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(54) A METHOD FOR SEPARATING POLLUTANTS FROM LIQUID

(71) We, REDERIAKTIEBOLAGET NORDSTJERNAN, a Swedish joint-stock company, of 3, Stureplan, Stockholm, Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to methods for separating pollutants from liquid.

In separation processes for cleaning water most municipal and many industrial waters must be subjected to precipitation/flocculation in a purification step in the separation process in order to obtain an effective separation of the pollutants from the water. According to known technique the so called chemical purification step includes in respect to this one or several flocculation tanks provided with stirrers or agitators followed by one or several sedimentation basins and chemicals are added in the early part of this chemical purification step. A disadvantage in having such a purification step is the large space and volume taken up by flocculation tanks and sedimentation basins. A further disadvantage is the long detention time required for the water in the flocculation tank as well as the sedimentation basin.

To use only flocculation tanks and sedimentation basins in the chemical purification step gives furthermore in many applications an insufficient degree of purity. A sand filter is in these applications arranged in the end part of the purification step and thereby the degree of purity has been increased. Since the sand in the sand filters must be cleaned by backwashing at comparatively short intervals, it is, in order to avoid shutting off, often necessary to provide each sedimentation basin with at least two sand filters, one of which can operate while the other is back-washed.

It is an object of this invention to avoid or reduce the above-mentioned disadvantages.

This invention, which is applicable not only in above-mentioned separation processes but also in other processes, provides a method for separating pollutants from a liquid, wherein one or more chemicals are added to the liquid to cause precipitaton and/or flocculation of pollutants wherein the liquid containing the added chemical(s) is supplied to and flows during preciptation/flocculation and filtration through a zone of particulate filter medium forming a moving filter bed operating continuously in such a manner that, while precipitation/flocculation, filtering, and discharge of filtered liquid phase are going on, the filter medium contaminated during filtration is transported to a wash process and is returned cleaned after the washing to the filter bed and the contaminated wash liquid is separately discharged.

By a method according to the invention it is for instance, as compared with the above described known technique, possible to obtain an equipment volume reduction of about 10 times, which obviously means great economic advantages. Moreover, compared with said known technique using flocculation tanks and sedimentation basins in the purification step, it is possible to obtain a considerably higher purification degree, at least as high as that obtained when according to the known technique the sedimentation basin is followed by sand filter which, however, as mentioned above, owing to necessary shutting off for back-washing often has to be provided in duplicate. Moreover, by the method according to the invention an advantage over prior art is obtained in that the time required for obtaining at least as high a degree of purification is 10—15 times shorter. Moreover, further flocculation, floc growth, takes place in the discharged wash liquid, which has the advantage that the flocculating material becomes easily separable.

It is an important feature of methods in accordance with the invention that the separation is carried out in a continuously operating bed filter. If the bed filter does not operate continuoisly, this will cause considerable disadvantages and difficulties. Due to the often high content of pollutants in the liquid

to be purified, back-washing of such a bed filter has to be done with necessity at short intervals. Due to this the effective work time is decreased and thereby the efficiency of the filter. These problems are eliminated when using the methods according to the present invention, in which the bed filter operates continuously. Since the particulate filter medium forming the filter bed is continuously washed and returned to the filter bed, the filter can accept a dirty inflow and/or considerable precipitation in the filter bed without any need for shutting off for the purpose of back-washing.

In a preferred method according to the invention the liquid, during the filtration thereof, flows in an upward direction through the filter bed zone and the filter medium during the filtration flows in a downward direction in the filter bed zone in countercurrent to the flow of the liquid through the filter bed. This method gives the advantage that the most contaminated filter medium is that removed from the bed for washing and therefore there is in the filter bed a material which has been in use for filtration in the filter bed for a significant period of time. Owing to this a further problem existing in non-continuously operating filters is avoided, which filters as mentioned above require back-washing. The fact is that newly washed filter material gives poor filtration effect for a comparatively long time after the back-washing, for instance for sand up to half an hour. Since furthermore, as mentioned above, the content of pollutants in the liquid treated in the purification step often is high, back-washing of a non-continuously operating filter must be carried out frequently resulting in relatively short filtration periods and at the same time the degree of purification is reduced due to use newly washed filter material.

Preferably according to the invention in order to obtain an increased precipitation and/or flocculation a homogenizing of a mixture of the liquid and added chemicals takes place prior to the supply thereof to the filter bed. By this it is possible to carry out the chemical admixture in the vicinity of the bed filter.

Further features and advantages of this invention will appear from the following claims and from the following description with reference to the accompanying drawings, in which:

Fig. 1 shows by way of example a block diagram of a known sewage treatment plant;

Fig. 2 shows a block diagram of the plant according to Fig. 1 but utilizing a method according to this invention;

Fig. 3 is a vertical section of an embodiment of a filtration apparatus adapted to be used in a method according to this invention.

Fig. 1 illustrates a sewage treatment plant in use. The dash dotted line L separates an upper purification part having apparatuses for the purification or separation process carried out in a selected number of process steps, indicated P_1—P_6, and a lower sludge treatment part having apparatuses for the treatment of sludge, separated from the separation process, in a selected number of steps, indicated S_1—S_7. The inlet for the sewage is indicated with I, the outlet for clarified water obtained after the separation process is indicated with OW and the outlet for sludge after the sludge treatment steps is indicated with OS.

The incoming sewage firstly passes a bar screen P_1, in which coarse or thick material, such as rags, is separated and removed as illustrated with the arrow P_1O. After the bar screen the sewage flows through a sand trap P_2 and sand being scraped out of the sand trap is removed as illustrated with the arrow P_2O. The sewage then flows through a first sedimentation basin P_3, an aeration basin P_4 and a second sedimentation basin P_5 in said order. The sediment or sludge separated in the sedimentation basin P_3 is transferred to the sludge treatment part, as illustrated with arrow P_3O. Usually the larger portion of the sludge separated in the sedimentation basin P_5 is recirculated, as illustrated with arrow R, and excess sludge is transferred (arrow P_5O) to the sludge treatment part. The sewage is finally purified in at last purification step P_6, which includes chemical admixture P_6T, at least one flocculation tank P_6F with agitators (not shown) and at least one sedimentation basin P_6S. Sludge discharged from the sedimentation basin P_6S is transferred to the sludge treatment part, as illustrated with arrow P_6O.

The sludge treatment part includes, as shown, in the treatment course a sludge thickener S_1, digesters S_2, S_3 and S_4, further sludge thickeners S_5 and S_6, and centrifuge S_7 having chemical admixture S_7T for flocculation and outlet S_7O for reject water. The sludge from the first sedimentation step P_3 is supplied to the sludge treatment part, built as shown, either to the sludge thickener S_1 or directly, as shown with dashed line, to the first digester S_2. The sludge from the second sedimentation step P_5 is supplied to the sludge thickener S_1 and the sludge from the final sedimentation step is supplied to the sludge thickener S_6.

In a sewage treatment plant according to Fig. 1 including a final purification step P_6 with precipitation/flocculation and separation in flocculation tank and sedimentation basin normally 3—10 mg/l suspended material in the discharged clarified water OW is obtained. A higher purification efficiency can be obtained if sand filter (not shown) is arranged in the final purification step after the sedimentation basin P_6S; however, as described above, at least two filters must in

most cases be arranged owing to necessary shutting off for back-washing. When using sand filters it is possible to come down to 0—2 mg/l suspended material in the discharged clarified water.

Fig. 2 illustrates the same sewage treatment plant as in Fig. 1 besides that the final purification step P_6 in the separation process is built for utilizing the method according to the present invention. A continuously operating filtration apparatus of bed filter type is arranged in the final purification step after the chemical admixture P_6T. The suspension being added with chemicals is supplied to and and flows during precipitation/flocculation and separation through a zone of particle filter medium forming the filter bed. The filter bed operates continuously in such a manner, that, while filtration and discharge from the purification step P_6 of the water (arrow OW) clarified by the filtration are going on, the filter medium dirtified by the filtration is transported to a wash process and is returned cleaned after the washing to the filter bed and further the wash liquid dirtified by the washing is discharged (arrow P_6O) from the purification step P_6.

Such a method according to the invention results in an equipment volume reduction of about 10 times in purification step P_6 compared with a method according to Fig. 1 including flocculation tank and sedimentation basin. Moreover, an improved purification result is obtained during a considerably shorter detention time, about 10—15 times shorter. The same purification result, i.e. 0—2 mg/l suspended material in the clarified water, is obtained as when the purification step P_6 in Fig. 1 also includes sand filters.

Chemicals are added for precipitation of hydroxides and phosphorous compounds in the waste water. Usually aluminium sulphate is used as chemical admixture but alternatively salts of for instance iron or calcium can be used. Aluminium hydroxides have gel form, are porous and have large surface, thereby having great ability of absorbing pollutants. Moreover, they adhere extremely well upon particle filter medium. They are at the same time light, which is a contributory cause for the comparatively long detention time required for separation in sedimentation basins. In industrial waste water metal salts can in certain cases be found. In these cases acid or caustic liquid can be added and when suitable pH has been reached precipitation/flocculation takes place in the bed filter. In cases where only flocculation is desired, organic polymers for example can be added.

Although not shown, it is appropriate to carry out a homogenizing in the inlet to the filter bed, for instance by dividing the flow into part flows by arranging a static mixer, said part flows being again united ahead of the filter, or by forcing energy into the flow by means of agitators.

In addition a filtration step in accordance with this invention can be used in other separation processes than those described above and shown in the drawings, different types of continuously operating filtration apparatuses of bed filter type can be adaptedly fitted in actual separation processes. However, a suitable embodiment of a continuously operating filtration apparatus is shown in Fig. 3.

In the apparatus 1 illustrated in Fig. 3 a particle filter medium is enclosed in a tank having walls 2 and a funnel-shaped bottom 3. The base of the cone or pyramid 3 should preferably coincide to the form of the tank as defined by the walls 2.

As filter medium sand is well suited. However, other materials, such as plastic, can be used or mixtures of several materials. A mixture of several grain size fractions of this material can also be used in a continuously operating filter of this type.

The suspension or emulsion to be filtered and added with chemicals (P_6T) is supplied to the tank through inlet 4, preferably as shown through the bottom of the tank. The flow of the suspension into the filter bed takes place in the lower part of the filter bed via a number of pipes 5 having pipe mouths 6. A roof 7 is arranged above each pipe mouth in order to prevent the filter medium to be in direct contact with the pipe mouths and in order to expose a larger surface of the filter medium to the supplied suspension. By this, the risk of rapid clogging of the filter close to the pipe mouths is reduced. The roofs have an inverted V-shaped cross section and owing to this and to the arrangement of the pipe mouths with roofs the movement of the filter medium downwards is not considerably reduced. The arrangement of the inlet pipe mouths 6 in the lower part of the filter bed involves the advantage that the most contaminated filter medium, i.e. the filter medium passing the roofs and the pipe mouths, continues downwards and is no more utilized for the filtration. By this, clogging at the inlets is prevented and new filter medium is always exposed to the incoming suspension. The incoming suspension flows in counter-current to the filter medium upwards through the filter bed towards cleaner filter medium. The filtered liquid phase obtained during the flow of the suspension upwards through the filter bed is kept as a zone 8 of filtered liquid phase above the filter bed and its surface level is in the shown embodiment fixed by discharging the filtered liquid phase from the filtration apparatus via a weir 9 to an outlet (arrow OW).

In the hopper above the tank bottom 3, down into which the dirty filter medium flows, the mouth of some suitable transport device 10 is located. As appears from the illustrated embodiment the transport device

extends centrally through the apparatus and can for instance consist of an airlift pump. Such a pump operates with air as transport medium and the air is supplied from above downwards through a pipe 11 extending alongside a transport pipe 12 forming a part of the transport device. The air is supplied to the transport pipe 12 through holes (not shown) in the lower part of the pipe. The filter medium is transported (arrow A) by the air through the pipe 12 up to a wash device 13 positioned above the filter bed. The wash device shall be described below more in detail.

If the air conducted into the airlift pump for some reason should escape through the lower part of the transport pipe 12 and infiltrate into the filter medium, there is a risk for local fluidizing of the filter medium resulting in a substantial reduction of the filtering capacity of the filter. In order to prevent such a disturbance a funnel 14 turned upside down is placed around the airlift pump above the bottom mouth. The funnel catches possible air gone astray and the caught air is discharged through holes in the top end of the funnel to a pipe 15 extending alongside the transport pipe 12. The funnel also serves as guide means for the flow of the filter medium downwards, so that a uniform flow profile (flow characteristics) is obtained over the cross section of the apparatus.

The above-described roofs 7 positioned above the inlets 6 contributes as well as the funnel 14 to achieve desired flow profile. Such roofs, although not shown, in order to ensure a desired flow profile can be arranged in the filter bed at other fitting places and without being combined with inlets for the suspension.

The wash device 13 shall now be described. The filter medium to be washed arrives from the upper end of the transport pipe 12, turns (arrow B) and flows downwards along a wash path formed by the space between the pipe 12 and an outer pipe 16. The outer pipe 16 is preferably concentrically arranged relative to the pipe 12. The filter medium can, owing to its dirtiness, contain aggregates combined together. Such possible aggregates are broken up when they hit a plate or obstruction 17 positioned in the flow path of the filter medium, at the same time as the velocity of fall of the filter medium is decelerated. The filter medium hits thereafter further down in the wash path an intermediate partition 18 provided with holes 19, preferably followed by a number of additional intermediate partitions of similar shape. In the embodiment shown there are five intermediate partitions. The holes 19 in two adjacent partitions are preferably displaced in relation to each other, so that a vertical free passage for the filter medium is prevented. Owing to this, there is a frequent deceleration of the filter medium during its passage through the wash device. The filter medium meets all the time a wash liquid in counter-current and at the holes in the intermediate partitions the velocity of the wash liquid becomes momentaneously higher, which results in especially favourable conditions for the washing of the filter medium.

The filtered liquid phase in zone 8 positioned above the filter bed is used as wash liquid. The wash device is in this respect immersed into the filtered liquid phase in zone 8 and, as shown with arrow C in the illustrated embodiment, the wash liquid, i.e. the filtered liquid phase, is supplied to the wash path through the opening 20 between the lower end of the outer pipe 16 and the transport device 10 and flows upwards along the wash path. The wash liquid which becomes dirty during the washing, i.e. the reject, is discharged from the wash path as shown with arrow D, flows over a weir 21 and is discharged from the apparatus as shown with arrow P_6O. This weir can be adjustable as to its height and width position, thereby making it possible to control the quantity of wash liquid. For instance, the quantity of wash liquid is increased upon lowering of the weir. The quantity of wash liquid is also automatically increased when the level of the filtered liquid above the filter bed arises, for instance by increased load on the filtration apparatus.

In order to guide the filter medium, discharged from the transport pipe 12, downwardly to the wash path and in order to separate the reject from the incoming filter medium, a pipe 22 is arranged between the outer pipe 16 and the pipe 12, said pipe 22 being lowered a distance past the top end of the transport pipe.

The pipe 22 projects out of the outer pipe 16, and air supply pipe 11 and air discharge pipe 15 are drawn through the pipe 22. The pipe 22 also encloses a device 23 for capturing water drops and material entrained by the air from the pipe 12 containing filter medium. In the illustrated embodiment this capturing device consists of downwardly faced cones and upwardly faced truncated cones, alternatively arranged.

Although not shown, a part of the filtered liquid phase can, if desired, be taken out within the filter bed zone below its top surface by arranging outlet pipe mouths for filtered liquid phase, preferably substantially vertically above the inlet pipe mouths 6. Moreover, these outlet pipe mouths can preferably be provided with roofs in conformity with the roofs 7 above the inlet pipe mouths 6. By taking out the filtered liquid phase through such outlet pipe mouths positioned within the filter bed zone below the top surface thereof a satisfactory filtered liquid phase is ensured also upon for instance possible shutdowns in the wash device, in which case the

filtered liquid phase existing above the filter bed could be dirty.

Below the bottom end of the wash device a cone 24 is arranged for spreading the filter material coming from the wash device out over the top surface of the filter bed. Moreover, the cone 24 is provided with a suitable number of holes 25 in order to obtain a supply of filter medium particles to the surface of the filter bed positioned below the cone.

Besides the above described automatic control of the wash liquid quantity also an automatic control of the quantity of filter medium supplied to the wash can, although not shown, be accomplished. By placing a quantity sensing or pressure sensing means in the supply pipe for the suspension a signal indicating a change in a relevant parameter, e.g. a pressure increase owing to accumulation of suspended material in the filter bed, is obtained. This signal can in a manner known per se be used for the control of the capacity of the transport device 10, so that the transported quantity of filter medium to the wash device is increased or decreased.

In the embodiment described above and shown on the drawings the wash device is immersed in the zone 8 of filtered liquid phase and the filtered liquid phase is from this zone admitted as wash liquid into the wash device through the opening 20. The filtered liquid phase utilized for the washing can, however, alternatively be laterally admitted through one or several openings in the outer pipe 16 at the lower portion thereof. In another alternative embodiment, not shown, in which likewise filtered liquid phase from the zone 8 is utilized as wash liquid, at least a part of the wash device is immersed into and separately arranged relative to the filter bed and one or several pipes are drawn from the zone 8 to the lower portion of the wash device for the supply of the wash liquid to the wash device such positioned.

The filtration apparatus described above and shown on the drawings makes a construction with comparatively small dimensions possible and thereby the advantage is achieved that the apparatus is easy to handle and easy to attend in operation. Moreover, owing to the fact that all elements required for the continuously operating apparatus are positioned within the apparatus and furthermore that certain devices, for instance the wash device and the transport device, can be formed as units, the apparatus is well adapted to be built as modules. When greater filtration capacities than one single apparatus can produce are required it is owing to this possible to build together in a simple and advantageous way several apparatuses into one large filtration plant.

WHAT WE CLAIM IS:—

1. A method for separating pollutants from a liquid, wherein one or more chemicals are added to the liquid to cause precipitation and/or flocculation of pollutants wherein the liquid containing the added chemical(s) is supplied to and flows during precipitation/flocculation and filtration through a zone of particulate filter medium forming a moving filter bed operating continuously in such a manner that, while precipitation/flocculation, filtering, and discharge of filtered liquid phase are going on, the filter medium contaminated during filtration is transported to a wash process and is returned cleaned after washing to the filter bed and the contaminated wash liquid is separately discharged.

2. A method according to claim 1, characterised in that the liquid being filtered flows, during the filtration thereof, in an upward direction through the filter bed zone, and the filter medium during the filtration flows in a downward direction through the filter bed zone in counter-current to the liquid and past the inflow of the liquid to the filter bed.

3. A method according to claim 1 or 2, characterised in that a mixture of the liquid and added chemicals is homogenized prior to the supply thereof to the filter bed.

4. A method according to claim 3, characterised in that said homogenizing takes place by dividing the liquid flow into part flows which again are united upstream of the filter bed.

5. A method according to claim 3, characterised in that said homogenizing takes place by agitation of the liquid.

6. A method according to any of the claims 1—5, characterised in that a part of the contaminated wash liquid is returned to the separation process.

7. A method according to any of the claims 1—5, characterised in that the contaminated wash liquid is supplied to a treatment process for treating material separated from the liquid in a prior step of the separation process, said treatment process being carried out in parallel with the continuous filtration process.

8. A method according to claim 7, characterised in that a part of the contaminated liquid being treated in the treatment process is returned to a prior step in the separation process.

9. A method according to any of the preceding claims, characterised in that the contaminated filter medium is washed during flow along a wash path in counter-current to a wash liquid.

10. A method according to claim 9, characterised in that at least a part of the filtered liquid phase which has passed through the filter bed zone is maintained above this zone as a zone of filtered liquid phase, and that

filtered liquid phase existing above the filter bed could be dirty.

Below the bottom end of the wash device a cone 24 is arranged for spreading the filter material coming from the wash device out over the top surface of the filter bed. Moreover, the cone 24 is provided with a suitable number of holes 25 in order to obtain a supply of filter medium particles to the surface of the filter bed positioned below the cone.

Besides the above described automatic control of the wash liquid quantity also an automatic control of the quantity of filter medium supplied to the wash can, although not shown, be accomplished. By placing a quantity sensing or pressure sensing means in the supply pipe for the suspension a signal indicating a change in a relevant parameter, e.g. a pressure increase owing to accumulation of suspended material in the filter bed, is obtained. This signal can in a manner known per se be used for the control of the capacity of the transport device 10, so that the transported quantity of filter medium to the wash device is increased or decreased.

In the embodiment described above and shown on the drawings the wash device is immersed in the zone 8 of filtered liquid phase and the filtered liquid phase is from this zone admitted as wash liquid into the wash device through the opening 20. The filtered liquid phase utilized for the washing can, however, alternatively be laterally admitted through one or several openings in the outer pipe 16 at the lower portion thereof. In another alternative embodiment, not shown, in which likewise filtered liquid phase from the zone 8 is utilized as wash liquid, at least a part of the wash device is immersed into and separately arranged relative to the filter bed and one or several pipes are drawn from the zone 8 to the lower portion of the wash device for the supply of the wash liquid to the wash device such positioned.

The filtration apparatus described above and shown on the drawings makes a construction with comparatively small dimensions possible and thereby the advantage is achieved that the apparatus is easy to handle and easy to attend in operation. Moreover, owing to the fact that all elements required for the continuously operating apparatus are positioned within the apparatus and furthermore that certain devices, for instance the wash device and the transport device, can be formed as units, the apparatus is well adapted to be built as modules. When greater filtration capacities than one single apparatus can produce are required it is owing to this possible to build together in a simple and advantageous way several apparatuses into one large filtration plant.

WHAT WE CLAIM IS:—

1. A method for separating pollutants from a liquid, wherein one or more chemicals are added to the liquid to cause precipitation and/or flocculation of pollutants wherein the liquid containing the added chemical(s) is supplied to and flows during precipitation/flocculation and filtration through a zone of particulate filter medium forming a moving filter bed operating continuously in such a manner that, while precipitation/flocculation, filtering, and discharge of filtered liquid phase are going on, the filter medium contaminated during filtration is transported to a wash process and is returned cleaned after washing to the filter bed and the contaminated wash liquid is separately discharged.

2. A method according to claim 1, characterised in that the liquid being filtered flows, during the filtration thereof, in an upward direction through the filter bed zone, and the filter medium during the filtration flows in a downward direction through the filter bed zone in counter-current to the liquid and past the inflow of the liquid to the filter bed.

3. A method according to claim 1 or 2, characterised in that a mixture of the liquid and added chemicals is homogenized prior to the supply thereof to the filter bed.

4. A method according to claim 3, characterised in that said homogenizing takes place by dividing the liquid flow into part flows which again are united upstream of the filter bed.

5. A method according to claim 3, characterised in that said homogenizing takes place by agitation of the liquid.

6. A method according to any of the claims 1—5, characterised in that a part of the contaminated wash liquid is returned to the separation process.

7. A method according to any of the claims 1—5, characterised in that the contaminated wash liquid is supplied to a treatment process for treating material separated from the liquid in a prior step of the separation process, said treatment process being carried out in parallel with the continuous filtration process.

8. A method according to claim 7, characterised in that a part of the contaminated liquid being treated in the treatment process is returned to a prior step in the separation process.

9. A method according to any of the preceding claims, characterised in that the contaminated filter medium is washed during flow along a wash path in counter-current to a wash liquid.

10. A method according to claim 9, characterised in that at least a part of the filtered liquid phase which has passed through the filter bed zone is maintained above this zone as a zone of filtered liquid phase, and that

said counter-current washing of the contaminated filter medium along the wash path takes place during flow of the contaminated filter medium in counter-current to filtered liquid phase utilized as wash liquid, said wash liquid of filtered liquid phase being supplied to the wash path from said zone of filtered liquid phase.

11. A method according to claim 10, characterised in that during the washing of said filter medium, the relative velocity between the filter medium and the wash liquid is increased momentaneously at least once.

12. A method according to claim 10 or 11, characterised in that during the washing of said filter medium, the flow velocity of the filter medium is reduced at least once.

13. A method according to claims 11 and 12, characterised in that said deceleration takes place along a zone of the wash path followed by said momentaneous increase.

14. A method according to any of the preceding claims wherein air is used for the transport of the contaminated filter medium to said wash path, characterised in that air is prevented from infiltrating into the filter bed zone by being previously trapped and discharged.

15. A method for separating pollutants from liquid, substantially as hereinbefore described with reference to Figures 2 and 3 of the accompanying drawings.

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