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(54) METHOD OF TREATMENT OF SLUDGE WITH SIZE-ADJUSTED CARBON/

(71) I, TORU SEKI, a citizen of Japan of No. 558 Kami-Kizaki, Urawa-shi, Saitama-ken, Japan/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 process of separating sludge concentrates with the use of fine dust coal or lignite. More specifically, the invention relates to a process for separating sludge solids in the highly concentrated state by employing fine dust coal or lignite having a specific size distribution, which comprises specific proportions of finer and coarser size particles.

In general, the solid contents of sludges, which may be concentrates, discharged from the process of the aerobic activated sludge treatment of sewage and waste water are about 4,000 to 13,000 ppm. For the treatment of such excessive sludges or concentrated sludges, various methods have been proposed. For instance, there has been proposed a method comprising incorporating into such sludge 5 to 30% by weight of an iron compound coagulant such as iron chloride or iron sulphate and 5 to 30% by weight of a neutralizing agent such as lime, dehydrating the admixture by employing a dehydrating apparatus and recovering the solids in the form of a cake. Incorporation of a carbonaceous substance such as naphtha carbon in conducting the above method has also been proposed as means for imparting the combustibility to the recovered cake.

However, in such a conventional method employing a coagulant which has heretofore been used for cleaning city water, it is difficult to separate solids of the sludge from water, because solids of the sludge are present in the form of a very stable sol well-admixed with water which acts as a dispersion medium. More specifically, in the above conventional method, when the sludge is incorporated with

the above chemicals and the admixture is allowed to stand still, it takes a very long time for solids of the sludge to coagulate and sediment, and since the phase separation between the sludge solids and the supernatant liquor proceeds under such conditions that the solids contain a great quantity of water therein, attainment of effective separation cannot be expected. Furthermore, in this conventional method, even when the coagulated sediments are subjected to a dehydration treatment such as filtration, the water content is still as high as 83—92% by weight; therefore, the drying treatment of the recovered solids is not easy in many cases.

In the concentration and separation of sludges, it is desired that the following two conditions are satisfied; one being that when an admixture of a sludge and a coagulant is allowed to stand still, the resulting sediment of the coagulated sludge solids is recovered in a short period of time in the form of a non-bulky compact mass while the supernatant liquor is so cleaned that it can be discharged directly without any further cleaning treatment; and the other being that the dehydration of the coagulated sediment can be accomplished very easily with cakes of a very low water content being obtained. It is also desired that the cost of the coagulant is low.

It has now been found that in the treatment of sludges, when fine dust coal or lignite having such a specific size distribution that it comprises predetermined proportions of particles of specific finer and coarser sizes is used as a coagulant, the coagulation and sedimentation of the sludge solids can be accomplished very promptly while keeping the solids in the very highly concentrated state, and that the resulting coal-containing sludge concentrate has characteristics facilitating filtration such that its water content can be reduced to 42 to 60% by weight.

In accordance with this invention, there is provided a process of concentrating and separ-

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ating solids from solid containing waste waters for example in the treatment of sewage sludge which comprises incorporating into such sludge 2 to 10% by weight of fine dust coal or lignite having a size distribution such that 30 to 50% by weight of the whole particles have a size not greater than 100 mesh (Tyler Standard) and 70 to 50% by weight of the whole particles have a size exceeding 100 mesh (Tyler standard), mixing them under agitation, and allowing the resulting admixture to stand in order to separate the coal-containing concentrated sludge from the supernatant liquor.

Further, in accordance with a further aspect of this invention there is provided a process of concentrating and separating solids from solid containing waste waters, for example in the treatment of sewage sludge, which comprises incorporating into such sludge 2 to 10% by weight of fine dust coal or lignite having a size distribution such that 30 to 50% by weight of the particles have a size not greater than 100 mesh (Tyler) and 70 to 50% by weight of the particles have a size exceeding 100 mesh (Tyler), mixing them under agitation, incorporating into this mixture a coagulant comprising a mixture of iron and aluminum compounds in an amount of from 1/50 to 1/10 by weight of the fine dust coal or lignite, and allowing the resulting mixture to stand still to separate the coal-containing concentrated sludge from the supernatant liquor, and if desired, filtering the coal-containing concentrated sludge to remove water therefrom.

In the above processes, the resulting coal-containing concentrated sludge exhibits a much lower resistance to filtration than sludge concentrates formed by the above-mentioned conventional methods, and the water content of the resulting filter cake is much lower than in the conventional methods.

In general, properties of sludges vary greatly depending on properties of waste water or sewage from which they have been discharged, and it is difficult to maintain the filtering and dehydrating efficiency at a high level in any of sludges regardless of variation in properties. For instance, when the coal-containing concentrated sludge coming from the above process is filtered and dehydrated, it is indispensable that coarser particles of the fine dust coal or lignite contained in the sludge settle uniformly on the entire face of a filter cloth in the form of a precoat layer. However, the time required for the coarser particles to separate from the concentrated sludge and settle on the filter cloth in the form of a precoat layer varies greatly depending on such factors as properties of the starting sludge, properties of the fine dust coal or lignite, the thickness of the coal-containing concentrated sludge fed on the filter cloth, the storage and residence length and the forwarding rate of the filter cloth.

I have found that in filtering and dehydrating the above-mentioned coal-containing concentrated sludge by feeding it onto the surface of a filter cloth, there can advantageously be used the apparatus described and claimed in the specification of copending application No. 37434/72 (Serial No. 1380591) in which there is described and claimed apparatus for the continuous dehydration of sludges, which comprises a liquid reservoir for receiving an admixture of fine dust coal and a sludge, a filtering zone connected with the liquid reservoir, in which vacuum suction filtration is to be effected, and an endless filter cloth with means for continuously forwarding it to the liquid reservoir and the filtering zone, the liquid reservoir being provided with a bottom portion inclined to the horizontal and extending to the surface level of the reservoir at least at the portion thereof where the liquid reservoir is connected to the filtering zone; the filtering zone being constructed of a vacuum chamber provided with roll bars at the upper portion thereof; the endless filter cloth being so disposed that it is at first introduced into the deepest portion of the liquid reservoir while being kept in contact with the bottom portion along a length sufficient for a precoat layer to lie on the surface thereof during use of the apparatus, and is then introduced on the roll bars of the filtering zone; and said liquid reservoir being connected pivotably with the filtering zone, means being provided for adjusting the inclination to the horizontal of the bottom of the liquid reservoir.

The process of this invention is useful for treatment of various sludges, for instance, concentrated sludges or discharged sludges discharged from the treatment of various waste waters e.g., city sewage water, excrement, waste water from livestock farms, waste water from marine product factories, waste water from butcheries, waste water from dye works, waste water from chemical-manufacturing factories and waste water from other ordinary factories or works. In general, sludges discharged from the treatment of such waste waters contain water at a content of 90 to 99% by weight, the remainder being composed of ashes and combustible components (which will be referred to inclusively as "solids" hereinbelow). As mentioned above, these solids are present in the form of a very stable sol well-admixed with water acting as a dispersion medium. Using the process of the invention, it is possible to separate effectively and promptly solids present in the state stably dispersed in the sludge. In the present process, solids can be effectively separated also from a secondary sludge concentrate (having a water content of 90 to 95% by weight) formed by concentrating the sludge by a conventional method such as mentioned above.

It is essential that fine dust coal or lignite

comprising the required ratio of finer particles and coarser particles is incorporated in an excessive sludge or partially concentrated sludge in an amount of 2 to 10% by weight based on the sludge, whereby it is made possible to coagulate and separate the solids in the sludge promptly and effectively.

Any of the fine dust coals and lignites may be optionally used after adjusting the particle size distribution so that particles having a size not greater than 100 mesh (Tyler) occupy 30 to 50% by weight of the particles and particles having a size exceeding 100 mesh (Tyler) occupy 70 to 50% by weight of the particles. For instance, precipitated fine dusts of low grade formed as by-products at the dressing step of the coal mining industry and coal dusts discharged from the steps of digging and dressing of lignites of low carbonization degree are usually discarded at collieries as useless by-products having no commercial value. Such fine dusts of low grade or dusts of brown coal or lignite of low carbonization degree may be used advantageously as a coagulant for precipitating and sedimenting solids of sludges, after they have been subjected to the required size distribution adjustment. These fine dusts of low grade and dusts of brown coal or lignite of low carbonization degree are much cheaper than commercially available coal dusts of high carbonization degree, and their activity of coagulating solids in sludges is rather higher than such commercially available coal dusts. In general, these fine dusts of low grade and dusts of brown coal or lignite of low carbonization degree comprises 60 to 80% by weight of particles having a size ranging from 32 mesh (0.5 mm) to 325 mesh (0.043 mm), and they have a calorific value of 3500 to 5000 Kcal/Kg and an ash content ranging from 10 to 40% by weight. These fine dust coals and lignite dusts are used as a precipitant and coagulant for sludge solids, after their size distribution has been adjusted as mentioned above.

In the fine dust coal or lignite to be used it is especially desirable that particles having a size not greater than 100 mesh, preferably not greater than 150 mesh (0.1 mm) but greater than 325 mesh (0.043 mm), occupy at least 30% by weight of the whole particles. This requirement is for promoting coagulation and sedimentation of sludge solids. On the other hand, in case the amount of coarser particles having a size exceeding 100 mesh is less than 50% by weight of the whole particles, prompt coagulation and sedimentation of sludge solids in the highly concentrated state cannot be expected any longer. Among finer and coarser particles constituting the fine dust coal or lignite, it is finer particles having a size not greater than 100 mesh, preferably a size ranging from 150 to 300 mesh, that best exhibit an action of adsorbing colloidal solids

dispersed in the sludge on the surfaces thereof and thus coagulating them. The finer particles, upon adsorbing the sludge solids, coagulate with one another, resulting in the particle growth, and with sedimentation of coarser particles, these finer particles are also sedimented in the flocky state. In short, the activity of coagulating and sedimenting sludge solids by the fine dust coal or lignite is due to cooperation of specific proportions of finer particles and coarser particles present in the fine dust coal or lignite, which can be readily understood from the following explanation made hereinbelow by reference to accompanying drawings, in which:

Figure 1 is a graph illustrating the size distribution (referring to Tyler standard mesh) in the size-adjusted fine dust coal ① to be used in this invention and comparative fine dust coals ② and ③;

Figure 2 is a graph illustrating the relation between the height of the sedimented solids and the sedimentation period, attained when a sludge is treated with above fine dust coals ①, ② and ③ shown in Figure 1.

In Figure 1 there are shown size distribution curves of the size-adjusted fine dust coal ① to be used in this invention and fine dust coals ② and ③ in which the size distribution requirement of this invention is not satisfied. As is seen from the curve ①, the size-adjusted fine dust coal to be used in this invention is characterized in that two peaks corresponding with finer and coarser particles, respectively, appear in its size distribution curve.

In Figure 2 there are illustrated results obtained when the above fine dust coals ①, ② and ③ are separately added to an excessive sludge having a solid content of 9500 ppm in an amount of 5% by weight and the sludge is allowed to stand still in a precipitation tank having a liquid surface height of 1050 cm. The curve C—1 of Figure 2 illustrates the result obtained when the coal-free starting sludge is allowed to stand still. In this case, sludge solids are not effectively coagulated or precipitated. As is seen from curves ② and ③ of Figure 2, when non-size-adjusted fine dust coals ② and ③ are incorporated into the sludge, the solids are concentrated only to such a degree that the volume of the sedimented solids is about 1/2 of the volume of the starting sludge. In contrast, in the case of the size-adjusted fine dust coal ① comprising finer particles and coarser particles at a specific ratio, as is seen from the curve ① of Figure 2, the sludge solids are coagulated, sedimented and concentrated in a short time so effectively that the volume of the solids is less than 1/3 of the volume of the starting sludge.

In Figure 2, the Curve C—2 illustrates the results obtained when as a comparative finely divided carbon, naphtha carbon formed as a by-product in the petro-chemical industry (having an average particle size of 40 μ at a

water content of 80% by weight) is incorporated in the sludge in an amount of 5% by weight. If the coagulation and sedimentation of solids in the sludge be influenced merely by the surface area of a carbonaceous substance used as the coagulant, it may be expected that the above naphtha carbon will be able to coagulate and sediment the sludge solids more promptly at a higher concentration. However, contrary to the above expectation, only in the case of the size-adjusted fine dust coal comprising finer particles and coarser particles at a specific ratio, prompt coagulation and sedimentation of sludge solids at a high concentration can be attained.

In practising the process, a fine dust coal or lignite having a size distribution adjusted as mentioned above is incorporated in an excessive or partially concentrated sludge in an amount of 2 to 10% by weight, preferably 2 to 7% by weight, especially preferably 3 to 5% by weight, based on the sludge, and the admixture is agitated sufficiently to bring about a homogeneous, well-compounded state between the coal and sludge. Then, the admixture is introduced into a concentration or separation tank, and it is allowed to stand still for between 20 minutes and 2 hours, preferably between 40 minutes and 50 minutes. Thus, substantial portions of the solids contained in the sludge are separated from the supernatant liquor, and are sedimented and deposited as coal-containing concentrated sludge. Accordingly, the supernatant from which substantial portions of solids have been separated is discharged as it is or it is returned to the waste water treatment plant and is used as water for primary washing of sludges.

As described above, properties of discharge sludges or concentrated sludges to be treated vary greatly depending on properties of the original waste water, and it is generally very difficult to obtain a coagulating agent which can exhibit an equivalent effect regardless of properties of starting sludges to be treated. However since in the fine dust coal or lignite the size distribution is preliminarily adjusted, it is possible to cope readily with variety in properties of sludges to be treated. In general, it is preferred to determine based on preliminary experiments patterns of size distributions giving optimum results depending on types of sludges to be treated within the size distribution range specified. In some cases, it is preferred to conduct a preliminary treatment for uniformizing concentrations and properties of sludges, for instance, a re-aerating treatment, prior to the coagulation and sedimentation treatment. In order to change the pattern of the size distribution in the fine dust coal or lignite to be used, it is possible to incorporate a finely divided carbonaceous material formed as a by-product at the thermal cracking step in the petrochemical industry, such as naphtha carbon or oil carbon, in an amount

of 5 to 30% by weight based on the fine dust coal or lignite, whereby the coagulating property of sludge solids can be improved or modified.

The objects of this invention can be fully attained only by the use of the above-mentioned fine dust coal or lignite having a specific size distribution such as mentioned above. However, in order further to lower the water content in a cake of the coal-containing concentrated sludge solids and further to lower the solid content in the filtrate water, it is especially preferred to use, in combination with the above-mentioned size-adjusted fine dust coal or lignite, a coagulant comprising a mixture of iron and aluminum compounds in an amount of 1/50 to 1/10 by weight, especially 1/20 to 1/15 by weight, of the fine dust coal or lignite. As such coagulant there may be employed, for instance, a coagulant comprising a mixture of iron sulphate and aluminum sulphate. For example a coagulant obtained by treating red mud discarded from the aluminum-refining process with sulphuric acid may advantageously be used. When such coagulants of a mixture of iron salt and aluminum salt, especially a coagulant composed of sulphuric acid-treated red mud, are used in the process, they cause formation of floccy hydroxides of aluminum, iron and titanium in the sludge, and these floccy hydroxides catch and coagulate colloidal solids in the sludge effectively. These coagulants of the iron-aluminum type, that is coagulants comprising a mixture of iron and aluminum compounds are generally effective when the pH of the sludge is maintained on the alkaline side (for instance, pH of 8 to 8.5). However, since such coagulants are used in combination with fine coal dust or lignite powder, addition of an alkalinizing agent such as limestone need not be effected, but such alkalinizing agent may be used depending on the kind of the sludge to be treated and any particular disadvantage is not brought about by use of such alkalinizing agent.

When employing a coagulant of a mixture of iron and aluminum compounds, the size-adjusted fine dust coal or lignite is in advance incorporated into the sludge and agitated. Then, the coagulant is added to the admixture of the sludge and size-adjusted fine dust coal or lignite. This sequence of addition is very important. In the case when the coagulant is added coincidentally with the size-adjusted fine dust coal or lignite, the excellent coagulating and separating activities of the size-adjusted fine dust coal or lignite are rather inhibited by the presence of the coagulant, and the best results cannot be obtained. It is preferred that addition of the coagulant is effected when 5 to 20 minutes, especially 5 to 10 minutes, have passed since addition of the size-adjusted fine dust coal or lignite. By adopting such procedures, co-

agulation of colloidal solids in the sludge can be further ensured and the water content of the coal-containing concentrated sludge cake can be further lowered.

5 Thus, the starting sludge is separated into two phases, one of the supernatant liquor and the other of the coal-containing concentrated sludge. The supernatant liquor is taken out from the top, or the coal-containing concentrated sludge is withdrawn from the bottom. 10 The so-separated coal-containing concentrated sludge is, if desired, subjected to the filtration treatment to remove water therefrom. Also at this filtering and dehydrating step, prominent advantages are obtained. More specifically, when the so-separated sludge is introduced on a filtering material, coarser particles of the size-adjusted fine dust coal or lignite contained in the sludge or coarser particles carrying sludge solids coagulated thereon are at first allowed to sediment on the filter cloth to form a precoat layer thereon, and then agglomerates of finer particles of the size-adjusted fine dust coal or lignite and sludge solids coagulated thereon are sucked and deposited in the form of a compressed sludge layer. Accordingly, filtration of agglomerates of finer particles of the fine dust coal or lignite and sludge solids coagulated thereon should naturally be accomplished through the precoat layer of the coarser particles of the fine dust coal or lignite, and removal of water can be performed very easily. Furthermore, the water content of the resulting filter cake is as low as 42—60% by weight. Therefore, this cake can readily be burnt out and it may be used as fuel for incineration of rubbish and refuse.

Sludges treated with the aerobic digestion method exhibit a specific filtration resistance γ of 1.0×10^{10} to 20.0×10^{10} when filtered by the vacuum filtering method or 0.2×10^{10} to 20.0×10^{10} when filtered by the filter-press filtering method (Journal of the Association of Drain and Sewerage, vol. 6, No. 57 and vol. 5, No. 55). In contrast, the coal-containing concentrated sludge obtained by the present process exhibits a specific filtration resistance γ of 1×10^6 to 3×10^6 . From the foregoing, it will readily be understood that the coal-containing concentrated sludge formed by the present process is very excellent in the filtering property.

It is preferred that the filtering step of this invention is practised by employing the apparatus for the continuous dehydration of sludges described and claimed in the specification of copending application No. 37434/72 (Serial No. 1380591).

As explained hereinabove, in accordance with this invention, by adjusting the size distribution in a fine dust coal or lignite powder of low grade which can be easily obtained at a low cost and using such size-adjusted fine dust coal or lignite, it is made possible to effect coagulation and sedimentation of sludge solids promptly and in the highly concentrated dense state, and final filter cakes can be obtained having a very low water content.

This invention will now be illustrated more specifically by reference to the following Example.

EXAMPLE.

The following coagulants were separately incorporated into a sludge having a solid content of 5.460 ppm which had been taken from a concentration tank of a sewage treatment plant:

- A. Fine dust coal having a size distribution shown by the curve (1) of Figure 1 in an amount of 5% by weight based on the sludge.
- B. Oil carbon having an average particle size of 40μ at a water content of 80% by weight and produced as a by-product in the petrochemical industry in an amount of 5% by weight based on the sludge.
- C. Fine dust coal described in A above in an amount of 5% by weight based on the sludge and sulphuric acid-treated red mud (Tradename: EDEX—S) in an amount of 0.5% by weight based on the sludge.
- D. Oil carbon described in B above in an amount of 5% by weight based on the sludge and the above-mentioned EDEX—S in an amount of 0.5% by weight based on the sludge.

In the case of coagulants A and B, after addition of the coagulant, the sludge was stirred for 5 minutes and then allowed to stand still for 2 minutes. In the case of combination coagulants C and D, at first the fine dust coal or oil carbon was added to the sludge, the agitation was conducted for 5 minutes, the admixture was allowed to stand still for 2 minutes, and then EDEX—S was added thereto, following which the admixture was allowed to stand still for 2 minutes.

The supernatant liquor was separated, and the sediment of the coal-containing concentrated sludge was fed on a filter cloth composed of Saran (Trade Mark) No. 30001. The suction filtration was conducted under a negative pressure of 200 mm Hg. Results are shown in Table 1.

Table 1

Coagulant	A this invention	B comparison	C this invention	D comparison
Volume ratio (%) of coal-containing concentrate to starting sludge	36			
Solid concentration (ppm) of supernatant liquor	(allowed to stand still for 30 minutes) 100	(allowed to stand still for 30 minutes) 220	(allowed to stand still for 30 minutes) 120	(allowed to stand still for 30 minutes) 200
Water content (%) of filter cake	64.5	92.3	57.1	91.8
Solid concentration (ppm) of filtrate water	980	1,140	810	910
Color of filtrate water	light grey	black	light grey	black
Percentage of sludge solids collected by filtration	96.4	91.0	98.3	90.6

From the results shown in Table 1, it will readily be understood that use of a fine dust coal or lignite having a specific size distribution is very important to coagulate and sediment sludge solids promptly in the highly concentrated dense state and to remove water from resulting filter cakes effectively.

WHAT I CLAIM IS:—

1. A process of concentrating and separating solids from solid containing waste waters for example in the treatment of sewage sludge which comprises incorporating into such sludge 2 to 10% by weight of fine dust coal or lignite having a size distribution such that 30 to 50% by weight of the whole particles have a size not greater than 100 mesh (Tyler Standard) and 70 to 50% by weight of the whole particles have a size exceeding 100 mesh (Tyler Standard), mixing them under agitation, and allowing the resulting admixture to stand in order to separate the coal-containing concentrated sludge from the super-natant liquor.

2. A process according to claim 1, wherein the fine dust coal or lignite comprises particles having a size of from 150 mesh to 325 mesh in an amount of at least 30% by weight based on total weight of the particles and particles having a size exceeding 100 mesh in an amount of at least 50% by weight based on the total weight of the particles.

3. A process according to claim 1 or 2, wherein the fine dust coal or lignite has a calorific value of 3500 to 5000 Kcal/kg and comprises ash components in an amount of 10 to 40% by weight.

4. A process according to claim 1, 2 or 3, wherein the admixture of the sludge and the fine dust coal or lignite is allowed to stand still for 20 minutes to 2 hours to separate it into the supernatant liquor and the coal-containing concentrated sludge.

5. A process of concentrating and separating solids from solid containing waste waters, for example in the treatment of sewage sludge, which comprises incorporating into such sludge



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- 2 to 10% by weight of fine dust coal or lignite having a size distribution such that 30 to 50% by weight of the particles have a size not greater than 100 mesh (Tyler) and 70 to 50% by weight of the particles have a size exceeding 100 mesh (Tyler), mixing them under agitation, incorporating into this mixture a coagulant comprising a mixture of iron and aluminum compounds in an amount of from 1/50 to 1/10 by weight of the fine dust coal or lignite, and allowing the resulting mixture to stand still to separate the coal-containing concentrated sludge from the supernatant liquor, and if desired, filtering the coal-containing concentrated sludge to remove water therefrom.
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6. A process according to any preceding claim, wherein the coal-containing concentrated sludge is filtered to remove water therefrom.
7. A process according to claim 6, wherein

the coal-containing concentrated sludge is fed onto a continuously moving filter cloth disposed so that it crosses with an inclined angle the liquid surface of the coal-containing concentrated sludge, thereby to form on the filter cloth a precoat layer of coarser particles of the fine coal dust coal and a layer of coagulates composed of finer particles of the fine dust coal or lignite and sludge solids, and conducting vacuum suction filtration from the back surface of the filter cloth, thereby to remove water from said layer of coagulates.

8. A process according to claim 1 of concentrating and separating solids from liquid/solid mixtures substantially as hereinbefore described in the Example and/or with reference to the accompanying drawings.

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