POLLUTION ENGINEERING PRACTICE HANDBOOK

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PREFACE

Pollution in its many forms—air, water, noise and solid waste—can be controlled. There are, however, two major problems which continually confront the individuals responsible for energy/environmental control—**economics and information.** Each is directly proportional to the other.

No one wants to spend money for the sake of spending money. Most of the time, pollution control means spending and not receiving any direct economic replacement for company funds. Therefore, it is absolutely necessary to perform a total engineering analysis of any pollution problem to determine the single most effective and economic solution. This means pollution engineers and managers must have information to do a thorough job.

The methods and equipment to control pollution are largely old techniques—some technology dates back more than 100 years. What has really been lacking in the field of environmental control is the broad dissemination of available information on the tried and proven methods. When an engineer is required to find the most economical and effective solution to the emission of environmental pollutants, he really wants essentially one thing—practical information, and right now!

That is the type of information that the editors have attempted to provide in this handbook—data that discusses the "how to do it" methods of practical problem solving. Much of the information has been derived from articles previously published in *Pollution Engineering.* Many of these articles were written by the editors of this book in their capacities as editors of the magazine. Additional valuable information has been contributed by other authorities in the field.

The purpose of this handbook is to furnish engineers, managers and students with guidance and direction in this rapidly growing field. Technically and economically feasible techniques, methods, equipment and systems are assessed.

To become an effective pollution engineer, you must take the time to analyze the whole problem along with all its many interrelationships. Then, you must systematically select the commercially available equipment to abate the problem considering all the economics involved—immediate, short and long range.

Paul N. Cheremisinoff
Richard A. Young

INTRODUCTION

The United States, as a modern industrialized nation, is the product of constantly advancing technology. Our mobility, our affluence, and our high overall standard of living are manifestations of our technological progress. So is pollution.

Technology can and does create pollution. Fortunately, it can also be applied to control and abate the contamination of our environment. The scientists and engineers who once designed industrial processes that spewed out poisonous wastewater and smoke are now developing new processes that function just as efficiently without polluting our air and water. The costs of this technology are more than offset by the immediate benefits to public health and the general improvement in what we have come to call the "quality of life."

For example, our scientists and engineers have developed substantially improved auto emission controls and stack gas cleaning technologies to curb choking fumes and noxious air pollutants from motor vehicles and power plants. Technology also is being applied to clean up industrial and municipal wastewater discharges, to suppress noise and to recycle solid waste. Resource recovery systems, a number of which are being developed with EPA demonstration grants, are perhaps the ultimate example of effective pollution engineering since they take a problem and turn it into a profit. The metals, glass and energy (combustibles) that are recovered from our waste, along with the savings from reduced landfill operations, can actually enable these systems to pay for themselves.

In controlling pollution, whether by establishing discharge standards for new sources or compliance schedules for existing facilities, improvements in technology must and will be a driving force in achieving our environmental goals. Without a strong commitment from our scientific and engineering community, our capability to utilize "best practicable" and "best available" technology will turn out to be a retreat to the lowest common denominator. That would be inadequate, derelict and a sham.

EPA has a definite responsibility to stimulate and support the necessary scientific research and application of the research results to technology and thus provide a solid foundation for control standards and regulations that are economically and technically realistic. Beyond any doubt, poorly drawn standards and regulations are a serious disincentive for industry to accelerate research and development efforts in pollution control.

But "best practical" and "best available" are not absolute terms, nor does the setting of standards dictate the manner in which we should go about the task of meeting them. The degree to which we can improve the quality of our environment is directly proportional to the extent to which we find efficient and economical solutions to our environmental problems. A pollution control system with a low energy factor is probably going to be preferable to a system that imposes a heavy fuel penalty. A waste disposal system that recovers valuable resources at a competitive cost should be preferable to one that doesn't. The logic is as obvious and overwhelming today as it was in the folk adage about what will happen when a man builds a better mousetrap.

Finally, we should avoid becoming wedded to any particular system or device as the definitive achievement or form of pollution control. The most valuable component of our scientific and technological sector has been and still is its creativity. An environment that encourages imaginative and inventive approaches to problem solving is going to have the best chance to solve our environmental problems. And our ability to find efficient, economical and practicable solutions to our environmental problems will be determined in large part by how effectively we apply the methodology and resources that are available to us. There is no greater waste than the waste of knowledge.

Russell E. Train
Administrator
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CHAPTER 1

ORGANIZATION AND ADMINISTRATION OF POLLUTION ENGINEERING AND CONTROL

POLLUTION CONTROL INTERRELATIONSHIPS[31]

Current social concern for protecting and preserving the environment is leading to increased regulation of production. Because of pollution standards and the prospect of waste handling surcharges, it is no longer possible to consider a pollution abatement problem in isolation. It has become necessary to determine the impact control of one problem will have on other parts of the environment. Fundamentally, pollution falls into four broad categories: air pollution, water pollution, solid waste and noise pollution. To a greater or a lesser degree, these are all interrelated, the exact nature of the interrelationship depending on the firm's business, the degree of control needed, and the predominant pollution problem.

Many polluters are trying to meet just the minimum standards now in force, but this is only a short-run solution to the problem and may be suboptimum from a long-range viewpoint. The optimum solution, on the other hand, is generally a long-range one, incorporating a total system of control.

Wet collection equipment in air pollution control more often than not results in a wastewater problem, heretofore widely ignored. Therefore, forthcoming standards for wastewater discharges will place additional technical and economic burdens on air pollution control. Liquid wastes resulting from air pollution control devices can no longer be discharged to surface waters or sewers without critical review. (Actually, it has never been realistic to solve an air pollution problem by transferring the undesirable pollutants to a liquid and discharging them to streams or sewers.) Table 1-1 shows interrelationships and the need for simultaneous consideration of air and water quality requirements.

Table 1-1. Simultaneous Air-Water Quality Requirements

Parameters	Recommended Concentrations for Effluents to Surface Streams	Threshold Limit Values of Airborne Contaminants	Primary Ambient Air Quality Standards 1975
pH	6.5-9.0	(HNO_3) 5-mg/M^3, (H_2SO_4) 1 mg/M^3	
Suspended Solids	20.0	(Graphite) 15 mg/M^3	(Particulates)
Cd	0.05	0.2	0.075 mg/M^3*
Cr	0.5	0.5	
Pb	0.1	0 0.2	
Cu	0.5	0.1 (fume), 1.0 (dust)	
Fe	2.0	1 (sol. iron salts), 10 (FeO fumes)	
Hg	0.5 mg/M^3	0.05, (0.01-alkyl) mg/M^3	
NH_3	2.5	25	
Sulfate	250		(SO_2) 0.14 **
Chloride	150	(chlorine) 1.0	
Fluoride	1.5	2.5 mg/M^3, (fluorine) 0.1	
Nitrate	45.0	(NO_2) 5.0	(NO_X) 0.05 **
Oil	10.0	(mist) 5.0 mg/M^3	

Values in ppm unless otherwise stated
* Annual geometric mean
** Annual arithmetic mean

Wet Collectors

A large variety of wet collectors is used for cleaning, cooling, and deodorizing of gas, particulate, and vapor emissions to the atmosphere. All these can contribute to the total quantity of liquid wastes discharged to waterways. By way of example, scrubbing liquids may include alkali additives for sulfur dioxide and hydrogen sulfide acid mist control or acids for ammonia recovery. These variations can also pose related problems in the selection of construction materials and auxiliary treatment and/or disposal systems.

Some of the more common wet-type air control apparatus include packed bed absorption columns, high-energy venturi scrubbers, wet-type precipitators and filtration systems.

High-energy wet inertial scrubbers are used where the scrubbing liquid polluted with the material can be recirculated. Electrostatic precipitators and fabric filters are used for particle removal and where the availability of water and disposal of it may present problems.

In venturi scrubber usage, if the sludge is disposed of without clarification, the operating costs will be proportionately low. But, capital cost of the venturi system may exceed that of an electrostatic precipitator system if sludge clarification and collection are mandatory.

Particulate Control

Particulate matter has traditionally been thought of as the principal air pollutant. Industrial processes, including industrial fuel burning, are responsible for about 50 percent of the particulate discharge in the form of dust, fumes, smoke or mist. Chief among the industries contributing to this discharge are gray iron foundries, steel mills, cement plants, petroleum refineries and paper mills. Almost invariably, the control methods considered include wet collectors—packed absorption columns, venturi scrubbers, mist eliminators or some other device. Some typical industrial applications of wet scrubbers for particulate removal are shown in Table 1-2.

Table 1-2. Typical Industrial Applications of Control Apparatus

Type	Typical Application
Spray Tower	Blast Furnace Gas, Fume Control
Spray Chambers	Smoke Abatement, Dust Cleaning, Kraft Paper
Venturi Throat	Cupolas, Foundries, Flue Gas, Abrasives, Rotary Kilns
Multiple Jet Venturi	Flyash, Coke Oven Gas, Lime Kilns
Flooded Dish Venturi	Pulverized Coal
Mechanically Induced Spray	Cupolas, Smoke, Iron Foundry
Disintegrator	Blast Furnace Gas
Mist Eliminators	Coke Quenching
Fabric Filter	Oil Mists, Radioactive and Toxic Dusts
Wetted Filters	Light Dust Loadings

The Steel Industry

Steel plants emit flue gases containing dust that is primarily oxides of iron. Sources of this dust include basic oxygen furnaces, blast furnaces and sinter plant gas washers. The larger particles are removed in gravity separators, whereas most of the fines are removed by wet scrubbers and wet-type electrostatic precipitators.

Dust from basic oxygen furnaces forms a substantial fraction of the particulate discharge from steel mills. Wet precipitators or venturi scrubbers may be used to intercept iron oxide dust generated when oxygen is blown into molten iron. Gas wash water is then stripped of coarse particles by cyclone separators or dragout tanks. Gases from open hearth furnaces may also contain high dust concentrations. These are usually treated by scrubbing. Dust particles collected in scrubbing liquors are sufficiently fine to require chemical coagulation prior to clarification. Electric furnace and coke oven gas also produce high dust loadings. The scrubbing waters contain high suspended solids that also require clarification before reuse.

In the foundry shop, adequate ventiliation is required to hold down airborne dust. The air is usually scrubbed by water spray units which will generate large amounts of suspended solid matter in the scrubbing liquid.

Thus, water effluents from furnace cooling, wet-type precipitators and wet scrubbers are thoroughly polluted. Primary clarification and settling can remove the major portion of the particulate matter from these effluents. Subsequent thickening and dewatering is then often employed to ease the handling of sludge. If gas wash water is in a closed-loop system for recycle, wash water flow can be reduced substantially so that the treatment volume is cut in hydraulic loading and flow. Recycling, however, may require a cooling system and acid treatment to stabilize the pH of the wash water to 7.0, since alkalinity will be caused by the build-up. From this discussion it can be seen that scrubbing systems in steel plants should be tied into the water treatment system. Therefore, any economic comparison of wet scrubbers with dry-type collection equipment should include part of the cost of wastewater effluent treatment.

Foundries

Gray iron foundry flue gases contain metal fumes, grease, dust and iron oxide in the form of particulate matter. Cupolas and core making and shakeout systems are the primary sources of emission. When trying to control these atmospheric contaminants, water pollution problems emerge. Scrubbing systems on cupola stacks and dust collection systems can capture a considerable amount of airborne solids. These contaminants are physically discrete, and settling lagoons can be used for sedimentation of the solids from the scrubber water. When mechanical equipment is employed for coarse solids removal, it can be followed by coagulation, clarifying, sludge dewatering and sludge collection.

Calcium Carbide Plants

Dust control in these types of plants utilizes wet collection devices, and almost all calcining kiln dust is water scrubbed. Electric furnace fumes are drawn in through wet scrubbers where water sprays remove the particulate matter. Baghouses can be used to collect fine dust from carbide crushing operations. This dust is then water-mixed and requires processing before disposal. Clarification produces sludge that may be stored in lagoons. Clarifier overflow is mixed with cooling water to reduce the solids concentration before discharge to sewers.

Petroleum Refineries

Sludges from petroleum refineries are a mixture of petroleum residue and inorganics. These sludges are generally atomized, and the organic matter burned in an incinerator. The unburned organics escape in exhaust gases and are collected in high-energy scrubbers. Air blowing of asphalts generates oil and tar mists, which are usually scrubbed with sea water. These waters may be passed through separators to reclaim tar and oil.

Other Industries

In pulp mills some of the more important sources of particulate matter are lime kilns and smelt tanks. Stack dust from lime kilns is collected by 85 to 95 percent efficient venturi scrubbers. Water sprays of 20 to 30 percent efficiency and mesh demisters of 80 to 90 percent efficiency are used on smelt tanks.

Paint-spraying operations can produce particulate matter that can be removed in wet air scrubbers. The water used as the scrubbing medium may be treated in the waste treatment plant.

A considerable amount of dust is produced by polishing and grinding operations in the plating industry. Water sprays are normally used for dust removal. Wet-type centrifugal separators are also used. Both systems result in substantial water pollution problems.

Water disposal from wet scrubbers is dependent on many factors, such as the quantity of the waste, slurry particle distribution, solids loading, recovery value and the corrosiveness of the solution. Some typical methods are compared in Table 1-3 and illustrated in Figure 1-1.

Gaseous and Vapor Contaminant Control

Many processes include extensive washing of a wide variety of products. Such washes usually result in dissolved chemicals in the effluents. Pulp and paper washes may contain organics, pulp particulates and dissolved chemicals; plating washing may result in dissolved metals, cyanides and chromates.

Any of the following methods may be used for removal of such dissolved chemicals, the choice depending on the concentrations, the flow rates, the space requirements, etc.: chemical precipitation, adsorption, ion exchange, solvent extraction, chemical oxidation, reverse osmosis, crystallization and dialysis. The potential water pollution from such effluents, including that from air pollution control equipment, cannot be underestimated.

The Steel Industry

Coke oven gas that is washed with water to remove dust must also be treated with acid to remove ammonia. It is treated with oils to absorb C_6H_6, $C_6H_5CH_3$ and $C_6H_4(CH_3)_2$, which are more valuable as by-products than as fuel. Sulfur compounds are sometimes removed by sodium carbonate. Such gas-cleaning systems result in an ammoniacal liquor containing cyanates, phenols, spent acid, spent caustic and spent adsorber solution, such as carbonate.