Special Report:

Clarifiers Can Settle Wash Water Problems

This series of photos shows that in only a minute or so the correct coagulant or flocculant rapidly clarifies wash water.

By Russell A. Carter

A northern Utah producer installs a compact wash-water clarification system at its 1.3 million-tpy quarry and reduces settling pond space requirements from 10 acres to zero. Now the company is cultivating profitable markets for the sludge produced by the process.

A large central California quarry recently commissioned a multimillion-dollar fines-management system designed to produce a final filter cake containing approximately 25% moisture from plant wash water carrying only 8% to 10% solids. The new system's design uses about one-fifth the flocculant per ton required by older systems.

After installing a clarification system and a 10,000-gal. water storage tank, an Indiana aggregate producer was able to replace his plant's 50- and 100-hp water pumps with two 25-hp units. Make-up wash-water requirements were reduced drastically, and the clarifier sludge has been sold profitably as a soil amendment.

Faced with unacceptably dirty return water from settling ponds and expensive bills for pond cleaning, an operator in the Northwest U.S. began adding a combination of anionic and cationic polymeric products to the 400 gpm of water leaving his plant's sand screw. The plant now recovers an additional 15 tpd of salable fines, and pond cleaning costs and associated downtime have been reduced by roughly 40%.

Aggregate producers are paying more attention to water clarification technology and products nowadays. Their interest is largely driven by a need to master the

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Efficient equipment design and improved chemicals can cut plant water costs

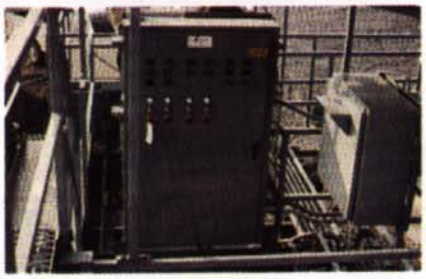
"three R's" of their business: real estate, regulation, and revenue.

How are these three basic elements tied to process-water quality and quantity? First of all, land covered by settling ponds or a thick bed of by-product slimes is unavailable for any other purpose, be it production, access, or storage, and the acreage consumed by ponds rarely diminishes over the life of an aggregate operation. In an industry in which the potential real-estate value of property to be mined sometimes eclipses the value of the reserves, this can be a significant concern.

Water availability, quality, and management are all areas in which regulations are increasingly stringent and prolific. Operators must be concerned about obtaining suitable water sources for plant operation, and for controlling the quality and quantity of water that intentionally or inadvertently leaves their properties. Contributing to industry concerns is the growing problem of what to do with the estimated 200 million tpy of so-called quarry by-products, of which a large percentage is pond fines contained in hard-to-handle slurries produced by an incomplete settling process.

Finally, process-water delivery and treatment are cost items that affect cash flow and eat away at profits. The labor and equipment costs associated with pond maintenance, for example, are not high-priority concerns at many operations, even though they may represent several cents per ton produced. In some cases, companies are forced to schedule overtime or even shut down production to clean out their ponds, after the "clarified" wash water becomes too dirty to adequately wash the plant's products.

However, improved technology, new products, and a growing awareness of potential markets for the by-products of water treatment are prompting many operators to check their plant's waterworks and start running numbers through their calculators. In this article, *Rock Products* looks at the products and techniques that can clear up a wide range of murky wash-water problems.



Output from the Jadair clarifier (above) is controlled by a solid-state electronics/microproccesor package (right).

Clarifier basics

Selling water-clarification products to aggregate producers may not be as difficult as peddling refrigerators to Eskimos, but it is regarded as a "hard sell" by industry vendors. Operators often are unfamiliar with the technology, suspicious of the benefits claimed by suppliers, and smaller companies may not be able to afford a system that can start at approximately $250,000 and reach several million dollars for larger installations.

Equipment and chemical suppliers, on the other hand, must wrestle with the prospect of serving what they regard as a small market. The demand for clarification chemicals such as coagulants and flocculants is estimated at between $5 million to $7 million annually for the entire North American aggregate industry, and only a handful of clarification systems are sold each year. Contrast this with the U.S. coal industry, in which the chemical market alone is pegged at $40 million to $60 million per year.

This can be regarded as the classic "is the glass half-empty or half-full" situation; although the aggregate industry by itself does not represent a large enough market to warrant major R&D budgets by equipment and chemical manufacturers, producers can benefit from advances in reliability and performance that have been devel-

oped to serve water-clarification needs in other applications.

This situation is underscored by the fact that only a half-dozen or so manufacturers actively market water-clarification systems to aggregate producers, and the market is dominated by two or three of those companies. Similarly, only a half-dozen primary producers supply the anionic polymers commonly used in aggregate applications. However, in this small universe of suppliers, the future market for clarifiers and chemicals looks promising, and competition for market position and sales is heating up.

The basic elements of any clarification system consist of a clarifier tank or basin, a mechanism for draining or scraping the settled solids from the tank, a pumping system to deliver plant water and return clean water, and a feed mechanism for distributing clarification chemicals as the dirty water enters the tank.

Specific configurations can be simple, relying on periodic checks by an operator to maintain chemical feedstocks and check performance parameters, or totally automated designs that start up, operate, and shut down under computer control.

The primary objective of these components is to hasten the natural settling rate of particles in the water. As the table below indicates, this settling rate can be impossibly long for certain particle sizes, and much faster for others. A correctly designed and operated clarifier system will handle most particle sizes efficiently and produce a solid, "transportable" sludge-like material with minimal water content, along with clear, usable water largely free of the slimes and other fine particles that can degrade washing operations.

The clarification equipment sold by EIMCO Process Equipment, Jadair Inc., Eagle Iron Works, Dorr-Oliver Inc., Enviro-Clear, Denver Sala, and others falls into two general categories:

- Compact, prefabricated units that typically use rectangular steel mixing/settling tanks with a small "footprint," and which produce clarified water and a sludge product in a single-stage process.
- Two-stage, higher-capacity systems that include circular gravity thickener basins and filter presses.

There are general and proprietary-design variations within each equipment category, and certain manufacturers can provide either type of system depending on application requirements.

Regardless of the specific system selected, it is important to find a supplier with a comprehensive knowledge of the processes involved in aggregate production and water clarification. Although material properties may seem similar from one site to another, the swings in tonnage and particle size that take place on a daily or even hourly basis at many operations can have a markedly adverse effect on clarification-system efficiency.

A supplier should be capable of conducting bench-scale testing to determine correct system design based on site-specific conditions. And, in cases where a new plant facility is contemplated or process samples are otherwise unavailable for evaluation, a company with the capability for conducting pilot-plant testing, using portable clarification modules, is recommended.

Available systems

Among the compact, rectangular-tank clarifier units available is the modular system developed by Jadair Inc. The Jadair system consists of one or more clarifier modules and a mixing/storage tank. The clarifier and mixing tanks are available in sizes starting at 300-gpm capacity and extending to 1,500 gpm. System capacity ratings are based on—and can vary because of—input flow rate, total solids in the wash water, and particle size and type. According to Jadair, its clarifiers can remove particles ranging from approximately 150 mesh to 400 mesh, and also can handle larger or smaller particles in small amounts.

The system can include one or more clarifier modules, as required to obtain the necessary throughput. One module is designated the master module, and contains the hydrostatic power and electrical control systems for itself and as many as two additional modules.

Liquids/solids separation is performed by gravity sedimentation, enhanced by the addition of polymer flocculants. Flocculant is distributed in the incoming water by a metering module that can handle either dry or liquid chemicals. Treated water is retained in a separate tank section to allow the flocculant to react.

From there, treated water is transferred to the main clarifier section, and compacted solids collected at the bottom of the clarifier tank are removed at intervals by a conveyor equipped with paddle scrapers. The scrapers lift the sludge over the lip of the tank and deposit it on a concrete apron, where it continues to "dewater"

Effect of Particle Size on Settling Rate

Particle size diam (mm)	Order of size	Total surface area (cm^2)	Time required to settle 1 ft
10	Gravel	3.142	0.03 sec
1	Coarse sand	3.142×10^1	0.3 sec
0.1	Fine sand	3.142×10^2	33 sec
0.01	Silt	3.142×10^3	55 min
0.0001	Colloidal	3.142×10^5	384 days
0.00001	Colloidal	3.142×10^6	105 yr

until it reaches a steady state of about 28% to 35% moisture content and can be removed by a loader. Clarified water is collected by a weir at the tank's discharge end and returned to the plant's clean-water recycling system.

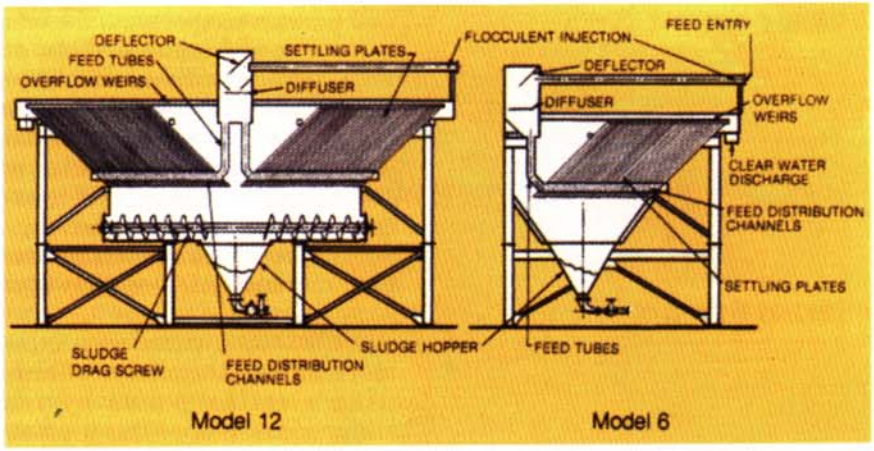
The flocculant mixer and silt-removal conveyor operate only intermittently, under command of a microcomputer included with the basic equipment package. The hydraulically powered conveyor has a selectable two-speed drive and other customizable features that allow tailoring of the conveyor speed to site requirements.

Eagle Iron Works markets a line of inclined-plate clarifiers ranging in capacity from 300 to 1,200 gpm. Designed for installation in limited spaces, the units may be combined in multiples to obtain added capacity. Standard models are offered with plates set at a 45° angle. Special units are available with plates at a 55° angle for settling materials with a low specific gravity.

The design theory behind inclined-plate clarifiers is that the multiple sets of plates in the clarifier tank provide an effective settling mechanism equal to a much larger basin-type clarifier. Eagle Iron Works, for example, claims that its Model 12, measuring 32 x 11 ft, provides an effective settling rate equal to that of a 55-ft-diameter basin thickener.

As the above diagram illustrates, flow starts with the process water entering an inlet pipe at the top of the tank. This pipe delivers the water and flocculant feed to a deflector box. Then the water flows downward into the feed distribution channels, which run across the bottom of the sloped plates. As the input slurry rises from these channels, suspended solids begin settling on the plates and then slide towards the tank bottom. Depending on the model, the solids either accumulate along the bottom of the tank and are moved to the center by an auger, or they settle by gravity into a sludge hopper where they remain to thicken. All Eagle Iron Works clarifier models can be equipped with an underflow discharge pump to remove the thickened sludge.

Optional equipment includes density-sensing controls with automatic sludge discharge valves, sludge collecting sumps/pumps, and skid mounting for the support structure.



This inclined-plate clarifier from Eagle Iron Works discharges sludge into twin bunkers (right), where it easily can be removed by a wheel loader. The internal configuration of Eagle Iron Works' two models are seen in the diagram above.

Aqua Clear Inc.'s clarifiers use a central flocculation chamber within a vertical cylinder. A hydraulically powered rake compresses and removes the solids from the bottom of the clarifier on a continuous basis. A non-shearing, positive-displacement pump is provided to pump the solids to a drying area or to a press.

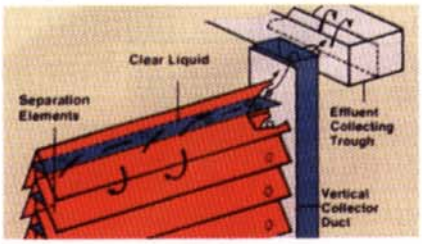
In designing this clarifier, Aqua Clear said it wanted to take advantage of the speed and efficiency of polymers and felt that sloped plates or delta stacks were unnecessary. Its vertical design is said to permit efficient use of steel and eliminate the screws or drag chains found in rectangular tanks.

An Aqua Clear clarifier installed in Illinois processes dolomitic limestone fines of which 80% pass 600 mesh. The clarifier extrudes sludge with a consistency of 55% solids by weight or better, according to Aqua Clear. Complete units, ranging from 600 to 3,000 gpm, include a polymer system, plumbing and hydraulics, and a programmable-logic-computer-driven control panel. For those who wish to stack the solids, a roller press for the silt and clay tailings was developed. Aqua Clear also offers 600- to 1,200-gpm portable clarifiers as well as polymer systems.

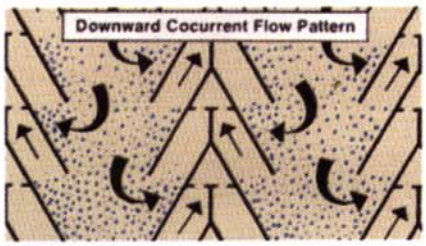
Ellis Corp. builds two different types of clarifiers that can be used to remove suspended solids from washing streams. The first, a 55° inclined-plate clarifier offered in models ranging up to 600 gpm, claims removal rates of as much as 95%, depending on the contaminants present in the wash water. The second is a dissolved air flotation clarifier that can be used to remove very light solids. In this type of unit, air is dissolved into the water under pressure, and when released to atmospheric pressure, comes out of solution as tiny bubbles. These bubbles then attach themselves to the contaminants in the water, floating them to the surface. The Ellis unit provides a mixing zone in which flocculants or other chemicals can be added to the feed stream. Capacities range from 10 to 1,000 gpm.

EIMCO's Delta-Stak clarifiers are a variation of the inclined-plate design, incorporating a "stack" of tent-shaped plates that extends from the floor to the top of the clarifier tank. Separation of the solids contained in the water occurs as the influent enters the top of the tank and passes down between the stack elements. A small amount of

Single element flow pattern



Internal flow pattern



By using the stacked arrangement of plates shown in the diagram, EIMCO's Delta-Stak clarifiers provide up to 20 times the clarification area of their actual square-foot "footprint."

the flow enters each of the elements, and clear liquid is collected at the plate's apex and then transported horizontally and upward to a collecting trough.

Solids continue to move downward by gravity, increasing in density as they pass each of the elements. Final compaction occurs in the sludge hopper at the bottom of the tank before the material is discharged. Units are available in a wide range of capacities—5 gpm to 4 million gpm—and can be operated with or without flocculant additives.

In a typical aggregate operation producing 500 to 700 gpm of dirty water containing 200 to 600 ppm effluent solids representing 5% to 10% (by weight) feed solids, a 12-ft-diam Delta-Stak clarifier produces an underflow containing 25% to 45% solids. The underflow sludge is then dewatered on a belt press to a product containing about 70% solids. A small portion of the clarified effluent is used as wash water for the belt press, and the rest is returned to the plant.

At the central California quarry mentioned at the beginning of this article, another EIMCO system processes underflow from a large-diameter, basin-type thickener in a series of belt presses to produce a manageable sludge product and clarified water. The 75-ft-diam Hi-Cap thickener represents the latest generation of a general class of thickeners referred to as "high-capacity" units designed to reduce floor-space requirements and take full advantage of the faster settling rates offered by polymer flocculants. Variations on the high-capacity thickener concept also have been marketed by Dorr-Oliver and Enviro-Clear.

As EIMCO points out, customers have the choice of eliminating settling ponds by installing one or more filter presses downstream from a clarifier, or of extending the life of existing ponds by installing only the clarifier. In the former case, the final filtered product can be moved, stored, and even sold in various forms. In the other configuration, the clarifier sends a thickened, dense slurry to the pond, reducing space requirements and enhancing the settling rate.

In the California installation, the thickener accepts a wash water inflow of 7,700 gpm carrying 8% to 10% solids, which represents approximately 240 tph of dry-weight solids. Underflow from the thickener, at 45% to 50% solids, is then transferred by five pumps to a bank of five filter belt presses with a cumulative capacity of 240 tph. Clarified water from the thickener is returned to the plant via a 36-in.-diam effluent pipeline.

An integral part of this highly automated system is a Series 2500 interface level analyzer/controller from Royce Instrument Corp. For optimum efficiency, the "sludge blanket" formed at the bottom of basin thickeners must be maintained at a predetermined, constant depth. The mass of the blanket, pressing down on the settled solids below, enhances the density of the sludge. If the blanket is too thin, compression is reduced and performance suffers; if too thick, it may overload the clarifier's drive system and degrade the quality of the overflow water.

Using microprocessor technology, the Royce instrument monitors and controls the settled solids. A sensor mounted just below the surface of the liquid emits an ultrasonic beam about four times per second. The instrument then analyzes the returning signals to compute a cross-sectional profile of the tank, which is stored in memory. The Model 2511 analyzer provides a serial output signal that can be used to link the unit to a central process-control computer.

Polymer use

At the California quarry, flocculant use is reported at roughly 0.2 lb per ton processed—compared with an industry-wide rate estimated at around 1 lb per ton.

Chemical-additive usage in a high-volume clarification system can be a significant cost factor that warrants close attention. As a Jadair spokesman explained, the most important factors to consider are "the net hourly cost versus the benefits of the polymer and the benefits of the entire water clarification system." A standard method for roughly determining polymer costs is to relate it to the tons per hour of finished or washed product, not including the solids discharged from the clarifier.

A typical range is from 2 to 10 cents per ton, with most operations falling somewhere in the 3- to 6-cents-per-ton zone.

Material cost is not the only important factor to consider; selection of the most effective flocculant or coagulant type and dosage can greatly affect system performance. Use the wrong type or incorrect mixture and risk either too little flocculation—thus degrading system effectiveness—or in the case of too strong a dosage, having unreacted flocculant returned to the plant water in the recycled water pipeline, causing problems with clays and slimes clumping in the screen circuits.

Polymer technology is advancing rapidly, and newer products offer performance and convenience benefits that weren't available just a few years ago.

Definitions of some terms are helpful before delving into the details of these products: *Coagulants* reduce the surface charge on particles to a level that allows them to agglomerate, or clump together.

Flocculants cause particles to agglomerate without substantially altering their surface charges, by

causing individual particles to adhere to a polymer molecule.

Cationic polymers neutralize the negative charge on the surface of a particle.

Anionic polymers are themselves composed of negatively charged molecules.

The various types of polymers traditionally have been marketed in liquid solution, liquid emulsion, and dry powder form. Liquid/solid separation processes associated with mining, including water clarification, generally work most efficiently with anionic polymers. However, new advances in coagulant chemistry provide enhanced performance and convenience.

Allied Colloids, for example, has introduced a line of Supercat polymers. These solid, microbead coagulants can be added directly to the process stream, resulting in better operational efficiency and reduced operating costs. (Conventional dry coagulants require mixing in solution before being introduced to the process.)

The microbead structure of these products—Percol 368, 370, and 371—allow them to dissolve at a controlled rate and provide a higher molecular weight than conventional coagulants, according to Allied. In many instances, the manufacturer said, these characteristics result in improved product utilization and better shear resistance. The ability to feed the coagulant directly into the water stream in dry form reduces labor in premixing chemicals and requires only a simple auger feeder instead of more complex make-up equipment.

Calgon Corp. recently introduced its line of Eclipse polymers. These high-molecular-weight, high-solids-content polymeric flocculants are claimed to provide the stability and activity of dry polymers with the convenience of emulsion polymers.

Eclipse polymers are sold in interlocking, stackable bins with capacities ranging from 30 to 280 gal. The bins are refillable and returnable, and provide improved protection against product contamination from water condensation, a common problem encountered with polymers delivered in conventional drums.

Aggregate producers can choose from literally dozens of flocculant and coagulant products, but optimum performance in any given system requires consultation and testing in close cooperation with the vendor. Several vendors interviewed for this article preferred not to provide product lists. Citing the constant R&D and product improvements applied to their chemical formulations, they suggest that customers specify a need and allow them to recommend a product based on site-specific requirements.

This Aqua Clear clarifier processes dolomitic limestone fines of which 80% pass the 600 mesh at a plant in Illinois

Operators can tap into a bonanza of liquids/solids-separation process data and experience by using the services offered by chemical suppliers. Nalco Chemical Co., in addition to its complete line of chemical additives, offers services ranging from laboratory process simulation to field testing, and products that include water-quality logging and analytical software, automated process-control systems, and an extensive line of chemical make-up equipment.

The effectiveness of any given clarification system depends heavily on proper preparation and addition of the chemical additives needed to coagulate or floc the solids suspended in the wash-water stream. A Nalco product specialist offered the following guidelines for handling the organic polymers commonly used in mine-water clarification.

- Work with a supplier that will perform bench tests and conduct in-plant evaluations prior to designing a polymer feed system.
- Polymers can attack mild carbon steel, and some may be corrosive to stainless steel. Refer to product bulletins for recommended system-construction materials.
- Use the right type of pump. In general, gear pumps, diaphragm pumps, and progressive cavity pumps are recommended for handling "neat" (undiluted) polymers and polymer solutions.
- Don't store made-up solutions in day tanks for more than 24 hours; 12 hours is considered the maximum for some products. Highly concentrated solutions are less susceptible to storage degradation than less concentrated solutions.
- When using neat or diluted polymers, avoid ambient temperatures in excess of 100° F, as well as freezing during storage. However, if frozen, most polymers can be thawed, mixed, and used without adverse effects. ■