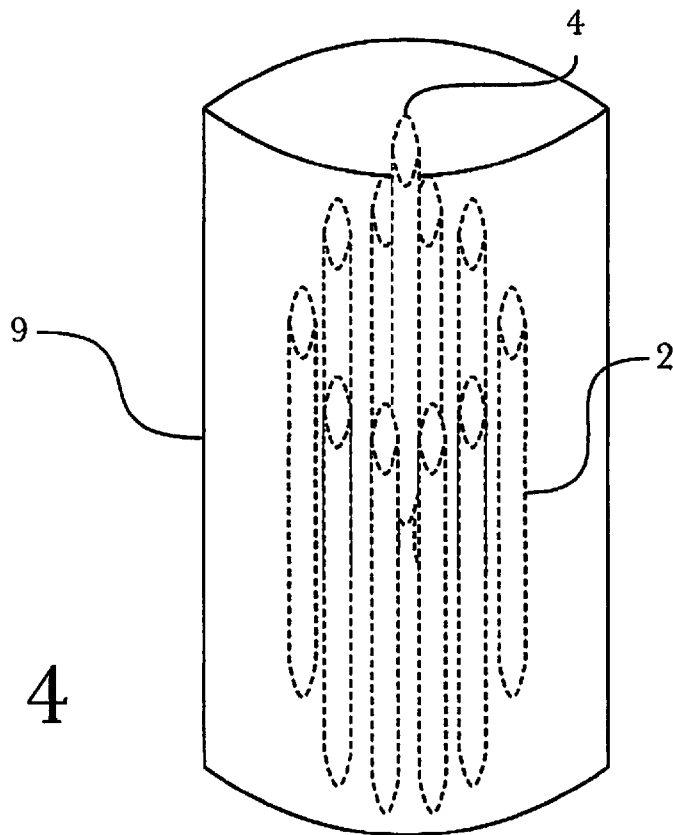


Fig. 4

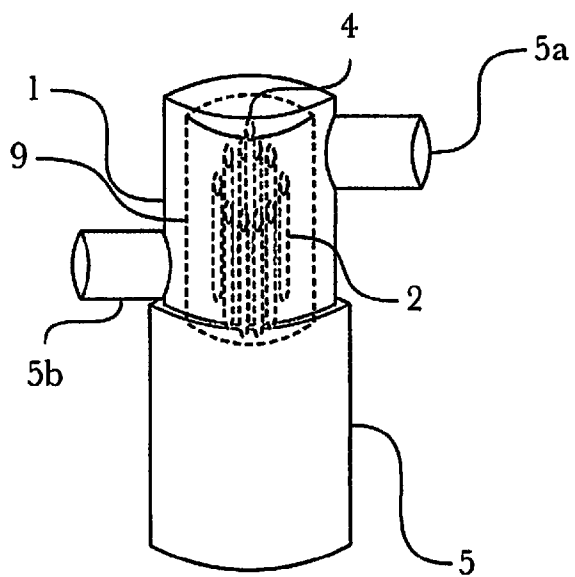


Fig. 5

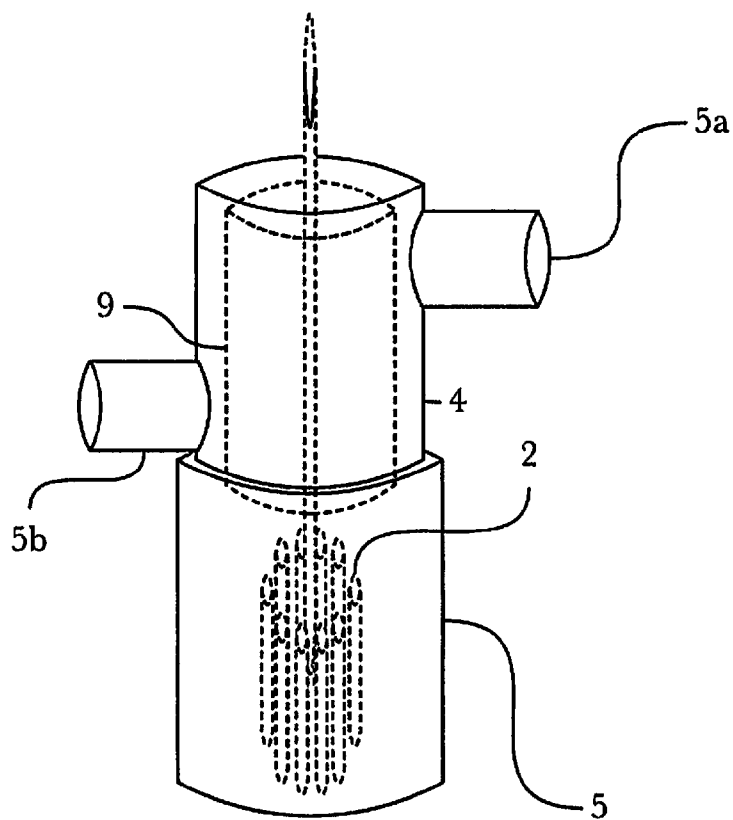


Fig. 6

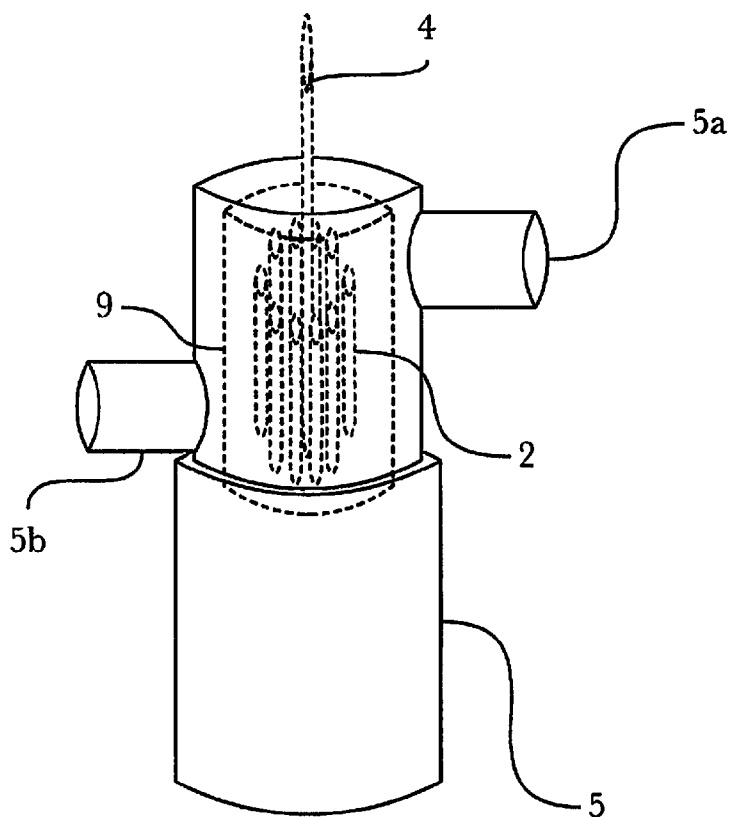


Fig. 7

**PROCESS AND RADIATOR DEVICE FOR  
WORT STERILIZATION BY RADIATION FOR  
ETHANOL PRODUCTION**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

**[0001]** This application is a continuation of U.S. patent application Ser. No. 13/938,219, entitled "PROCESS AND RADIATOR DEVICE FOR WORT STERILIZATION BY RADIATION FOR ETHANOL PRODUCTION", filed on Jul. 9, 2013, which is the national stage entry of Brazilian patent application serial number 1020120271680, filed on Oct. 23, 2012 and titled, "PROCESSO E DISPOSITIVO IRRADIADOR PARA ESTERILIZAÇÃO DE MOSTO POR RADIAÇÃO PARA A FABRICAÇÃO DE ETANOL", the entire specifications of each of which are incorporated herein by reference. A certified translation of the Brazilian patent application is filed herewith.

BACKGROUND OF THE INVENTION

**[0002]** 1. Field of the Invention

**[0003]** The invention relates to the field of ethanol production from plant-based fluids, and more particularly to application of radiation to such fluid.

**[0004]** 2. Discussion of the State of the Art

**[0005]** Ethanol is an organic substance obtained from the fermentation of sugars, hydration of ethylene, or acetaldehyde reduction widely used as a process for production of fuel for engine combustion.

**[0006]** The "wort" is the juice of any fruit or vegetable that contains sugar, upon fermentation, and before completely purified by it. It is an intermediate product common to several processes, such as in the production of ethanol from sugar cane, sugar beets, and other vegetables. The result of fermentation of the wort is called wine. The wort is an organic fluid naturally contaminated by a range of microorganisms that will compete with the yeast incorporated into the mixture (for fermentation) in the production of ethanol. This problem is common to these techniques, and the existence of a wide range of bacteria in these plants that contaminate the wort is well known in the art. This combination is responsible for reducing bacterial productivity of these processes.

**[0007]** Microorganisms contaminate the process of production of alcohol, represented by bacteria and yeast that settle in the process. These contaminants are causing problems such as the consumption of sugar that would otherwise be converted into ethanol, decreased viability of yeast cells because of toxins excreted in the fluid by the microorganisms, flocculation of yeast that causes loss of yeast cells by the fund in the dressage or spin, and consequent fall in the industrial output. Furthermore, the formation of gum increases viscosity of the broth, causing operational problems in the production facility.

**[0008]** The juice of sugar cane contains varying amounts of organic and inorganic nutrients, high water activity, favorable pH and temperature conditions, and therefore provides for great growth of microbial flora. The very conditions of each stage of the production of alcohol select for microorganisms and the whole process is subject to contamination from the sugar cane field until the fermentation of its broth.

**[0009]** Yeasts and bacteria contaminants can produce lactic acid and other organic acids that, in quantities exceeding the normal, may be responsible for a decrease in the yield of

fermentation. When this bacterial contamination reaches levels above  $10^7$  cells/ml, a significant drop in the yield of the alcohol may occur, and out-of-control bacterial contamination may indirectly cause a reduction in yield of fermentation because of the increased viscosity of the broth causing a greater loss of yeast broth centrifuged and higher consumption of sugar, diverting this from the production of sugar and alcohol.

**[0010]** The form currently used to overcome this problem in the art is the addition to the wort of various antibiotics, thereby reducing bacterial contamination. However, this process entails some new drawbacks among which are:

**[0011]** High cost of antibiotics

**[0012]** Need for periodic study of the range of bacterial contamination

**[0013]** Effects of bacterial action on yeast reduce productivity

**[0014]** Continued use of antibiotics can lead to biological and environmental problems by being re-released into the environment such as with, for example, the creation of resistant bacterial species

**[0015]** What is needed is a sterilization procedure that avoids the use of antibiotics.

SUMMARY OF THE INVENTION

**[0016]** Accordingly, the inventor has conceived and reduced to practice, in a preferred embodiment of the invention, a method and apparatus for wort sterilization by radiation for production of ethanol from sugar cane, comprising an autonomous principle that replaces the use of antibiotics, thereby eliminating this step in the process of production of ethanol from plant fluids. According to studies, irradiation reduces the dramatic contamination caused by bacteria and alterations of wort are also lower after irradiation contributing to a marginal increase in productivity. Among the main benefits of irradiation of wort are:

**[0017]** Elimination of the need to use antibiotics

**[0018]** Elimination of environmental risks generated by the combings of antibiotics in the environment

**[0019]** Reduction of production costs such as total elimination of costs associated with antibiotics

**[0020]** Increased productivity by eliminating the effects of bacterial action in the wort

**[0021]** The absorption of ionizing radiation causes chemical alterations in the cellular components of microorganisms, which may have consequences for the activity of the cells. Of all the mechanisms that are involved in radiation action on cells, the alteration in a cell's DNA is considered the most important and, as a consequence of such alterations induced by radiation, cell death may be caused. Yeasts and molds have increased sensitivity to radiation compared to some non-spore-forming bacteria.

**[0022]** Numerous studies have also demonstrated that the combination of coolant with the irradiation causes an inhibitory effect on the multiplication of spoilage microorganisms, reducing the radiation dose required to control the proliferation of these microorganisms. A radiation dose required may also vary according to the product being to be produced, for example the dose applied to apple or grape wine may be different from that applied to sugar cane, which in turn may differ from that to be applied to orange wine.

**[0023]** Care should be taken with regard to wort irradiation external dose (i.e., surrounding region), internal dose (such as of the wort itself), and environmental contamination.

**[0024]** With respect to an external dose, caution should be taken regarding the shielding of equipment, with monitoring the level of radiation in surrounding areas; proper protective equipment is necessary particularly when personnel access is needed.

**[0025]** With respect to an internal dose, some care should be taken to ensure uniformity of the applied dose of the mash and the minimum dose necessary for an appropriate level of sterilization to be reached, and with respect to the environment necessary care should be taken to reduce the possibility of radioactive leakage.

**[0026]** Radiation sterilization is an efficient method already proven in numerous applications from irradiation of food products to irradiation of medical supplies. The use of gamma radiation, as previously mentioned, is often indicated by its greater ability to penetrate the material to be sterilized with respect to other types of radiation, such as ultraviolet (UV), or electron, proton, or neutron-based radiation types.

**[0027]** Irradiation with  $\text{Co}^{60}$  gamma radiation from decay has proven to be effective in the sterilization of sugar cane pumice wort and a dose of about 10 kGy was possible to reduce to 10% the initial contamination of some bacteria. For comparison, radiation used in sterilization of medical equipment often utilizes a dosage of around 50 kGy. Thus, it can be appreciated that the optimal dose for sterilization of wort should fall between these two values, as an overdose of the wort could cause undesirable chemical changes. However, studies have shown that modification of the medium are smaller than those produced after the addition of antibiotics.

**[0028]** According to a preferred embodiment of the invention, a process of wort sterilization comprises sterilization in fluid from a radioactive source, where the fluid may be irradiated in ducts. Accordingly, the radiation can be performed in a continuous manner also incorporating fluid movement within a duct-based irradiation apparatus, as described below.

**[0029]** This process of irradiation need not be only restricted to the wort and can even replace other methods in various fields, such as the pasteurization of liquid foods or sterilization of contaminated gasses against pathogenic microorganisms. Radiation doses applied are different and may vary according to a particular purpose or application, and may feature two distinct forms, namely scaling of a source (i.e., the actual dose) and a fluid flow regulation in a duct apparatus, i.e. length of exposure to radiation. In general, any source or radiation may be utilized, however the as envisioned by the inventor  $\text{Co}^{60}$  is utilized due to its high natural abundance.

**[0030]** According to another preferred embodiment of the invention, a wort irradiator apparatus is disclosed, comprising a radiation source in a container with dimensions suitable for use in a production facility, which may be installed alongside a pipeline in such a production facility. This device may function such as to eliminate microorganisms that may contaminate a wort through irradiation appropriately sized or dosed for the application and a device may be built in a modular way such as to facilitate ease of replacement or repair in the event of damaged or faulty components or device failure.

**[0031]** According to the embodiment, the device may comprise three distinct modules: a drum for a sealed radiation source, a container that may be used for housing a fluid, and an outer shield that may be used to cover the entire container such as to prevent external radiation leakage. The apparatus may further comprise two connections, an input and an out-

put. An input connection may be located at the bottom of the apparatus and an output near the top. In this manner, the apparatus of the invention may be readily adapted to any existing production facility through the use these input and output connections.

#### BRIEF DESCRIPTION OF THE DRAWING FIGURES

**[0032]** The accompanying drawings illustrate several embodiments of the invention and, together with the description, serve to explain the principles of the invention according to the embodiments. One skilled in the art will recognize that the particular embodiments illustrated in the drawings are merely exemplary, and are not intended to limit the scope of the present invention.

**[0033]** FIG. 1 is an illustration of a wort irradiator device, according to a preferred embodiment of the invention.

**[0034]** FIG. 2 is an illustration of a radiating rod containing pellets and spacers.

**[0035]** FIG. 3 is an illustration of a complete arrangement of a radioactive source containing rods.

**[0036]** FIG. 4 is an illustration of a radioactive source drum.

**[0037]** FIG. 5 is an illustration of an outer shield casing.

**[0038]** FIG. 6 is an illustration of a device mounted in the off state.

**[0039]** FIG. 7 is an illustration of a device in the bound state.

#### DETAILED DESCRIPTION

**[0040]** The inventor has conceived, and reduced to practice, in a preferred embodiment of the invention, a method and apparatus for wort sterilization by radiation for production of ethanol from sugar cane, comprising an autonomous principle that replaces the use of antibiotics, thereby eliminating this step in the process of production of ethanol from plant fluids.

#### Detailed Description of Exemplary Embodiments

**[0041]** FIG. 1 is an illustration of a wort irradiator device, according to a preferred embodiment of the invention. As illustrated, an irradiation container 1 may be installed in a drum on top of a fluid source 5 for connection via two ducts, one inlet 5a where a wort may enter such as to undergo a sterilization process and one outlet 5b such as for exiting of a wort after sterilization. According to the embodiments (and as illustrated in the following figures, below), a wort irradiator according to the invention may comprise a container 1, round rods 2 a radiation source 3, driving rod 4, a drum source 5, and a mixer 6, an arrangement of a source 7, spacer 8, and the entire apparatus protected by a shield casing 9.

**[0042]** Referring now to FIG. 2, round rods 2 may further comprise a plurality of radiation sources 3 that may be arranged with mechanical spacers 8, such as to prevent radiation sources from coming into physical contact and to regulate a radiation dosage. Exemplary radiation sources may include (but are not limited to) Cesium-137, Iodine-131, Lanthanum-140, or any of a variety of suitable gamma radiation emission sources, as are commonly known in the art. Spacers 8 may serve to regulate total dosage of radiation, and homogeneity of irradiation applied to a wort.

**[0043]** Referring now to FIG. 3, inside a radiation container 1 may be installed an arrangement of a source 7. Such an arrangement may be formed by irradiation of cylindrical rods

2 and a driving rod 4 that may be interconnected. A number of irradiation rods 2 arranged in an array as illustrated may vary according to the invention (for example, rearranging to include more or fewer rods, or to vary the spacing or relative position of individual rods). Various vertical ducts may be fixed in an irradiation container 1 such as for separating a fluid source within the container. In this manner, it can be appreciated that a fluid may never come into direct physical contact with a radiation source and that a central duct may be reserved for movement of a driving rod 7. Cylindrical rods 2 may be connected in parallel to the bottom of a driving rod 4. This arrangement of irradiation rods 2 and driving rod 4 forms an arrangement of the source inside which radioactive sources 3 and spacers 8 may be placed.

[0044] During a sterilization process a wort may be continuously flowing inside an irradiation container 1 without the need to interrupt a grinding process. This may make a production facility's output slightly higher than that allowable by antibiotic sterilization.

[0045] Referring now to FIGS. 4 and 5, an exemplary wort irradiator drum and apparatus constructed according to an embodiment of the invention are shown. In an "off" state (as illustrated in FIG. 6), an arrangement of a source 7 positioned within a drum 5 and thus radiation may be limited within its interior, that is, an input fluid (i.e., a wort) may not be irradiated. Consequently, when an apparatus is in an "on" state (as illustrated in FIG. 7), the arrangement of a source 7 may be raised by a movement rod 4 into vertical ducts set in an irradiation container 1 and therefore radiation may be applied to an internal volume of the container 1 and maintained within the inner boundaries of a shielding enclosure 9. Thus, if a fluid is input as described above, it may be irradiated within an irradiation container 1 and exit an apparatus completely sterilized.

[0046] Taking into account that safety is a factor of extreme importance, an irradiation container 1 may be designed to be affixed into the ground (Such as within concrete), thus preventing the surrounding region to be affected by an elevated dose of radiation above that which is natural. It may also be designed with a mechanism such as to allow easy installation or uninstallation of equipment without risk to workers. Such

a mechanism may comprise a supply drum 4, which may be isolated underneath a radiation container 1. When installing or removing an arrangement 2, it may be lowered until it is installed completely within a source drum 4. Drum 4 may then be sealed, preventing radiation leakage, and may then be safely removed from a production facility.

[0047] The skilled person will be aware of a range of possible modifications of the various embodiments described above. Accordingly, the present invention is defined by the claims and their equivalents.

What is claimed is:

1. A method for sterilization of a wort, comprising the steps of:
  - conducting the wort through a plurality of fluid ducts; and irradiating the wort with gamma radiation using a plurality of radiation sources enclosed within a plurality of cylindrical rods within the fluid ducts;
    - wherein a level of radiation exposure provided to the wort is controlled by moving the plurality cylindrical rods axially within the fluid ducts, thus exposing more or less of the wort to the plurality of radiation sources.
2. The method of claim 1, wherein the wort is used for ethanol production.
3. An apparatus for sterilization of a fluid, comprising:
  - a plurality of fluid ducts;
  - a plurality of cylindrical rods;
  - a movement rod; and
  - a shielding enclosure;
 wherein the fluid ducts conduct the fluid into and out of the apparatus,
  - wherein the cylindrical rods are in a fixed arrangement and emit radiation,
  - wherein the fixed rod arrangement is movable along an axis,
  - wherein the movement rod directs movement of the fixed rod arrangement along the movement axis to regulate radiation emission dosage, and
  - wherein the shielding enclosure fully encloses the apparatus and prevents radiation contamination from leaking during operation.

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