Advanced Aqueous Waste Treatment Concepts

8034

By: C.G. Steiner

Presented at the Environmental Management and Technology Conference & Exhibition International, June 9-11, 1993, Atlantic City, New Jersey

Physical/Chemical Treatment Breakthrough

In the somewhat recent explosion of the hazardous and toxic waste environmental remediation effort in the USA, the vast majority of aqueous waste treatment designs were suddenly inherited by consulting engineering firms retained by governmental agencies and private industry. Since the timetables for accomplishing site remediation were frequently established by court orders or consent agreements, sufficient time for but short term treatability studies existed at best. The concept of research to develop innovative and cost effective treatment concepts could not be considered because of the exigencies of the clean-up requirement. Consequently, most projects utilized prior well established technologies that were modified, as required, for the project at hand.

The above approach was subject to continuing criticism from the purview of installation and operating costs. Ever sensitive to cost concerns, some governmental agencies have since switched from the completely "engineered" approach to a "performance" based approach. This switch permitted a much faster approach to the fix work by remediation contractors which permitted, in turn, more time for treatability studies and ancillary research to develop improved cost-effective methods of treatment. The above switch spawned most of the aqueous treatment improvements reported on.

The first and most applicable, and therefor most important advanced waste treatment concept represents a breakthrough in physical/chemical process design. It has remained hidden until now for two reasons:

1. Most companies that specialize in physical/chemical water treatment do not place much emphasis on sludge dewatering. Likewise, companies that have specialized in sludge management have generally neglected physical/chemical treatment technologies that generate sludge. Only those few limited companies that routinely pursue both such technologies were technically positioned to incorporate the greatly improved performance characteristics of modern day treatment chemicals.

2. Alums and iron compounds were the traditional chemicals used for the coagulation of water borne contaminants along with specially formulated flocculents, which are more commonly referred to as polymers. Coagulation was historically accomplished in about three minutes of intense mixing whereas continuation flocculation required some twenty minutes or more under gentle mixing conditions. Thereafter, the flocculated particles had to be settled out followed by filtration of the clarified effluent.

Standard physical/chemical treatment was frequently modified by designers for hazardous and/or toxic aqueous waste treatment by adding oil/water separation and air stripping at the head of the plant and granular activated carbon polishing treatment as the last treatment process. Sludge was typically gravity thickened and subsequently dewatered in a plate and frame type filter press at typical hydraulic feed rates of from 2 to 5 gallons per hour per square foot of filter cloth area (1.4 - 3.5 $L/h/m^2$).

The advanced treatment that represents a break through in state-of-the-art technology consists of:

1. The use of modern coagulants and flocculents which accomplish complete coagulation in less than 20 seconds and complete flocculation in less than 40 seconds thereby achieving chemical precipitation and sludge conditioning in the pipeline rather than individual dedicated vessels.

2. The in-line use of a sludge dewatering device, like a plate and frame filter press, in the main process flow stream rather than merely as a side stream treatment unit at much greater processing rates than traditionally employed for this kind of device. The use of a filter aid (as body feed) along with the modern coagulation and flocculation chemicals permits processing rates of 2-5 gallons per minute per sq.ft. of filter cloth area (84 - 210 $L/min/m^2$) or a 60-fold increase from traditional filter press dewatering rates.

The chemical precipitation which occurs during coagulation removes substantially all suspended solids. radioactive constituents, turbidity, alkalinity, heavy metals, PCBs, dioxins, pesticides, iron, manganese, other divalent cations, and both chemically and mechanically emulsified oils while accomplishing some removal (typically 25%) of dissolved organics (VOCs and SVOCs) through chemical coprecipitation phenomena. If substantial organics are present, powdered activated carbon (PAC) can be added to, or completely substituted for, the filter aid resulting in first stage PAC adsorption in the surge tank followed by PAC polishing adsorption in the filter press. The filter press itself is sized to accommodate filter cake production and press cleaning schedules rather than hydraulic through put limitations.

If hexavalent chromium and/or cyanides are present, both can be removed by adding ion exchange treatment as end-of-treatment polishing equipment, or by altering chemical treatment at the head of the plant, whichever proves to be more cost effective.

The above described treatment breakthrough results in dramatically lesser costs to treat aqueous wastewaters while also greatly simplifying both plant operation as well as precursor treatability studies, if required, prior to full scale design. There are no gaseous discharges to the atmosphere and the process itself has a wide range of applicability to toxic and hazardous waste clean-up projects. Drawing D2-2100-02 following shows the process treatment comparisons.

Powdered Activated Carbon Treatment

On aqueous waste clean-up projects that require extensive activated carbon adsorption, current practice is to use granular activated carbon (GAC) adsorbers. At least two adsorbers are usually used in series flow with another on standby. On occasion, granular activated carbon adsorbers have been used, intentionally or unintentionally, as media filters to remove suspended solids as well. When so used, the capture of suspended solids requires frequent vessel backwashing. Each GAC adsorber backwash partially destroys the adsorption profile of the GAC bed thereby accelerating contaminant break-through. Therefore, decreasing or eliminating GAC adsorber backwashing maximizes the adsorptive capacity of the GAC bed.

Removal of suspended solids prior to GAC treatment represents preferred treatment. To remove suspended solids prior to GAC adsorption, physical/chemical treatment followed by filtration is generally employed along with dewatering of the sludge generated. A typical GAC adsorption system is shown on drawing S-1102 following.

Powdered activated carbon (PAC) costs only one-third as much as GAC but, on a per pound basis, is theoretically capable of adsorbing the same mass of organics as GAC. In order to take advantage of the favorable cost of PAC, a two-stage counter current PAC adsorption system may be used. The spent PAC is dewatered as filter cake that may then be disposed of or reactivated as required. The PAC adsorption system is shown on drawing S-1101 following.

Simultaneous Ground and Groundwater Remediation

At a remediation site, contaminated ground invariably exists above contaminated groundwater and vise versa. Customary remediation practice is to remediate the ground separate and distinct from the groundwater remediation task. By separate is meant at different times by perhaps different remediation contractors. The ground remediation takes but a normal amount of time (1-2 years) but the groundwater pump and treatment system may require some 10-25 years to complete depending on the size of the contaminated plume and its velocity and/or direction of subsurface migration.

By remediating the ground and groundwater simultaneously with contaminated groundwater plume control, total site remediation time can be reduced to only two or three years thus permitting significant remediation cost savings. By the adding of required nutrients and dissolved oxygen, the contaminated soil may be biologically remediated in-situ thus obviating the need to remove the soil. Even heavily contaminated soil can be so remediated without adding significantly to the total remediation time required since the initial rate of biological decomposition is largely proportional to the amount of contamination initially present.

By carefully selecting the locations of the treated water injection wells, contaminated plume control can be achieved. In order to accomplish this objective an excellent understanding of the size of the initial contaminated plume, its direction and velocity of migration, its location depthwise, and soil porosities must be acquired through hydraulic and geological testing. With this prerequisite in place, the actual dual remediation is thereafter easily achieved. The bacteria required to accomplish in-situ ground remediation are present in ample seed quantities to permit the biological process to "take off" rapidly from initial plant startup. No seeding of specially cultured bacteria is thought necessary. By monitoring the level of carbon dioxide in the recirculated water the biological activity of the ground can be closely tracked to determine the current rate and percent completion of remediation achieved. A simultaneous ground and groundwater remediation system is shown on drawing S-1003 and S-1004 following.

Two-Phase Anaerobic Treatment With Power Generation

On certain projects the degree of organic contamination of groundwater is pronounced. BOD/COD concentrations as high as 60,000/240,000 mg/L are known to exist. Clearly, biological treatment of these aqueous wastes represents the most cost-effective approach in practically every instance.

The designer has several options to choose from when biological treatment is selected. Traditionally, the most cost effective type of biological process on stronger aqueous wastes is anaerobic treatment.

State-of-the-art anaerobic treatment is achieved in a single vessel or basin. Anaerobic treatment proceeds in two distinct steps or phases. The first phase may be characterized as the biological production of simple acids by a group of bacteria known as "acid formers." The second phase may be characterized as the biological production of methane gas by a group of bacteria known as "methane formers." Each of the above reactions occurs simultaneously, but inefficiently, in the single vessel approach.

When each of the biological reactions is studied individually, it is found that the optimum pH for the acid forming bacteria is close to 3.8 whereas the optimum pH for the methane formers is close to 7.9. By dedicating a first phase vessel to cultivate the acid formers at their optimum pH and by dedicating a second phase vessel to cultivate the methane formers at their optimum pH, the total single vessel size that would otherwise be utilized with state-of-the-art anaerobic treatment can be substantially reduced if two-phase (two vessel) anaerobic treatment is utilized. The reduction in equipment size is directly attributable to the much greater rates of biological activity of the two reactions at their optimum pH environments.

Further studies on cost optimization indicate that thermophilic bacteria have faster activity rates than mesophilic bacteria. This finding is not surprising in that chemical reaction rates follow a similar pattern.

Lastly, company sponsored studies have established that fixed growth biological systems can remove a greater amount of BOD/COD per unit tank volume than suspended growth systems. In the case of anaerobic treatment system design, the fixed media utilized must also be able to separate gaseous and settleable solids from the aqueous flow stream in order to maximize fixed growth surface areas.

Incorporating the several optimized features into a single treatment process translates into the use of two-phase thermophilic bacteria fixed growth biological treatment which utilize gaseous/solids/liquid separation fixed growth media.

State-of-the-art anaerobic treatment is well known to generate far lesser quantities of sludge than aerobic treatment processes. The two-phase thermophilic process herein described produces even less sludge. Anaerobic treatment is well known to produce generous quantities of biogas. The two-phase process herein described produces even more biogas on a per mass treated basis. The biogas can be converted into electrical energy or used as fuel to generate steam.

A two-phase anaerobic system is shown on drawings S-1104-1/2/3 and S-1105 following. The system shown was designed for a high strength non-toxic aqueous waste project that required water reuse. The water reuse concept can be disregarded vis-a-vis the two-phase anaerobic treatment process described.

Water Treatment and Reuse for Car/Truck Wash and Laundry Facilities

Aqueous waste treatment projects can occur at sites that have radioactive contamination. If a major site, such as a nuclear power plant, vehicle decontamination wastewater as well as garment laundry wastewaters will both contain radioactive constituents. The radioactive contamination can be successfully removed in the form of easily containerized filter cake while the radioactive free treated water can be reused indefinitely with minimum water make-up required. The laundry and car/truck wash treatment and water reuse systems shown on drawings S-1820 and S-1830 following may be used for these applications. The processes shown make use of the advanced physical/chemical breakthrough treatment process initially described herein.