PATENT SPECIFICATION

(11) 1 584 373

1 584 373

(21) Application No. 33909/77 (22) Filed 12 Aug. 1977
(31) Convention Application No. 261 707
(32) Filed 21 Sept. 1976 in
(33) Canada (CA)
(44) Complete Specification published 11 Feb. 1981
(51) INT CL[3] C02F 3/30//1/58, 3/08, 3/12
(52) Index at acceptance
C1C 210 216 217 253 311 400 40Y 426 431 432 436 43Y 442 461 612 623 633 665 66Y 672 67Y 68X 721 765 76Y 770 77Y 787 K

(19)

(54) PROCESS FOR PURIFYING WASTE WATERS

(71) I, FERDINAND BESIK, a Canadian citizen, of 3243 Chokecherry Cres., Mississauga, Ontario L5L 1B1, Canada, do hereby declare the invention for which I pray that a patent may be granted to me and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a purification process for removing contaminants from waste waters. The process incorporates the use of finely divided mineral or minerals to form an active sludge to increase the concentration of and to enhance the distribution of active micro-organisms in the reaction system and to assist and enhance the yield of simultaneously occuring biological and chemical reactions.

It is important to remove contaminants from raw and/or waste waters before discharge of such waters, because contaminants such as those found in sewage waters, various industrial waste waters, storm sewer waters and the like, have a destructive effect on the environment. Existing processes for removing such contaminants from waste waters entail breaking down the biodegrable contaminants by the action of active micro-organisms and removing other contaminants by physical and/or chemical precipitation techniques. With such processes, several different process steps are usually carried out in separate stages of a treatment system requiring relatively expensive equipment and the use of substantial areas of land. This type of treatment is not readily scaled down for use in treating small volumes of raw or waste waters at a site of limited size.

Embodiments of the invention seek to provide a process for removing contaminants from contaminated waters with a minimum of process steps.

Embodiments of the invention also seek to provide a waste treatment process where various organic suspended solids, nitrogen containing compounds, and phosphorus containing compounds are removed from the waste waters by co-acting biological and chemical reactions.

Embodiments of the invention further seek to provide a process for purifying contaminated waters, which is capable of unattended operation and readily lends itself to use in large municipal waste water treatment systems, apartment size waste water treatment systems, single family dwelling waste water treatment systems, waste treatment systems on boats, ships, recreational vebicles and the like, in shopping centres, airports, recreational areas, such as camps, waste treatment systems in food processing industries, fish hatcheries, pulp and paper industries, coke processing stages of steel mills, paint industry, and in any other type of industry, domestic area or raw water purification wherein partially or wholly biodegradable contaminants and non-biodegradable contaminants are to be removed.

Embodiments of the invention also seek to provide a purifying process for waste water where compared to existing systems the waste water may be processed in a more efficient manner to thereby reduce the physical size of the treatment system.

Embodiments of the invention also seek to provide a waste treatment process whereby waste waters are efficiently contacted with highly concentrated activated sludge containing the mixed active microbial population for digesting the contaminants.

According to the invention there is provided a purification process for the removal of bio-degradable suspended and dissolved organic solids and nitrogenous comounds, and phosphates from contaminated waters by biological and chemical reactions carried out simultaneously in the presence of an active media which includes mixed microbial population and powdered minerals, said process comprising:

i) adding to the system of finely divided mineral of a particle size less than 50 mesh United States Standard Screens to provide a concentration of mineral in such active media ranging from approximately 1 gm/l. up to approximately 200 gm/l., the selection of mineral being determined by the characteristics of:

a) its being non-toxic to the micro-organisms

b) having surfaces which attract micro-organisms, and absorb organic and, nitrogenous compounds and phosphates to assist in and expedite the simultaneously occurring biological and chemical reactions, and

c) having limited solubility in the processed waste waters, where the metal ions released by the mineral's dissociation in such waters react with phosphates present in the processed waste waters to form insoluble metal phosphates;

ii) building up a mixed microbial population by retaining and growing the various micro-organisms present in the waste waters on the surfaces of the mineral particles retained in the various zones of the reaction system;

iii) circulating the active media which includes mixed microbial population and powdered minerals through a reaction system which comprises three zones in which biological oxidation and biological denitrification reactions occur simultaneously with the chemical reactions throughout the system;

iv) flowing such contaminated waters through the first biological oxidation zone to contact such waters with the active media wherein such process comprises:

a) maintaining the concentration of dissolved oxygen in the zone's upstream end at approximately 1 mg./l. to 2 mg./l., to support the biological oxidation of bio-degradable organic solids to carbon dioxide and the biological oxidation of nitrogenous compounds to nitrites and nitrates, the particulate mineral expediting the biological oxidation reactions by concentrating the micro-organisms and the organic nitrogenous compounds at it's particles surfaces,

b) controlling the duration which such waters remain in said first zone as they flow therethrough to maintain a concentration of dissolved oxygen at the downstream end of the first zone below 1 mg./l. to thereby induce biological denitrification reactions, the amount of dissolved oxygen being reduced by the biological and chemical reactions, and simultaneously

c) precipitating phosphate ions by the reaction of said metal ions which are released by dissociation of said mineral with the phosphate ions to form insoluble precipitates to thereby lower the concentration of phosphate ions in the first zone of the system.

v) flowing such waters and a portion of the active media from said first zone upward through the second zone which is a sludge settling zone, the biological denitrification reactions continuing wherein the second zone the concentration of dissolved oxygen is reduced further to less than 0.5 mg./l., the biological denitrification reactions reducing the concentration of nitrites and nitrates, the particulate mineral in the active media expediting the biological respiratory denitrification reactions due to the organic matter attached to the mineral particles while simultaneously precipitating more of the remaining phosphate ions by the released metal ions to thereby reduce further the concentration of phosphate ions in the processed waters;

vi) controlling the upward rate of flow of such waters in the second zone to provide a quiescent region which permits most of the active media to separate from such waters;

vii) flowing such waters and a small portion of the active media from the second zone to the third zone which is the clarifying zone, maintaining the concentration of dissolved oxygen in said third zone below 1 mg./l. so that the biological denitrification reactions are continued with remaining organic matter absorbed on the particulate mineral surfaces supporting the activity of the denitrifying organisms, the precipitation of phosphate ions continuing due to the constant release of metal ions from the mineral so that the concentration of phosphate ions in the processed water is reduced even further and separating the treated waters from the active media to provide a clarified effluent with substantially reduced concentrations of suspended solids, organic and nitrogenous compounds and phosphates;

viii) recirculating a portion of the active media from said third zone to said first biological oxidation zone, and

ix) withdrawing a portion of the active media from said third clarifying zone, aerating same and recycling the aerated active media back into the third clarifying zone where the dissolved oxygen content is maintained at below 1.0 mg./lit.

The process of the preceding paragraph involves contacting contaminated waters with active media which includes, among other things, active micro-organisms in activated sludge, and one or more powdered or finely divided minerals. The presence of mineral in the active media enhances the concentration and distribution of the active micro-organisms within the reaction system and assists in efficient microbial degradation of biodegradable contaminants and in the precipitation of ionic species present in the processed waste water. The selected powdered mineral or minerals should be essentially insoluble in the waste waters and non-toxic to the active micro-organisms.

Although the powdered mineral or minerals used have limited solubility or are essentially insoluble in the processed waste water they will, however, dissociate to a certain degree to release metal ions. The released metal ions assist in the control of the pH of the processed waste water and also combine with other ion species in the waste water, such as phosphates, to form insoluble precipitates and thereby assist in the removal of phosphates from the waste water. Due to the essentially insoluble nature of the minerals used in the process, replenishing of the minerals is kept to a minimum.

To improve the clarity of the effluent, powdered or granular activated carbon may be added to the active media. In addition, various treatment chemicals, such as alum and flocculating agents, may be added to improve the quality of the effluent according to standard sewage treatment techniques.

The use of one or more powdered minerals in waste treatment systems particularly enhances the efficiency of fluidized bed reaction systems. The minerals combine with or collect on their surfaces the active micro-organisms so that the suspended mineral particles in the fluidized bed enhance the distribution of the micro-organisms in the waste waters as they pass through the fluidized bed. Due to their relatively high density, the minerals assist in maintaining a high concentration of the mixed microbial population in the fluidized bed and also permit the treatment of higher flow rates of waste waters than could be treated by prior processes.

The concentration of the powdered mineral in a fluidized bed may vary considerably, depending upon the density of the selected mineral and the flow rates of waste waters through the fluidized bed. The concentration of mineral should be sufficient to increase the density of the activated sludge by the combination of mineral therewith so that there is an effective net increase in the concentration of active micro-organisms within the fluidised bed. The mineral is usually finely divided and is of a particle size of 50 mesh or less United States Standard Screens.

Suitably, a fluidized bed of active media is established in the lower region of the third clarifying zone to increase the concentration of the active micro-organisms in this zone to enhance the contact of the micro-organisms in this zone with the upward flowing waters, and to provide efficient separation of suspended solids from the treated waste water by the fluidized active media, the height of said fluidized bed established in the third clarifying zone being sufficient to permit separation of active media from the treated waters to provide a clear effluent.

Alum may be added to the fluidized bed of activated sludge to assist in the removal of phosfhates from contaminated waters, the quantity of alum ranging from approximately 20 to 200 mg./lit.

The mineral used in processes embodying the invention may be selected from Calcite, Cerussite, Clinoptilolite, Corundum, Diaspore, Gibbsite, Halloysite, Hematite, Kyanite, Millerite and mixtures thereof.

Activated carbon may be added to such waters in a ratio of activated carbon to mineral ranging from 1:10 up to 1:3, said activated carbon being powdered or granulated.

In order to promote the various biological processes which take place in the microbiological degradation of the contaminants, differing concentrations of dissolved oxygen should be maintained in the treatment system to ensure the bio-oxidation of suspended organics, the nitrification of ammonia compounds and respiratory denitrification of nitrites and nitrates. Further, the mixing in the fluidized bed promotes the precipitation of phosphorus containing compounds by metal ions dissociated from the minerals, promotes the flocculating or coagulating of the suspended solids and maintains a pH of the liquid favourable to the formation of phosphate ions and the like.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings wherein:

Figure 1 is a schematic view of apparatus which may be used in carrying out the process according to this invention;

Figure 2 is a partially cut away perspective view of the equalization and aeration chamber according to a preferred embodiment of the invention for use in treating waste waters;

Figure 3 is a cut away perspective view of the clarifying chamber of the apparatus, which is in communication with the reactor chamber shown in Figure 2 of the drawings;

Figure 4 is a section taken along the line 4—4 of Figure 3; and

Figure 5 is a graph showing the settling rates of various forms of active media.

It is not fully understood how the powdered mineral combines with the active micro-organism and affects the simultaneously occurring biological-chemical reactions, however, it is theorized that the powdered minerals provide surfaces on which active micro-organisms locate to thereby increase the density of the formed active sludge and the activity of the solid surfaces assist in some way in the chemical reaction. This expedites separation of the sludge from the waste waters and enhances the distribution of the micro-organisms in the active sludge as waste waters flow therethrough and the yield from the simultaneously occuring chemical and biological reactions. As the population of the micro-organisms increases, the mineral serves to retain the micro-organisms in the sludge and this helps to maintain a high concentration of micro-organisms in the reaction system. There are several types of minerals which may be used providing they are non-toxic to the micro-organisms, finely divided and are essentially insoluble in the waste waters. Examples of minerals which may be used in the process are: Calcite, Cerussite, Clinoptilolite, Corundum, Diaspore, Gibbsite, Halloysite, Hematite, Kyanite, Millerite, mixtures thereof and the like.

Most of these minerals are insoluble, or essentially insoluble in water, for example Gibbsite and Hematite are essentially insoluble whereas Calcite and Corundum have a slight degree of solubility in water. It is understood, of course, that even the minerals which are essentially insoluble in water tend to dissociate and release metal ions into the processed waste water. These released metal ions may combine with phosphates and other ionic species in the waste water to form insoluble precipitates. The released metal ions also assist in the control of the pH of the system where the desired range is between 6 to 8.

The powdered minerals are ground so that they pass through United States Standard Screen Mesh Size 50 and up to 300 or more. The more finely the mineral is divided, the larger the surface area on which the micro-organisms and suspended solids may locate and are adsorbed thereon.

The waste waters when treated according to the processes of this invention are contacted with a mixture of active micro-organism, one or more powdered minerals, precipitates, and other additives. This combination is referred to, as hereinbefore, as the active media.

With the attendant advantages of the process of this invention, sewage treatment systems may be developed in various sizes ranging from that which may be installed in the basement of a single family dwelling to sizes which are capable of handling municipal waste waters, industrial waste waters and other sources of large volume of waste or raw waters. The process according to this invention may be readily used in the existing sewage treatment systems, such as the activiated sludge process which treats both municipal and industrial waste. According to a preferred embodiment of the invention, Figure 1 shows a schematic of a reactor system in which an aspect of the process according to this invention may be carried out.

The reactor system 10 comprises an equalization chamber 12, an aeration chamber 14, a sludge separation chamber 16 and a clarifying chamber 18. Air is supplied to the various air pumps in the reactor system 10 by air line 20. Waste waters enter the reactor system 10 by pipe 22 which feeds into the equalization chamber 12. Equalization chamber 12 dampens the effect of wide variations in the flow rate of incoming waste waters on the hydraulics and liquid levels in the remainder of the system.

The level of the waste waters in the equalization chamber 12 may vary from level 24 up to level 26 without substantially affecting the levels in the aeration chamber 14 nor the sludge separation chamber 16. An air diffuser 28 is located between plate 30 and the wall of chamber 12 to promote mixing in the direction of arrows 32. The mixing of the raw incoming waste waters with the material already in the equalization chamber tends to level out extremes in the concentration of various types of contaminants.

The material in the equalization chamber 12 is pumped into the aeration chamber 14 by air pump 34. Depending on the type of air pump used the hydrostatic head can affect the flow rates through the pump. For higher levels of liquid in the equalization chamber the pump may transfer the liquid at a higher flow rate than when the liquid level is lower. The flow rate of the waste liquid through the pump 34 determines the flow rates of waste waters through to the clarifier and, in turn, the flow rate of the effluent because the remainder of the system is balanced hydrostatically. It is understood, of course, where a constant flow rate of incoming waste water can be achieved and is at a rate so as not to upset the hydraulics of the remainder of the system, the equalization chamber 12 may be eliminated.

The aeration chamber 14 is essentially isolated from the sludge separation chamber 16 by a slanted partition 36. Air diffusers 38 are positioned behind a partition 40 to draw active media and the processed waste water from the sludge separation chamber and lift it upwardly through aeration channel 42. The aerated waters flow out of channel 42 into the aeration chamber 14 in the direction of arrow 44. The slanted plate 36 isolates the waters from the sludge separation chamber 16 so that such waters flow downwardly towards the throat 46 at the base of the aeration chamber 14. Due to the air diffusers 38 drawing liquid from the sludge separation chamber 16, the flow rate of the liquid increases as it passes through the throat 46 because it acts as a constriction to the flow. The liquid then flows upwardly in the direction of arrows 48 to expand a bed of active media settled at the base of chamber 16 and with a sufficient upward flow rate of liquid the bed of active media is expanded further to form a fluidized bed in this area of the sludge separation chamber 16. In addition, the upward flow of the liquid lifts active media settling at the base of the sludge separation chamber up into the fluidized bed area to maintain a high concentration of active micro-organisms in the fluidized bed of active media. The active micro-organisms in the active media is therefore fluidized in this area for a particular flow rate of the waste waters as determined by the rate at which the air diffusers 38 pump the liquid up through channel 42 and as influenced by the rate at which pump 34 transfers liquid from equalization chamber 12 into the aeration chamber 14.

A minor portion of the aerated waste waters as it leaves channel 42 flows across the top of reactor chamber 14 and empties back into the equalization chamber 12 through the opening 50 provided in the partition 52 of the reactor system. In this manner the active media including micro-organisms is introduced into the equalization chamber for purposes of beginning the biological and chemical degradation of contaminants in the waste waters and also to offset variations in concentrations of contaminants in the incoming waste waters.

The concentration levels of dissolved oxygen in the aeration chamber 14 and the sludge separation chamber 16 vary a substantial amount to provide an aerobic environment in which the mixed population of micro-organisms oxidize the organics and nitrify the ammonia compounds to form metal nitrates and nitrites and to provide an essentially anoxic environment in the same system whereby the mixed microbial population denitrify the nitrates and nitrites to form free nitrogen. The dissolved oxygen levels in the upper portion of aeration chamber 14 are the highest due to passage of waste waters through aeration chamber 42. The oxygen levels are usually in the range of 1 mg./l. up to 2 mg./l. As the waste waters and active media flow downwardly in the reactor chamber 14 the level of dissolved oxygen decreases due to the take-up oxygen in the biological oxidation of degradable organics and the nitrification of the ammonia compounds. The dissolved oxygen is at a lower level in the throat area 46 of the reactor and may be less than 0.5 mg./l. The environment in the chamber 16, therefore, approaches anoxic conditions and as a result the mixed microbial population begins respiratory denitrification of the nitrates and nitrites to remove oxygen molecules thereform and release free nitrogen from the system. The denitrification of nitrates and nitrites is continued in the fluidized bed area of arrow 48. A portion of the active media in the fluidized bed area is extracted as shown by arrow 54 and returned to the aeration channel 42. Above the fluidized bed area 48 the active micro-organisms, precipitates and other solids separate from the processed waste liquid in the quiescent zone 57. The processed waste waters flow into the clarifier 18 via conduit 56.

The concentration of the micro-organisms in the active media can become high, particularly in the fluidized bed area of the sludge separation chamber due to the inherent efficiencies of a fluidized bed. It has been found that the concentration of active media in the mixed liquor is in excess of 20 gm./l. Due to the characteristics of the fluidized bed the active media do not flow out through conduit 56 to clarifier 18 unless there is an excess caused by growth in the microbial population.

Biochemical reactions are carried out also in clarifier 18. To ensure that active micro-organisms are in the clarifier without relying on excess being transferred by conduit 56, air pump 58 is provided to pump active media which contain micro-organisms into clarifier 18 through conduit 60. Chemicals such as alum and flocculating agents may be introduced into the clarifier in accordance with standard sewage treatment procedures.

The clarifier serves to separate the suspended solids from the waste waters and to further reduce the level of contaminants in such waters to provide a clear odourless effluent with concentration of phosphates, nitrates, nitrites, ammonia and BOD which is safe for the environment.

The clarifier 18 has a fluidized bed formed in the general area 62 by the arrangement of the hydraulics shown in the drawings in the directions of the arrows. Air pumps 64 withdraw liquid from the fluidized bed area in the direction of arrows 66 and lift the liquid upwardly in annular channel 68. The material flows over into and downwardly in channel 70 as it is combined with effluent coming from the sludge separation chamber 16. The quantity of dissolved oxygen in the processed waste waters in the channel 70 of the clarifier is usually below 1.0 mg./l, so that in essence the mixed microbial population finds itself in an anoxic environment. The respiratory denitrification of the nitrites and nitrates is continued where remaining organic matter adsorbed on the particulate mineral surfaces serve as a source of carbon to support the biological reactions. As the material exits from channel 70 it flows upwardly in the direction of arrows 71. Due to the configuration of the chamber 18 with the outwardly sloping sidewalls, the flow rate of the liquid is highest at the bottom and decreases as it flows upwardly to effectively form a fluidized bed of active media in the area 62. Above the active media a layer 72 of light particles or sludge is formed from which a portion of solids is extracted by skimmer 74 and either returned to the aeration chamber 14 by conduit 76 or a portion thereof discarded by conduit 78.

Flocculating agents and coagulants may be added to complete the removal of phosphates and other undesirable suspended solids in accordance with standard sewage treatment techniques to provide clarified waste water in the upper portion 80 of the clarifier. Any solids floating on the top of the waters are removed by skimmer 82 and returned to the aeration chamber 14 by conduit 84. The effluent leaves the clarifier by conduit 86 where floating solids are separated from the effluent by trap 88.

The powdered mineral or minerals may be added to the aeration chamber or the clarifier. The minerals are then circulated amongst the remaining chambers via the hydraulics of the system. A major portion of the mineral circulates in the clarifying chamber due to its greater size. As discussed, in the fluidized bed area 62, the top layers 72 thereof contain predominantly the biological solids mixed with the precipitates and some minerals. The lower portion of the fluidized bed contains the major portion of the powdered minerals. Thus, the excess sludge which is removed by skimmer 72 is mostly non-degradable solids, excess biological solids, the formed precipitates and some minerals which are recirculated. The oxygen required to continue the bio-oxidation of remaining organic matter and ammonia in the fluidized bed 62 is introduced by air diffusers 64. A small amount of active media is recirculated to the clarifier via lines 60 and 61 to supplement the active micro-organisms in the clarifier. During the cold weather, the activity of the micro-organisms in the fluidized bed of the clarifier can be increased by adding methanol or some other acceptable source of carbon in addition to organic matter already present in waters to satisfy the diet of the micro-organisms.

As can be appreciated, the waste waters as contacted with the active media, are treated in various chambers of the treatment system to provide a clarified effluent which after disinfection by ozone treatment or the like, is safe for discharge into the environment. The treatment system provides by selected hydraulics a fluidized bed which enhances the removal of contaminants from waste waters in an efficient manner. Such a system can be considerably miniaturized for use in limited quarters such as in the treatment of domestic sewage in apartment buildings, townhouse developments, single family dwellings or the like. It is understood, however, that the system can also be substantially enlarged to handle very high volumes of municipal waste liquids. Figures 2 through to 4 show a preferred embodiment of the inventive apparatus for the treatment of domestic sewage.

Figure 2 shows the equalization chamber 90, the aeration chamber 92, and the sludge separation chamber 94. The clarifying chamber is located at the back as shown in shadow at 96. This system is therefore analogous to and functions in the same manner as the system schematically shown in Figure 1. Raw sewage waters are fed into the equalization chamber 90 where the level in the equalization chamber may go as high as level line 98. The equalization chamber 90 is separated from the aeration chamber 94 by partition 100. The processed waste waters in the aeration chamber 92 are returned to the equalization chamber 90 via the V-shaped opening 102 provided in the partition 100. The mixture of active media and raw sewage waters in the equalization chamber is lifted into the aeration chamber 92 by air pump 104 and discharged in the direction of arrow 106.

The rate at which air pump 104 pumps the waste waters into the aeration chamber 92 varies depending on the height of hydrostatic head of the waste liquid in the equalization chamber. If there is a large influx of waste waters to raise the level in the chamber 90, the air pump 104 pumps at an increased rate. The flow rate in the aeration chamber and the remaining chambers depends upon the flow rate of waste waters through the air pump 104. The equalization chamber 90 therefore dampens extremes in flow rates of incoming raw sewage.

The active media is circulated through aeration chamber 92 and sludge separation chamber 94 by way of air diffusers 108 which are placed behind a partition 110. An intake 112 is provided at the base of the reactor as more clearly shown in Figure 4. An aeration channel 114 is defined between the partition 110 and the backwall 116 of the aeration chamber. Waste waters and active media are lifted up through channel 114 by air diffusers 108 and split over the top of partition 110 into the aeration chamber 92. The waste waters and active media move downwardly in aeration chamber 92 and are caused to flow to the front of the chamber in direction of arrow 117 by slanted baffle plate 118. The baffle extends all the way across chamber 92 to its sidewalls 100 and 101 to isolate chamber 92 from chamber 94. The waste waters travel into the sludge separation chamber 94 through gap 120 at the base of baffle 118. The gap 120 constitutes a constriction to the flow of liquid so that the flow rate is increased as it rises in direction of arrow 121 to thereby create a fluidized bed in sludge separation chamber 94. The mineral present in the active media assists in retaining the active micro-organisms in the fluidized bed so that in the upper portion of chamber 94, skimmer 122 takes off the processed waste waters and transfers them by air pump 124 through the conduit 132 in the direction of the arrow 126. A small portion of active media may be continuously circulated from the aeration chamber 92 to the clarifier 96 by way of air pump 128 through conduit 134 in the direction of arrow 130.

Turning to Figure 3, the active media and processed waste water enter the clarifier chamber 96 via a funnel-shaped downflow channel 136. The base 138 of the funnel-shaped channel is above the bottom 140 of the clarifier to define a gap 142 as shown in Figure 4. From this point the material flows upwardly in the direction of arrow 146 to create a fluidized bed of active media in the area 144. Slanted plates 148 and 150 define a chamber 145 around funnel-shaped channel 136. The plates 148 and 150 extend upward a sufficient distance to provide a volume of adequate size to ensure the formation and maintenance of a fluidized bed in chamber 145. Air lifts 152 and 154 are located between plates 148 and 150 and the respective outside walls 149 and 151 of the clarifier. The air lifts have intakes at 156 and 158 to withdraw material from the base of the sludge settling chambers 160 and 162 and lift the material upwardly and direct it into the funnel-shaped chamber 136. The location of intakes 156 and 158 assist in the settling of sludge in chamber 160 and 162. The openings 164 and 166 are directed in a manner so as to cause the material in the funnel-shaped channel 136 to form a vortex in the funnel-shaped chamber to assist in the mixing of the material. The air lifts 152 and 154 add some oxygen to the active media so that the biological oxidation of contaminants may continue as the active media and waste water descends in chamber 136.

Active media and waste water from the fluidized bed 144 are lifted directly from the fluidized bed by air lift 168 and dumped into chamber 136 so as to ensure a level of actve media in the downflow portion of funnel-shaped chamber 136.

Floatable solids are skimmed off the surface by skimmers 170 and 172 and returned to the aeration chamber and to the equalization chamber by conduit 174 and 176. A portion of settled sludge is extracted from sludge settling chamber 160 by air lift 178 and returned to the equalization chamber by pipe 180. Some of the returned sludge may be discarded through T-junction 181 in pipe 180.

The clarified effluent which is above the fluidized bed area 146 and the sludge settling chamber 148 is removed from the clarifier by separator 182. A baffle plate 184 is located beneath the separator 182 to deflect the upflowing lighter suspended solids of the fluidized bed away from the separator 182.

The selected mineral or minerals may be added to the clarifier where, due to the recycling of active media between the clarifier and the aeration chamber, the system equalizes with a major portion of mineral circulating in the clarifier and the minor portion circulating in the aeration and sludge separation chambers.

The effluent from separator 182 may be collected in a sump and periodically pumped from the sump for discharge. As previously discussed, flocculating agents and chemicals which cause precipitation of ion species in the waste waters may be added to the clarifying chamber. The addition of these treatment materials may be by metering pump where the quantity added is based on the quantity of effluent. It follows that with the use of a sump for collecting effluent, each time the sump pump is activated to discharge a predetermined quantity of effluent, the metering pump can be activated to dispense the desired quantities of treatment chemicals.

As is appreciated by those skilled in the art, several different types of flocculating agents may be used in accordance wtih standard sewage treatment techniques. Particularly useful agents are the cationic polyelectrolyte type such as "CATFLOC" (trademark) sold by Calgon Corporation.

Figure 5 illustrates the effect the addition of a mineral has on the settling rate of the active media. Curve 1 shows the settling time for standard activated sludge; Curve 2 shows the settling time for the combination of standard activated sludge with activated carbon; and Curve 3 shows the settling time for the combination of mineral, activated carbon and active micro-organisms. Curve 3 is substantially below Curve 1. It is therefore apparent that the addition of minerals to the active micro-organisms substantially increases the density of the active media so as to assist in the settling of sludge.

Example 1.

The reactor system shown in Figures 2, 3 and 4, was used to treat raw domestic sewage from an apartment building in TORONTO, CANADA. The total volume of sewage processed varied from 100 to 360 Imp Gallons per day on a batchwise flow basis.

For purposes of comparison, two experimental runs were carried out. Run #1 had the mineral Gibbsite added to the active micro-organisms together with powdered activated carbon, coagulant and alum. Run #2 had all the ingredients of Run #1 plus the addition of methanol to the clarifier. The flocculating agent and alum were added to achieve maximum clarity in the effluent.

The operating parameters of the process are shown in Table 1 and the quantitative results of the tests are shown in Table 2. Average values are noted for samples taken.

TABLE 1

OPERATING DATA	RUN #1	RUN #2
TOTAL SYSTEM'S VOLUME (Imp. Gal.)	350	350
REACTOR & SLUDGE SEPARATION CHAMBER VOLUME (Imp. Gal.)	240	240
CLARIFYING CHAMBER VOLUME (Imp. Gal.)	110	110
FLOW RATE OF SEWAGE (Imp. Gal./Day)	100–200	100–200
PROCESS AIR (SCFM)	6	6
DISSOLVED OXYGEN:		
Aeration Chamber (mg./l.)	1.0–2.0	1.0–2.0
Clarifier (mg./l.)	0.0–1.0	0.0–1.0
SUSPENDED SOLIDS		
Aeration Chamber (gm./l.)	100	100
ACTIVE MEDIA		
Mineral – Gibbsite (lb.)	200	200
Activated Carbon (lb.)	30	30
Micro-organisms	Yes	Yes
TREATMENT CHEMICALS		
Alum (mg./l. of effluent)	100	100
"CATFLOC" (mg./l. of effluent)	5	5
Methanol (mg./l. of effluent)	–	300

TABLE 2

WATER QUALITY	RAW SEWAGE	EFFLUENT			
		RUN #1	% REMOVED	RUN #2	% REMOVED
SUSPENDED SOLIDS (mg./l.)	40–400	<3.0	99	3.0	99
TOTAL DISSOLVED SOLIDS (mg./l.)	300–600	<500	–	<500	–
TURBIDITY (NTu)	80–160	<0.7	99	<0.5	99+
BOD_5 (mg./l.)	200–400	<2.0	99+	<2.0	99+
NH_3–N (mg./l.)	10–30	<0.1	99+	1.0	96.6
NO_3–N (mg./l.)	0.1–0.2	10–15	–	1.5	–
PO_4–P (mg./l.)	4–10	<0.1	99	<0.1	99
pH	7–8	7.0–7.5		7.0–7.5	

Referring to Table 2, the amount of ammonia in Run #1 was substantially removed, however, there was still a high level of nitrates in the system. The addition of methanol to the clarifier in Run #2 provided the additional source of carbon needed to satisfy the diet of the micro-organisms to promote the respiratory denitrification of the nitrates and nitrites as evidenced by the substantial reduction in level of nitrates to 1.5 mg./l. The use of mineral in fluidized beds of a sewage treatment system of the type disclosed herein provides for the efficient removal of contaminants from waste liquid as illustrated in Tables 1 and 2.

WHAT I CLAIM IS:—

1. A purification process for the removal of bio-degradable suspended and dissolved organic solids and nitrogenous compounds, and phosphates from contaminated waters by biological and chemical reactions carried out simultaneously in the presence of an active media which includes mixed microbial population and powdered minerals, said process comprising:

i) adding to the system a finely divided mineral of a particle size less than 50 mesh United States Standard Screens to provide a concentration of mineral in such active media ranging from approximately 1 gm/l. up to approximately 200 gm/l., the selection of mineral being determined by the characteristics of:

a) its being non-toxic to the micro-organisms

b) having surfaces which attract micro-organisms, and adsorb organic and, nitrogenous compounds and phosphates to assist in and expedite the simultaneously occuring biological and chemical reactions, and

c) having limited solubility in the processed waste waters, where the metal ions released by the mineral's dissociation in such waters react with phosphates present in the processed waste waters to form insoluble metal phosphates;

ii) building up a mixed microbial population by retaining and growing the various micro-organisms present in the waste waters on the surfaces of the mineral particles retained in the various zones of the reaction system;

iii) circulating the active media which includes mixed microbial population and powdered minerals through a reaction system which comprises three zones in which biological oxidation and biological denitrification reactions occur simultaneously with the chemical reactions throughout the system;

iv) flowing such contaminated waters through the first biological oxidation zone to contact such waters with the active media wherein such process comprises:

a) maintaining the concentration of dissolved oxygen in the zone's upstream end at approximately 1 mg./l. to 2 mg./l., to support the biological oxidation of bio-degradable organic solids to carbon dioxide and the biological oxidation of nitrogenous compounds to nitrites and nitrates, the particulate mineral expediting the biological oxidation reactions by concentrating the micro-organisms and the organic nitrogenous compounds at it's particles surfaces,

b) controlling the duration which such waters remain in said first zone as they flow therethrough to maintain a concentration of dissolved oxygen at the downstream end of the first zone below 1 mg./l. to thereby induce biological denitrification reactions, the amount of dissolved oxygen being reduced by the biological and chemical reactions, and simultaneously

c) precipitating phosphate ions by the reaction of said metal ions which are released by dissociation of said mineral with the phosphate ions to form insoluble precipitates to thereby lower the concentration of phosphate ions in the first zone of the system,

v) flowing such waters and a portion of the active media from said first zone upward through the second zone which is a sludge settling zone, the biological denitrification reactions continuing wherein the second zone the concentration of dissolved oxygen is reduced further to less than 0.5 mg./l., the biological denitrification reactions reducing the concentration of nitrites and nitrates, the particulate mineral in the active media expediting the biological respiratory denitrification reactions due to the organic matter attached to the mineral particles while simultaneously precipitating more of the remaining phosphate ions by the released metal ions to thereby reduce further the concentration of phosphate ions in the processed waters;

vi) controlling the upward rate of flow of such waters in the second zone to provide a quiescent region which permits most of the active media to separate from such waters;

vii) flowing such waters and a small portion of the active media from the second zone to the third zone which is the clarifying zone, maintaining the concentration of dissolved oxygen in sad thrd zone below 1 mg./l. so that the biological denitrification reactions are continued with remaining organic matter adsorbed on the particulate mineral surfaces supporting the activity of the denitrifying organisms, the precipitation of phosphate ions continuing due to the constant release of metal ions from the mineral so that the concentration of phosphate ions in the processed water is reduced even further and separating the treated waters from the active media to provide a clarified effluent with substantially reduced concentrations of suspended solids, organic and nitrogenous compounds and phosphates;

viii) recirculating a portion of the active media from said third zone to said first biological oxidation zone, and

ix) withdrawing a portion of the active media from said third clarifying zone, aerating same and recycling the aerated active media back into the third clarifying zone where the dissolved oxygen content is maintained at below 1.0 mg./lit.

2. A purification process according to Claim 1, wherin the velocity of such waters as they flow upwardly in said second sludge settling zone is controlled to form in the zone's lower region a fluidized bed of the active media to efficiently remove the suspended particles from the upwardly flowing treated waters, and to provide an effective reaction zone for the simultaneously occurring biological reactions and chemical precipitation reactions.

3. A purification process according to Claim 1 or Claim 2, wherein a fluidized bed of active media is established in the lower region of the third clarifying zone to increase the concentration of the active micro-organisms in this zone to enhance the contact of the micro-organisms in this zone with the upward flowing waters, and to provide efficient separation of suspended solids from the treated waste water by the fluidized active media, the height of said fluidized bed established in the third clarifying zone being sufficient to permit separation of active media from the treated waters to provide a clear effluent.

4. A purification process according to Claim 3, alum being added to the fluidized

bed of activated sludge to assist in the removal of phosphates from contaminated waters, the quantity of alum ranging from approximately 20 to 200 mg./lit.

5. A purification process according to Claim 3 or Claim 4, a flocculating agent being added to said fluidized bed of activated sludge to assist in the removal of suspended solids from the contaminated waters.

6. A purification process according to Claim 3, Claim 4 or Claim 5, sludge being withdrawn from said clarifying chamber at the upper level of the fluidized bed, a portion thereof being returned to said aeration chamber and the remainder discarded.

7. A purification process according to any preceding Claim, wherein an equalization zone is added before said first biological oxidation zone, flowing contaminated waters to be treated into said equalization zone, mixing the content in this zone by air, constantly flowing a portion of such waters from said equalization zone into said first biological oxidation zone, recirculating a portion of active media from said first biological oxidation zone to said equalization zone to begin the various biological and chemical reactions in said equalization zone, and maintaining the concentration of dissolved oxygen in equalization zone at below 1.0 mg./lit.

8. A purification process according to any preceding Claim, wherein a portion of active media from said first biological oxidation zone is constantly transferred to said third clarifying zone to establish and maintain a level of active media therein.

9. A purification process according to any preceding Claim, said mineral being selected from Calcite, Cerussite, Clinoptilolite, Corundum, Diaspore, Gibbsite, Halloysite, Hematite, Kyanite, Millerite and mixtures thereof.

10. A purification process according to Claim 9, activated carbon being added to such waters in a ratio of activated carbon to mineral ranging from 1:10 up to 1:3, said activated carbon being powdered or granulated.

11. A purification process according to any preceding Claim, a source of carbon being added to said clarifying chamber to assist in the respiratory denitrification of nitrates and nitrites, said source of carbon being digestable by the micro-organisms of the active media.

12. A purification process substantially as hereinbefore described with reference to the accompanying drawings.

For the Applicant:—
RAWORTH, MOSS & COOK,
Chartered Patent Agents,
36 Sydenham Road,
Croydon,
Surrey, CR0 2EF.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1584373 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

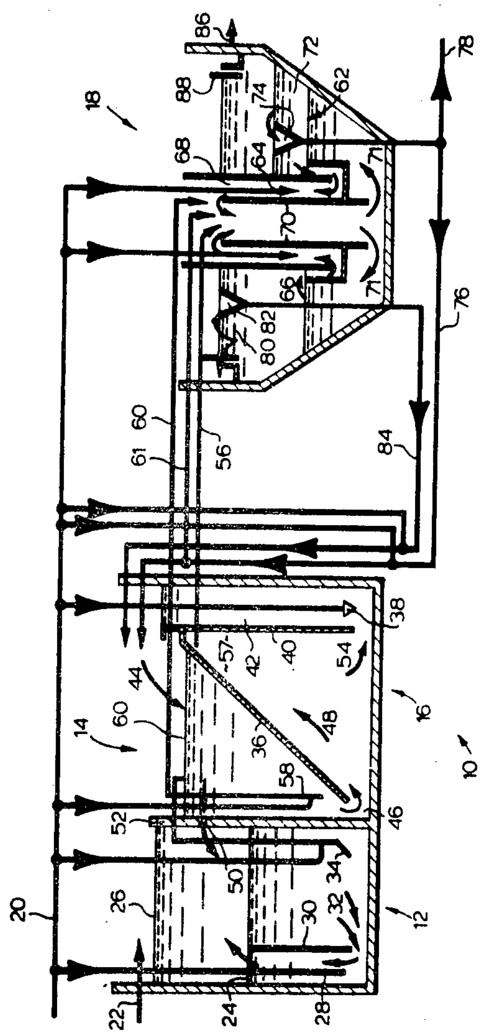

FIG. 1

1584373 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

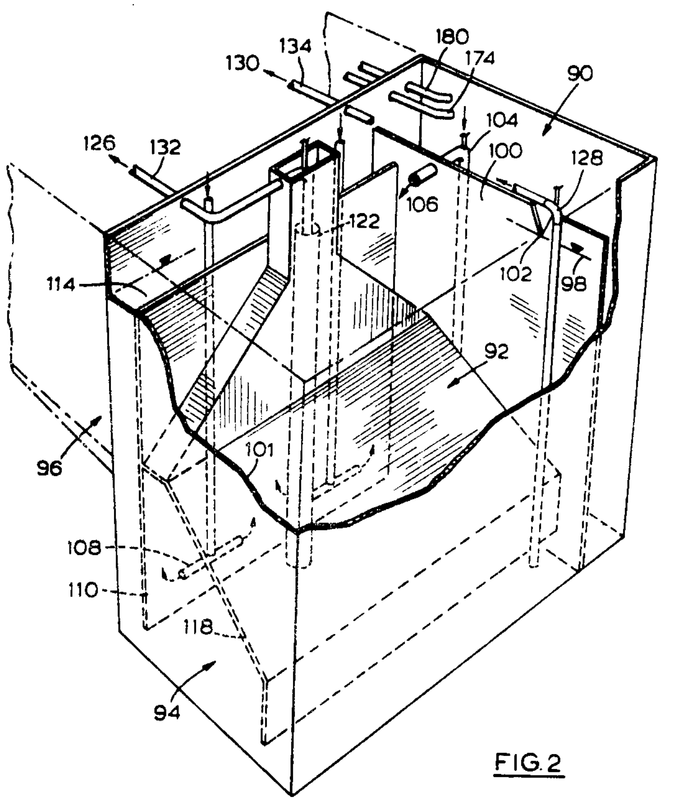

FIG. 2

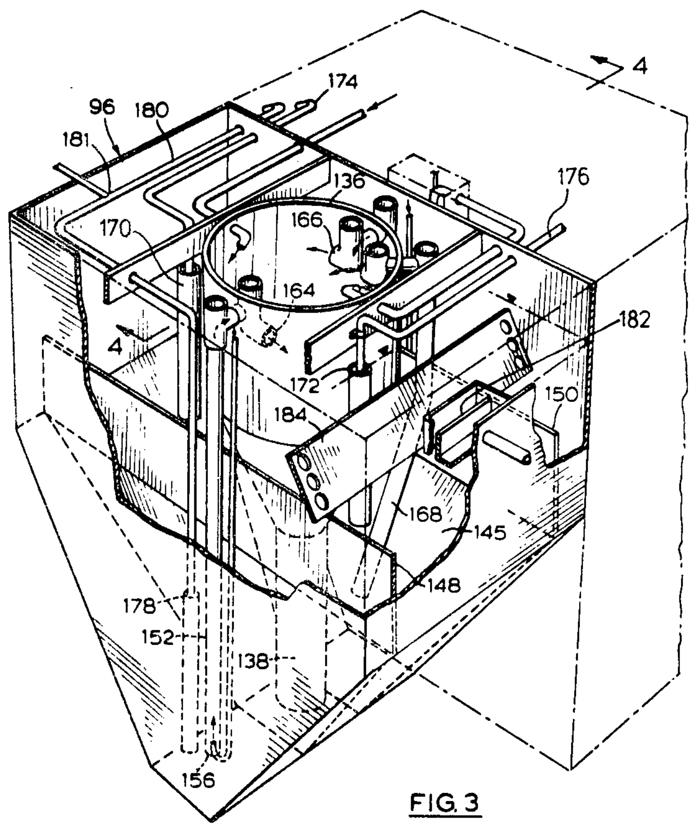
4
174
96
180
181
136
176
166
170
164
182
4
172
150
184
168
145
148
178
152
138
156

FIG. 3

1584373 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 4

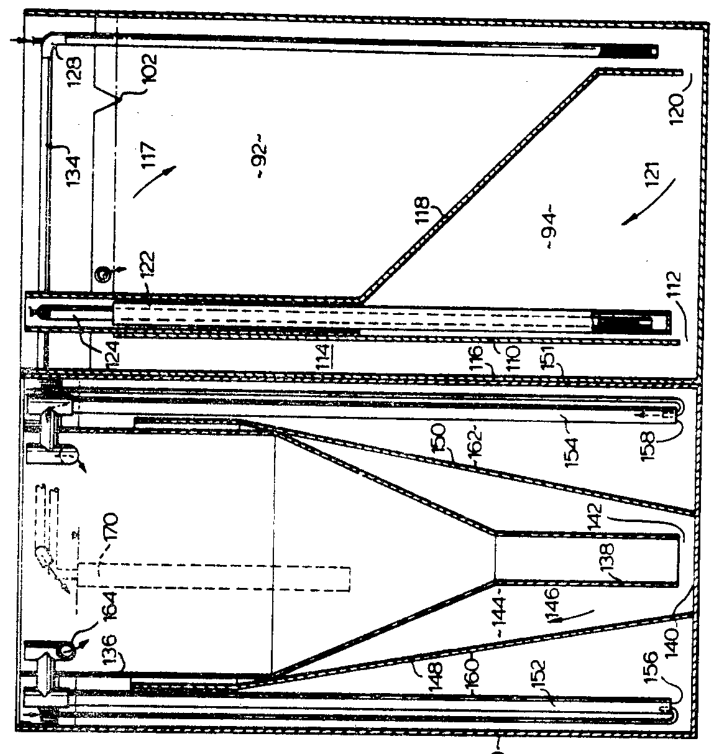

FIG. 4

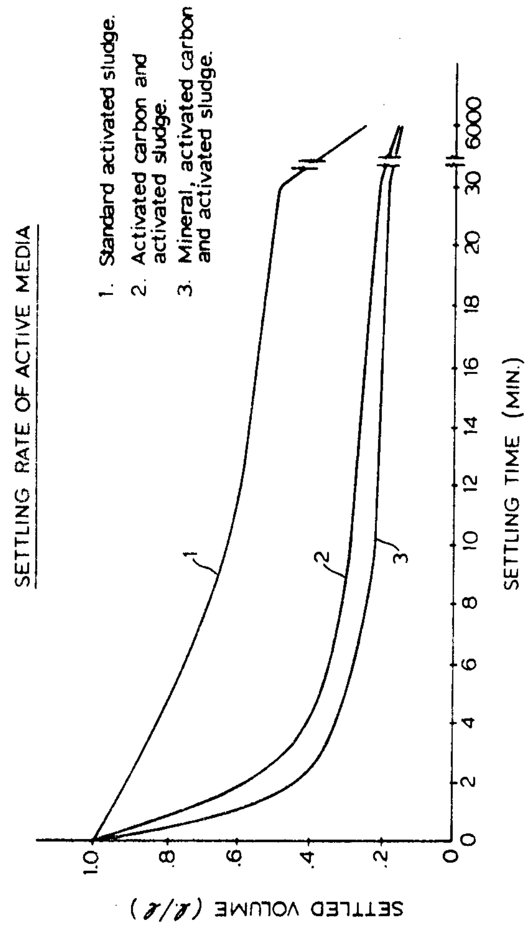
SETTLING RATE OF ACTIVE MEDIA
1. Standard activated sludge.
2. Activated carbon and activated sludge.
3. Mineral, activated carbon and activated sludge.
SETTLED VOLUME (l/l)
1.0
.8
.6
.4
.2
0
0
2
4
6
8
10
12
14
16
18
20
30
6000
SETTLING TIME (MIN.)
1
2
3

FIG.5