Dec. 3, 1940. W. J. HUGHES 2,223,764

COAGULATION

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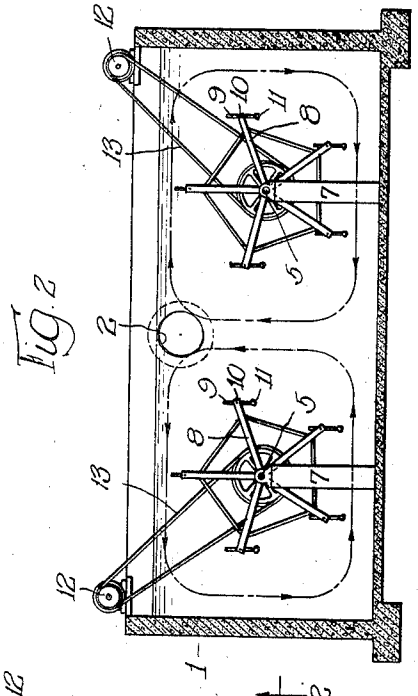

Fig. 2

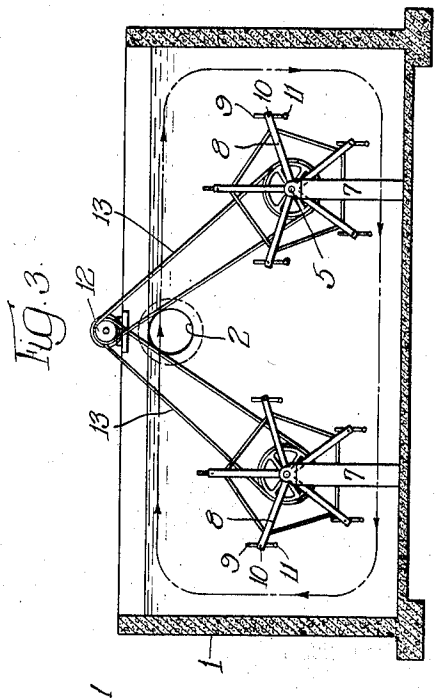

Fig. 3

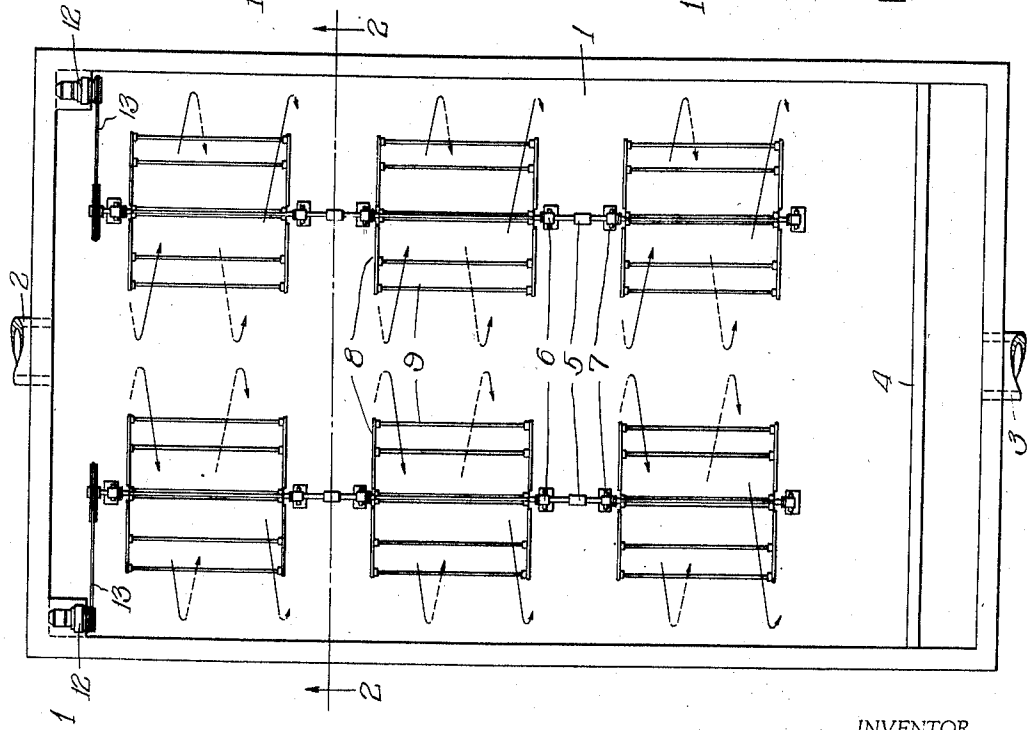

Fig. 1

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COAGULATION

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1 Claim. (Cl. 259—131)

This invention relates to liquid treatment and in particular to the treatment of water, sewage or other liquid wherein mechanical means are utilized for causing or aiding the agglomeration, coagmentation or aggregation of solid particles contained in the liquid into heavier or larger masses, which masses settle more rapidly or more completely when exposed to subsidence or sedimentation, and are generally easier to handle. Such agglomeration or other aggregation is commonly spoken of as coagulation or flocculation. The solids contents of the liquid which are to be aggregated by the process may be originally present in the dissolved, colloidal or suspended state and if necessary the solids may be subjected to some preliminary treatment, as precipitation by means of chemicals, to make them available for treatment according to this invention. The invention will be described with particular reference to a method of clarification of turbid water, for purposes of illustration.

It has long been known that by suitable agitation discrete particles suspended in a turbid water may be aggregated or agglomerated to form larger particles or flocs which for such reasons as their larger size and weight will settle more rapidly. It is particularly important that the smaller particles be gathered in such aggregations since these are naturally the slowest to settle and they would normally determine the time required and so the size of basins, etc. required to obtain proper clarification. Also since the fine particles often form the greater part by number if not by weight of the suspended solids present, their agglomeration is the greater part of the task to be accomplished. Such particles, as well as the larger and coarser ones, are originally suspended in and spaced by the surrounding water. Although certain chemical and physical details of the process are not understood as yet, it is obvious that for two or more particles to adhere, they must be brought in contact. It is further obvious that in general the agglomeration will proceed the more rapidly the greater the number of contacts per unit of time and volume. Therefore, the more rapid and the more general the agitation, turbulence or eddying motion in a coagulating zone, the greater the number of contacts. However, there are distinct limits to the permissible violence or turbulence of agitation or permissible acceleration of water relative to other bodies of water or solid surfaces, beyond which limits particles brought together will not adhere, or coherent particles will be torn apart. Obviously such excessive velocities must be avoided and yet the maximum number of contacts provided in order to effectively build up any agglomerations and in particular to build up agglomerations of the finest particles. It is one object of the present invention to provide particularly for the aggregating or inclusion of the finest particles in the larger particles obtained by treatment in accordance with the principles stated.

Obviously, too little opportunity is given for suspended solids to aggregate or clump unless the liquid containing them is maintained in suitable motion throughout the period and zone devoted to coagulation; and the motion must be properly controlled as to direction and other features as well as with respect to its velocity. The problem of producing and maintaining the most effective type of liquid movement has long engaged the attention of persons skilled in this art. Over a period of many years different forms of apparatus and procedures have been put forth to effect solids aggregation. All of these are based upon the fact that discrete particles if brought close together or caused to collide or contact under proper conditions will adhere, and all such proposals include or look to some form of agitation to promote contact between particles. Aggregation may be aided for instance by the use of reagents such as alum, or by other means that produce changes in electrical charges of particles or in the pH of the liquid, or provide nuclei or surface to which other particles may adhere; but contact is still necessary before aggregation can take place.

In earlier work attempting to provide such contact, reliance was chiefly upon baffles over or around which the water was caused to travel, this being done to agitate and, of course, also to distribute the water travel. Good flocs were so formed but too great loss of head was incurred and too great space is taken if such a process is carried far enough to produce relatively complete coagulation. In the majority of cases efficient coagulation cannot result from passing water through a basin containing said baffles in any arrangement. The velocity of flow in such apparatus is subject to excessive variations between the several parts of liquid flow; it is generally too low in large parts of the apparatus, in which parts too little opportunity will then be given for solids to aggregate, or else the velocity will be too high in certain parts, resulting in a reduction rather than an increase in particle size; and it is ordinarily impossible to reform particles of coagulated matter properly after they have been broken up by too violent agitation. Fur-

thermore, operation with baffles is almost completely inflexible, as to flow velocities, and is frequently accompanied by a useless expenditure of energy.

To overcome this, mechanical agitators and paddle wheels were later resorted to, to produce more proper motion in the liquid and so to obtain more suitable contact in less time and space and with smaller cost. In some cases agitators of various sorts have been combined with baffle systems and in such ways all sorts of complicated systems have been built up. In other cases the agitators have been comparatively simple but large coagulating basins were required to get passable results, there being a large reliance upon time to secure such results throughout the large bodies of water to be treated. My invention is directed on the one hand to producing more favorable conditions for satisfactory results and, on the other, to doing so in a simple and inexpensive way and with a minimum of power requirement.

Studies made at various times and places and under different conditions have made it apparent to me that most favorable conditions can be brought about in the liquid undergoing treatment by giving it what is termed a "barrel roll." This term is applied to circulation in which the liquid rolls or revolves generally around a horizontal axis, each particle of the liquid traveling in a circuit in a substantially vertical plane. In a batch process the liquid may be stationary except for such rotation and the particles travel in generally closed circuits, but as used in a continuous treatment process, for which it is especially adapted, fresh liquid enters at one end or side of the basin, travels across and is discharged at the opposite end or side, being rolled over one or more times during its period of retention, so that each particle travels a generally spiral path through the basin.

The apparatus heretofore used to produce such motion has been of two types. In one there has been used one or more horizontal shafts laid in the direction from inlet to outlet and carrying rigid paddles. Rotation of the shaft will impart rolling motion to the liquid; but this form of agitation has two important deficiencies, among others. For one thing, there is no uniformity of motion or of contacts throughout the liquid, since the velocity of paddles will vary with distance from the center or rotation, and consequently generally favorable conditions cannot be had even where the average may conform with what is considered good practice. For another thing, this form is very poorly adapted to basins wherein the cross section of the liquid is not substantially equal in depth and width since the greater the departure from this, the greater the inequality of conditions. Also dead spaces will be formed. Short circuiting will be experienced through the spaces of relatively slow liquid circulation; and as mentioned before, it is not practical to eliminate such undesirable features by means of baffles. It is not often practical to make the basin fit the agitator, this being contrary to considerations of cost. In water treating plants the liquid depth of the treating basin is usually about 12'; volume being provided by variations of width and length. While two or more agitators of the type referred to can readily be put side by side in a basin, they are then even less effective.

In another form of apparatus used to produce the barrel roll, liquid portions are discharged in jets in the desired direction of roll and along or close to a wall or the bottom of the basin. Propellers of some form are used to draw the liquid into and discharge it from the directing tube. This form is in many respects a considerable improvement on the one first referred to, but it still leaves much to be desired in the way of uniformity and continuity of contacts and avoidance of short circuiting and also tends to be more costly to install and operate.

To overcome or offset these difficulties and aid the formation and maintenance of the aggregates or flocs, it has been proposed to bring back to an earlier stage of the process flocs from a later stage after they have been seasoned, as it were, and become more rugged. In particular such flocs have been picked up from the underflow of the sedimentation or mechanical clarification basin following the zone of aggregation, to be recirculated to the inlet of the aggregating zone. Such returned flocs serve to some extent as nuclei to which other smaller particles may adhere and they are also said to have a sort of washing or scouring action and to so carry down particles suspended in liquid through which they fall. Doubtless such return of floc may be of aid in some cases, particularly so where the agitation provided is not well suited to the purpose. However, with the method of agitation I propose, excellent aggregation is obtained without any return of old floc, which is objectionable for several reasons. One objection is that the only practical way to return floc is to wash this back with a very considerable flow of water, already treated water being ordinarily used for this. Since this backflow is added to the incoming water, the basin must be larger, and larger and perhaps more agitators used and power consumption correspondingly increased. Another objection is that particles to be returned or being returned may become septic or detrimental in other respects. Also the process of picking them up may interfere with proper sedimentation and may add to the cost. While old flocs can be returned and agitated with new water in my apparatus, if this were desired in some case, such return is not contemplated or specifically provided for the present disclosure, the flow in my basin being continually forward from inlet to outlet.

It has also been proposed to provide agitation comprising a plurality of zones of different turbulence, generally of decreasing turbulence, so that reagents may first be vigorously stirred into the large flow of water to be treated, and the mixture may then be exposed to the more gentle agitation which is known to be conducive to solids aggregation. As to the latter treatment in particular, it has been proposed to provide decreasing rates of turbulence within the zone set aside for the gentle agitation. Apparatus and operation according to my present invention may be provided in combination with structure or procedure according to such earlier ideas, but due to improved operating results, and mainly due to elimination of short circuiting, successful application of my invention is possible without any such additional features.

I have found that it is possible to establish and maintain a very great degree of uniformity of flow or motion and of favorable conditions and opportunity for aggregation throughout the whole of a considerable volume of water. For this purpose I apply force, preferably by means of paddles or blade-like structures in selected directions only, preferably in horizontal directions

so that resultant liquid movements are horizontal both in the top and bottom zones of the basin and in the centers of the revolving paddle structures. Throughout the side portions of the path of impeller rotation, the impeller paddles, being kept in a vertical position, feather through the liquid without imparting appreciable vertical motion to it, but still contributing to promote the aforementioned flow in selected directions throughout the top and bottom zones, respectively. Desirably and as actually provided by my invention, contacts between flows of opposite direction and of relatively high velocity are minimized, and substantially uniform agitation provided. With liquid entering at one end of the basin and discharging at the opposite end, the liquid is caused to travel a flattened spiral path including parallel and substantially straight-lined flows creating substantially uniform agitation throughout the length, width and depth of the agitation zone. Due to such improved barrel roll motion there is no short circuiting and no dead spaces in any part of the basin. There will be a continuity of large and small internal eddies traveling with the flow, instead of only local eddies around the paddles as in prior apparatus.

The general type of agitating or water moving structure I employ to produce such improved barrel roll motion is not in itself new. Similar devices have been proposed for use in aerating apparatus and the like, where however the type and velocity of liquid movement desired and provided is not the same as herein disclosed and referred to and in many respects contrary to the type of liquid movement hereof; it being usual and indeed essential for liquid aeration either to discharge streams of bubbles of compressed air into the liquid or to cause some sort of surface ruffling or splashing, or to combine both methods. When attempting to use the apparatus referred to for aeration purposes in such manner as has been proposed, a high degree of agitation and eddying will occur. Such agitation is beneficial for aeration in that it tends to break up air bubbles and to promote diffusion of dissolved air. The same degree of agitation is undesirable for solids coagulation where the flocculent particles must be protected from mechanical destruction and other undesirable influence. Similar apparatus, as far I know, has not heretofore been used either for the purposes or in the way I employ it. Also I have embodied in my construction certain features to the end of reducing the power required and of minimizing variations in torque.

Having set forth the general objects, advantages and features of my invention, I will now for purposes of illustration and exemplification set forth a preferred embodiment thereof for use in carrying out the above-described method so that those concerned may know how to make and use it.

Fig. 1 is a plan view of an apparatus embodying my invention.

Fig. 2 is a sectional view taken along lines 2—2 of Fig. 1.

Fig. 3 is a sectional view corresponding to that of Fig. 2, but showing a modification.

As illustrated in these figures, the apparatus comprises two rows of revolving agitating elements, this being done to better illustrate how they may co-operate. In practice, the number of rows as well as the diameter of each element, etc., will be determined by the cross sectional area of the basin, type of water to be treated, necessary and allowable expenditure of power and so on. The apparatus comprises a basin 1 which may be of any suitable dimensions according to the quantity of water to be treated. Preferably the length of the basin in the direction of water travel will be greater than the width or depth. Water to be treated to which reagent may or may not have been previously added enters through inlet 2 and leaves through an outlet 3. Desirably one or more baffles or launders are provided to aid in distributing the flow. One such baffle 4 is indicated at the outlet end of the basin in Fig. 1. Intermediate the inlet and outlet and extending in the direction of flow are provided one or more shafts 5, shown carried in bearings 6 mounted on piers 7. On these shafts are mounted sets of radial arms 8. For reasons given later, the number of arms in each set of the same is preferably 5. At the end of these arms are mounted longitudinally extending blades 9. Instead of being rigidly attached to the arms, as has hitherto been the practice in apparatus for similar purposes, these blades are pivoted, as at 10, so that they may turn or feather as they are moved through the water. Provision is also made that they will remain in an approximately vertical position throughout the revolution of the arms on which they are mounted. Various well known means are available to cause this action. It may be effected by linkage or by pivoting the blades toward the top edge, or the lower edge may be weighted as indicated at 11 so that the blades are balanced in vertical position. The shafts may be driven by any suitable means. In Fig. 1 each shaft is driven by its motor 12, through sprocket and chain connections 13. In Fig. 3 a common drive is shown.

In operation water enters through 2 and in its flow toward outlet 3 will come within the influence of the revolving blades and be diverted from its otherwise normal path of flow and the whole of the flow will be shaped in the manner of one or more flattened spirals. Due to such diversion, by the time the water has reached the outlet it has traveled a much greater distance than it otherwise would. Furthermore, it will be noted by reference to Fig. 2 that throughout the liquid layer above the left hand shaft 5, liquid streams are positively propelled from right to left in accordance with the direction of rotation selected for this shaft, the velocity set up by such action being relatively low in the horizontal liquid layer located in the immediate neighborhood of shaft 5, where less velocity is obviously desired to set up equal agitation. This will be fully understood by reference to the zone below the same shaft 5, wherein a flow is created in the opposite direction, but otherwise in similar manner as in the top zone. Obviously no zone of absolutely slow motion can be formed around either one of shafts 5 or elsewhere. Also due to the liquid motion and to the direct action of the blades and arms a great deal of internal motion in the way of small eddies and other internal currents is created to aid contact of particles so that by the time the water leaves the basin the contained particles have been aggregated into such form and size as to settle readily.

In the past a somewhat similar arrangement of longitudinal shafts with arms and blades thereon within a basin has been used for the purposes of coagulation or aggregation. In such cases, however, the blades have been rigidly mounted on the arms. It will be apparent upon consideration that when the blades are rigidly mounted the direct tendency upon rotation thereof is to set up

a circular rotation of the water in which the water follows the blades around, with the shaft as a center. A perfect circular motion of course cannot take place in a rectangular tank, yet that tendency of action exists, with several undesirable results. For one thing, there are left dead spaces in the corners of the basin, for another, there is not enough interaction and co-operation of adjoining blades or agitators where two or more lines of shafting are used in a basin, and more or less dead spaces are left between parallel shafts through which forward flow takes place, or else too much agitation is set up in such zones. As a consequence, the mixing and coagulation suffers and some water will reach the outlet without having been given proper treatment.

When the blades are pivoted or feathered and constantly held in selected positions as I now propose such difficulties are avoided for the action thereof on rotation of the shaft is all in a elected and preferable horizontal direction, tending to cause horizontal motion of the water in one direction at the top of the basin and in the opposite way at the bottom. There is little or no direct action of the blades to cause rotation of the water around a center, although there is a rolling or rotation of the water due to the deflecting action of walls or the like. When two shafts are used they will co-operate fully in producing a common rolling motion as shown in Fig. 3 if turned in the same direction, or each its own motion if turned in opposite directions as shown in Fig. 2. If any treating reagents to be used have been completely mixed with the water prior to its entry into basin 1, either the common or reverse direction of rotation may be used, but if such mixing is incomplete or if, as may now be the case, the reagent is added to the water in basin 1, then the action shown in Fig. 3 is very desirable and even necessary to insure proper mixing and agitation. Due to the uniform directional action such mixing of reagent and water may be quickly had with my apparatus, making unnecessary prior mixing apparatus and providing fuller use of the basin.

It has been generally overlooked or not sufficiently considered heretofore that coagulation or aggregation of particles is not the result of any direct action of the agitating mechanism but only of the motion of the water itself. This must be so for the particles are suspended in and separated by the water and can be only brought together in the water. It follows from this that whatever degree of aggregation may be accomplished by local eddies and currents, and these are very effective and indeed indispensable for that purpose, uniform and complete coagulation can be had only by some uniformity of liquid motion throughout the body of water all the time, otherwise some parts will be well coagulated and others not unless an unnecessarily large coagulating basin is used. While my improved apparatus does produce the local eddies required in any such process, yet its main effect is the uniform displacement and directional movement given the water and it is a result of this movement and the intersurface movements thereof and particularly those set up at the corners where direction is changed that the improved results are obtained. Such intersurface movements in turn promote the creation of eddies which will then travel with the water.

It is to be noted also that because of the directness and simplicity of the motion imparted to the water by unidirectional application of force, less power is required to secure the necessary agitation. Furthermore, I have found that the amount of power required may be reduced by using an odd number of arms with feathered blades thereon and that for uniformity of torque and smoothness of operation five such arms is most advantageous. Of course, a larger number, as seven or more, can be used, but this adds to the cost of the apparatus without corresponding benefit. If but one arm with feathering blade is used the torque to drive it, so far as the blade is concerned, varies from a maximum at the top and bottom to nearly zero when the arm is horizontal. Thus in each revolution there are two maxima and two minima. This requires a larger motor and heavier construction throughout because the necessary work is to be done in part of a revolution and also the alternations of load produce greater wear. With two arms at 180° the effect is the same of a nearly 100% variation in load. Three arms spaced at 120° reduce the torque variation to 13½%. Four arms equally spaced give a torque variation of 30%. With five arms equally spaced at 72 degrees the torque variation reduces to about 4% or less, which is practical uniformity.

While the torque is thus even, the application of force to the water is not even in the sense of being symmetrically applied. Instead there is alternate maximum drive at the top and bottom of the basin which promotes internal currents and other desirable effects while not interfering with the main directional impulse of motion. It will thus be apparent that the use of feathered blades combined with use of an odd number thereof, preferably five, produces superior coagulating and mixing flow and better use of the basin with accompanying economy of power and simple and light construction.

The length of the arms and the width of the paddles will vary with the dimensions of the basin. They are preferably turned at peripheral velocities of the order of one to three feet per second. The longitudinal dimension of the paddles in the direction of the length of the shaft is usually within the range of five to eight feet. It is not necessary that the total length of the paddle spools on a shaft be equal or close to that of the shaft. On the contrary once the peculiar movement of the water characteristic of my invention has been imparted to the water it continues for some distance. This permits the last spools to be spaced some distance from the outlet end of the basin as illustrated in Fig. 1. Also the spools may well be spaced along the shaft at intervals separating them by from about ½ to nearly or quite the full length of the paddles or even more than that. Such arrangement further reduces the cost of apparatus and the power requirements.

It will be apparent that apparatus of this kind is suitable to any basins even of very large size and that variations of many kinds may be applied to accommodate it to basins of different shape and capacity; also that no single part is necessarily of any particular size or shape.

I claim:

In agitating apparatus, a shaft, paddles mounted parallel to and co-extensive with sections of said shaft and angularly spaced around the same at 72 degrees, and automatic means to vertically position said paddles.

WALTER J. HUGHES.