Control of Water Pollution from the Discharge of Liquid Effluents of Wet-Collector Type Gas-Cleaning Systems

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Wet-collector systems, designed and operated for air-pollution control without concern for or consideration of the stream-pollution effects of their liquid-borne wastes, may cause significant localized pollution of surface and ground water bodies. Wet-collector systems can be designed with presently known technology to decrease contaminants in effluent outfalls to acceptable levels. Increasing strictness and complexity of air-pollution regulations will result in growing diversification in the use of versatile wet-collector systems. Judicious selection of wet-collector type, and advantageous use of design innovations in the scrubbing liquid circuitry, will ensure the most economical overall gas-cleaning system design that meets the objectives of both air and water pollution-control regulations.

INTRODUCTION

In the field of gas cleaning, wet collectors or scrubbers are distinguished from dry collectors (comprising cyclone, fabric filter, and electrostatic precipitator types) in that a liquid medium is used to contact the gas and remove gas contaminants. Wet collectors provide gas cleaning system designers with a flexible and versatile device for controlling atmospheric emissions in a great many applications in which dry collectors are either impractical, uneconomical, or otherwise unsatisfactory.

SIMPLE WET COLLECTOR INSTALLATIONS

Since their earliest history of application, low energy wet scrubbers of simple design have served to reduce the visual intensity of stack emissions by collection of plus-micron particulate matter. The most economical and trouble-free operation of these scrubbers is achieved by using once-through scrubbing water, disposing of the collected contaminants in the waterway from which the scrubbing liquid is obtained. Where practical and advantageous to do so, simple, inexpensive wet collectors of the spray tower, wet cyclone, and flooded bed types continue to be installed and operated in this manner to meet gas cleaning objectives.

TRENDS IN WET COLLECTOR SYSTEM DESIGN AND APPLICATION

Increasing emphasis by governmental pollution control authorities on the control of environmental quality during the late 1950's and during the 1960's has encouraged improved design practices. Gas cleaning system designers and operators are now often required to provide both for improved gas cleaning efficiency and for the orderly disposal of collected contaminants. Increasing attention and importance is, therefore, being given to the minimization or elimination of secondary pollution problems resulting

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from liquid effluents of gas scrubber systems. Notwithstanding the increasing cost and complexity of wet collection systems brought about by the need to control liquid effluent wastes, wet scrubbers, particularly venturi scrubbers of advanced design, are being systematically applied to an even greater diversity of difficult gas cleaning problems. A number of the important factors contributing to the increasing acceptance of wet collectors are:

1) The singular capability of wet collectors to be designed to simultaneously control emissions of contaminants in both gaseous and particulate form.

2) Operating flexibility and versatility of wet collectors.

3) Favorable economics (cost of ownership and operation).

4) Availability, experience with, and continuing development of suitable long-lived materials of construction.

The bulk of this paper discusses the water pollution problems related to wet collectors in principal industries in which they are currently employed and in important new industrial applications.

SCRUBBING LIQUID RECIRCULATION SYSTEMS

Recirculation and reuse of scrubbing liquid is a necessary means of achieving the most economical control of water pollution. This feature is basic to many large wet collectors installed in recent years. When the design of a scrubber includes spray nozzles or other components susceptible to fouling by suspended or settleable solids in the scrubber inlet water, efficient clarification of the liquid recycle stream may be required. For other types of wet collectors, the system design may provide only for removal of the coarse settleable particles from the recycled liquid, using a liquid cyclone separator, small-size recycle tank, or solids classifier. Direct recycle of the scrubber discharge water is possible in some services using wet approach venturi scrubbers.

Many wet collector systems are installed in large industrial plants having provision for central industrial waste treatment and take fullest advantage of scrubbing liquid recirculation and reuse.

REMOVAL OF COLLECTED CONTAMINANTS FROM WET COLLECTOR LIQUID SYSTEMS

Provision must be made for the withdrawal or bleeding of a portion of the recirculating scrubbing liquid in order to control total dissolved solids concentration and other liquid constituents or characteristics. Normally, the aim of the system design is to minimize the effluent bleedstream flow rate so as to minimize the size and cost of final effluent treatment equipment. At the same time, the resulting weight flow of settleable solids, suspended solids, etc., in the effluent outfall (at prescribed concentrations) is minimized. Wherever feasible, industries are generally encouraged to discharge to municipal waste treatment plants after they have provided suitable clarification and pretreatment of waste to remove materials that may be toxic in biological treatment processes.

TYPES OF LIQUID CONSTITUENTS COMMON TO WET COLLECTOR SYSTEMS

Any substance that may enter or be contained in ground or surface waters may be deemed to be a potential pollutant – potential in the sense that if concentrated sufficiently, it can adversely and unreasonably affect such waters for one or more beneficial uses; and yet, if diluted adequately, it will be harmless to all beneficial uses [1].

Pollutants generally common to all scrubbing liquids and scrubber effluents are:

SETTLEABLE SOLIDS

In the absence of an efficient clarification step, scrubbing liquid effluent will contain settleable solids that tend to settle out slowly on the stream bottom. In sufficient quantity, such solids tend to smother bottom organisms, covering and destroying spawning beds, blanketing bacteria, fungi and decomposing organic wastes, and in general to trap and maintain offensive and deleterious stream conditions.

SUSPENDED SOLIDS

Suspended solids in scrubber outlet liquid may be as low as 0.1 percent by weight in once-through circuits or as high as 2 to 30 percent in recycle liquid of some types of scrubbers in specific services. Clarified liquid effluent from wet collectors may contain as little as 15 to 200 ppm of suspended solids. High concentrations of suspended solids can kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light and because, by carrying down and trapping bacteria and decomposing organic wastes on the bottom, they promote and maintain the development of noxious conditions and oxygen depletion. Suspended solids in water intake interfere with many industrial processes, and cause foaming in boilers, or incrustations on equipment exposed to water, especially as the temperature rises.

DISSOLVED SOLIDS

As a result of recirculation and reuse of scrubbing liquid, evaporative effects in the scrubber and extended liquid retention time can greatly increase the total dissolved solids content of the scrubbing liquid and of the final effluent [2]. In plants designed for maximum reuse of industrial water, liquid effluent will contain 5000 ppm or more of dissolved solids. However, because of the accompanying minimal effluent volume, the effect of the scrubber effluent on the dissolved solids content of the receiving stream will generally be negligible. All salts in solution change the physical and chemical nature of the water and exert osmotic pressure. In addition, possible synergistic or antagonistic interactions between mixed salts in solution may have a further adverse effect on water quality. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 ppm. Each water with a total salt concentration over 1000 ppm should be judged on the basis of the local situation, alternative supplies, and the reaction of the local population. Dissolved solids in industrial water intakes can cause foaming in boilers and interference with clearness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion. In some scrubber applications, toxic substances become dissolved in the scrubbing liquid, requiring special treatment steps.

WET COLLECTORS IN THE STEEL INDUSTRY

In the steel industry, the principal market for wet collectors, scrubbers are successfully used in a number of gas cleaning applications. Dust and fumes encountered in these gas cleaning services contain a significant proportion of submicron iron oxide particles, particularly in oxygen metallurgy operations. High energy venturi scrubbers are used extensively to obtain 99 percent particulate collection, resulting in bleed slurries that generally require flocculation and sedimentation. Settled solids are continually raked to a central collection point at the bottom of the clarifier. The solids are then drawn off as an underflow slurry and dewatered in rotary vacuum filters or centrifuges, the filtrate recycling back to the clarifier feed well [3].

Blast furnace flue dust cake is recovered by sintering and recharging to the blast furnace. Such recovery and reuse of collected solids is an important step in eliminating surface and ground water pollution from solid waste dumping areas. Due to presence of zinc and other tramp materials originating in purchased scrap iron, cake from wet collectors on open-hearth furnaces [4], basic oxygen furnaces and electric arc furnaces is generally dumped in an available land fill area.

In a few steel plants, only small quantities of purchased scrap are melted, and BOF cake is acceptable for recovery via the sinter plant. In such an installation in Holland [5], the BOF cake is dried to 15 percent free moisture content by pugging with quick lime, resulting in a suitable crumbly material that does not interfere with sinter bed permeability.

A limited quantity of soluble iron is present in all liquid effluents from steel plant scrubbers. Such iron salts ultimately dissociate, and the ferric ions combine with hydroxyl ions to form an iron hydroxide precipitate that adds to the suspended solids loading. But if the dosage is sufficient and the receiving stream is small or not strongly buffered, the addition of soluble iron salt can lower the pH of the water to a toxic level. Soluble iron has an adverse effect on taste of water and is lethal to some types of fish at concentrations as low as 0.2 to 0.9 ppm [1]. Effluents containing significant quantities of dissolved iron are treated to precipitate the iron in the clarification step. Industrial waste treatment designers in the steel industry strive for an ideal arrangement with maximum water reuse and with a minimum quantity of clarified liquid effluent from central treatment facilities discharging to an evaporation and percolation pond. However, when dissolved contaminants are present, the seepage from ponds can pollute ground water tables. This is becoming of increasing concern. In addition, use of valuable land space for ponding facilities cannot always be justified, requiring effluents to be suitably treated for disposal in natural surface water streams.

WET COLLECTORS IN THE FOUNDRY INDUSTRY

The ferrous and non-ferrous foundry industry is another major user of wet collectors. Scrubbers accomplish vapor solution, gas absorption, and mechanical collection of metallurgical fumes, oils, gases, and particulates emitted by metal-melting cupolas. Cupola emissions include solids such as calcium carbonate, fly ash and iron oxide, and absorbed gases such as sulfur dioxide, fluorine, oils, phenols, and fluorides.

As in other industries, simple inexpensive scrubbers with once-through scrubbing liquid have been employed where air and water pollution regulations permit. Recycle scrubbing liquor systems are commonly used to minimize liquid effluent and the size and cost of effluent treatment equipment. In the foundry industry, recycle scrubbing liquor systems have either integral or separate settling tanks [6]. The tank capacity is usually sized to permit the settling of relatively coarse solids and their removal as a cake by means of a flight or wet screw conveyor. The water can thus be recirculated to the wet collector again with minimum erosion or fouling of the piping, nozzles, and other parts of the collector.

Typically, cupola wet collection systems are bled of scrubbing liquid at the rate of 0.25 gpm per 1000 cfm of collector capacity. Clarifiers are installed when necessary to handle bleed effluent, removing settleable solids by simple gravity settling, or colloidal solids by coagulation following chemical flocculation. Clarifiers will also float oil and permit its removal. When large quantities of oil are present, as in cupolas that have below-charge gas takeoffs, and which melt oily scrap, consideration may be given to the installation of a flotation system. The flotation process consists of adding and dissolving air in the wastes under pressure and then releasing the wastes into a tank. The oil and small solids will cling to the air bubbles and float on the surface of the tank where they can readily be removed. In the absence of treatment to remove oil, oil films on natural water bodies can interfere with gas exchange, coat bodies of birds and fish, impart a taste to fish flesh, exert a direct toxic action on some organisms as a result of soluble components, and interfere with fish-food organisms and the natural food cycle [1].

To remove finely divided suspended matter and color, adjust pH or eliminate toxic compounds, chemical treatment is used. This may be accomplished with a rapid mixer to adequately disperse chemical additions, followed by coagulation in a flocculation basin. In coagulation, a flocculent precipitate is produced having a large surface area per unit volume. This precipitate can remove suspended and colloidal matter from the waste flow by electro-physical attraction, absorption, adsorption, and physical entanglement. The resulting increase in particle density, caused by the finely divided and colloidally suspended materials gathered together into larger particles, called floc, permits rapid settlement in a subsequent settling basin.

In some cases, phenolic compounds, originating from cupola coke charge previously quenched with phenolic waste water during its manufacture, may be present in foundry scrubbing liquid effluent in low concentrations. This may be objectionable from the standpoint of taste and odor in subsequent downstream reuse of the water. Phenolic compounds may be removed by biological methods. This activated sludge process or biological filters may be used to remove substantially all of the phenolic compounds.

WET COLLECTORS IN THE FERTILIZER INDUSTRY

The phosphate fertilizer industry is a major user of wet collectors in controlling emissions of gaseous and water soluble fluorides. In the vicinity of Polk County, Florida, the principal center of this industry, there are over 200 wet scrubbers within a 7.5-mile radius [7].

Most scrubbers in fertilizer plants use low pH scrubber water recirculating from gypsum settling ponds, the principal purpose of which is to store waste gypsum flushed from filters in the phosphoric acid manufacturing process. The gypsum ponds, varying in size from 2 to 60 acre-ft, require a supply of makeup water due to evaporative heat rejection and seepage. Accordingly, pond water is not normally discharged directly to local waterways, particularly since it is at 2 pH and contains 5000 ppm of fluorides.

Under conditions of heavy rains or other unusual conditions causing excessive gypsum pond level, pond water must be discharged on an emergency basis. This effluent can be satisfactorily treated by double liming and double settling. However, dissolved phosphates remain and can cause a temporary buildup in stream nutrients.

WET COLLECTORS FOR MUNICIPAL INCINERATORS

Simple wet collector systems comprising liquid sprays and wetted baffles have been used to achieve limited control of fly ash emissions from municipal refuse incinerators. Newer and stricter regulations on fly ash emissions during the 1960's have resulted in the construction of a growing number of incinerator gas scrubber systems of advanced design.

Combustion of municipal refuse produces acid gases and other gaseous contaminants in addition to fly ash, which are absorbed by, and become dissolved in, the scrubbing liquid. As a result, scrubbing liquid effluent has been found to contain chloride concentrations in excess of 1000 ppm and cyanide in excess of 5 ppm [8]. Due to poor combustion control in many incinerator plants, phenols are not completely oxidized and may be present in the scrubbing liquid at concentrations higher than 1 ppm. In addition, at the low liquid pH (2 to 5) created by the absorbed acid gases, the scrubbing liquid may dissolve toxic heavy metals, such as copper, zinc, and lead. Effluent BOD is generally 20 to 120 ppm.

Notwithstanding these extreme water pollution problems, it may be expected that codes will be enacted to limit incinerator stack emissions of acid gases and other gaseous contaminants, further encouraging the use of wet collectors for this purpose. One method of controlling the water pollution problem is by eliminating effluent outfall, bleeding only as much scrubbing liquid as can be assimilated in the wetting and cooling of the incinerator residue [9].

WET COLLECTORS FOR THE POWER INDUSTRY

Until the late 1960's, with very limited exception, dry-type gas cleaning systems have been used for power plant boiler flue gas. With the advent of criteria and codes for control of stack emissions of sulfur dioxide, dry equipment collecting only fly ash may be expected to be gradually superseded by wet collector systems. Initial installations of wet collectors utilize cheap alkaline raw material to react with and collect sulfur dioxide, forming alkaline sulfite sludge admixed with collected fly ash. Fly ash dumps and ponds receiving the sulfite sludges may be expected to have an increased potential for secondary pollution of ground water and surface water bodies. More economical scrubbing system designs, which provide for the recovery and conversion of collected sulfur dioxide to the form of sulfuric acid, are becoming available. These advanced scrubbing and recovery systems can be expected to meet most future sulfur dioxide emission control applications with a negligible or minimal water pollution potential, particularly where they provide for the recycling and processing or sulfite/-sulfate mother liquors.

ULTIMATE DISPOSAL OF LIQUID EFFLUENT AND SOLID WASTE

By use of available liquid waste treatment processes noted previously, the designer is able to control the concentration of contaminants in the liquid effluent outfall from the scrubber system. In a well-designed effluent treatment system, the minimal liquid effluent flow, afforded by closed-loop circulation of scrubbing liquid, discharges to surface waters with minimal quantities of pollutants that are readily diluted and assimilated by the receiving stream. Thus, the gas cleaning system designer has broad control over both the amount of liquid effluent from the gas scrubber and the concentration of potential pollutants therein, giving him maximum design flexibility in meeting diverse stream quality criteria.

Solid waste collected in and derived from wet scrubber systems is usually not recoverable in a useful form, and the designer must provide for its disposal. Such matter is generally noncombustible, and it is, therefore, not feasible to reduce its bulk by incineration. The ultimate disposal of this solid waste material is limited to land sites by practical considerations. Scrubber solid wastes are of predominantly stable inorganic composition and are, therefore, generally suitable for landfilling. Since seepage from landfills may pollute surface and ground water, grading and drainage should be designed to minimize storm water runoff onto and into the fill, to prevent erosion or washing of the fill, to drain off storm water falling on the fill, and to prevent the collection of standing water [10].

Land disposal should conform with the following additional guides:

1) Never place solid wastes in direct contact with ground water supply. Since a ground water mound may be formed, a minimum of 7 ft of separation is desirable.

2) Do not locate solid wastes on or near water-bearing strata, springs, wells, or where seepage or leachate may cause contamination [11].

CONCLUSIONS

Wet collector systems designed and operated for air pollution control without concern for, or consideration of, the stream pollution effects of their liquid-borne wastes may cause significant localized pollution of surface and ground water bodies.

Wet collector systems can be designed with presently known technology to decrease contaminants in effluent outfalls to acceptable levels. Such system designs can and should be based on [12]:

1) The uses which are or may likely be made of the receiving streams

2) The size and nature of flow of the receiving stream

3) The quantity and quality of effluent wastes to be treated

4) The presence or absence of other sources of pollution on the same watershed.

Increasing strictness and complexity of air pollution regulations will result in a growing diversification in the use of versatile wet collector systems. Judicious selection of wet collector type and advantageous use of design innovations in the scrubbing liquid circuitry will insure the most economical overall gas cleaning system design meeting the objectives of both air and water pollution control regulations.

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