

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

Environmental Protection Agency

TABLE OF CONTENTS

1.	ORGANIZATION AND ADMINISTRATION OF POLLUTION ENGINEERING AND CONTROL	1
	Pollution Control Interrelationships	1
	How to Make Pollution Control Decisions	11
	PR and the Pollution Engineer	12
	Establishing a Corporate Department for Pollution Control	16
	Environmental Protection—A Corporate Example	21
	Environmental Factors in Plant Site Selection	29
	Preparation of Environmental Impact Statements	35
	Planning Pollution Control Projects by PERT	37
	Air Pollution Health Effects	45
	OSHA Checklist	47
	Graphical Determination of Pollution Problems	51
	Measurement of Pollution in Air and Water	53
2.	PARTICULATE CONTROL OF AIR POLLUTION— DRY METHODS	61
	Economics of Selecting Particulate Control Equipment	61
	Fabric Filters for Dust Collection	67
	Fabric Filter Types	75
	Variables Affecting Efficiency	89
	Design and Operation	93
	Electrostatic Precipitators	98
	Cyclones	110
3.	WET SCRUBBERS	125
	Applications and Limitations	125
	Scrubber Selection	131
	Design and Cost of High-Energy Scrubbers	143
	Selecting Materials for Wet Scrubbing Systems	165
	Increasing Venturi Scrubber Efficiency with Steam Jet Ejectors	168
	Suppressing Scrubber Steam Plumes	170
	Vinyl Plastic Mist	175
	Selecting Pumps for Minimum Scrubber Maintenance	180
4.	FANS, BLOWERS AND VENTILATION	185
	Fans and Blowers	185
	Ducting Design	196

5.	AIR POLLUTION STACK TESTING AND INSTRUMENTATION	225
	Instrumentation for Stack Monitoring	225
	Stack Testing and Monitoring	227
	Sampling Techniques	240
	Tape Samplers	243
6.	FUME COMBUSTION AND INCINERATION	251
	Fume Incineration	251
	Catalytic Incineration	262
	Cost Comparison for Burning Fumes and Odors	265
	Relating Flares to Air Quality	269
7.	ODOR CONTROL	275
	Odor Source Inventories	275
	Chemical Control of Odors	280
	Odor Modification	283
	Odor Control of Paper Recycling	287
8.	AIR POLLUTION CONTROL IN SELECTED APPLICATIONS .	293
	Automated Air Pollution Control in the Steel Industry	293
	Air Pollution Control in Foundries	299
	Flyash Emissions Estimating	302
	Minimizing Air Pollution Control Costs in Older Plants	304
	Aluminum Bonding Oven Emission Control	308
	Aluminum and Copper Recycle Process Emission Control	312
	SO ₂ Control for Small Boilers	321
	Sulfur Plant Tail Gas Abatement	324
	Degreaser Solvent Recovery by Carbon Adsorption	327
	Airlifting—An Installation Alternative	330
9.	WORK AREA AIR PROBLEMS	335
	Air Sampling and Analyses of Contaminants in Work Areas	335
	In-Plant Air Cleaning	340
	Respiratory Protective Equipment	345
	Handling and Disposal of Chemicals	350
10.	STACK DESIGN AND AIR POLLUTION DISPERSION	355
	Introduction	355
	Meteorological Factors	355
	Effect of Topography	360
	Effects of Initial Parameters	364
	Effects of Multiple Sources	364
	Effluent Considerations	365
	Prediction of Plume Characteristics	366
	General Guidelines	367
	Material and Equipment Considerations	369
	Determining Wind Chill Factor	369
	NEXUS—A New Way to Measure	370
11.	WASTEWATER TREATMENT METHODS	375
	Industrial Water Treatment	375
	Surface Water Quality	378

Neutralizing Industrial Wastes	380
Chemical Water Treatment	384
Water and Wastewater Disinfection	387
Ozone	393
Ion Exchange	399
Ultraviolet Water Purification	404
Deep Well Disposal of Liquid Waste	411
Converting Contamination Concentration in Waste Discharge to Total Pounds	416
12. FILTERS AND FILTRATION	419
Wastewater Treatment for Removal of Suspended Solids	419
Dewatering Screens	427
Gravity Filters	431
Flocculation	434
Sludge Filtration	441
Reverse-Osmosis Ultrafiltration	446
Tube Settlers for Sedimentation	453
Diatomite Filter Aids	457
Trickling Filters	461
13. AERATION	465
Aerators	466
Designing a Mechanical Aeration System	472
Aerated Lagoons	478
Compressed Air Subsurface Aeration	481
Dispersed Air Flotation	487
Dynamic Aeration Economics	490
14. SELECTED APPLICATIONS OF WATER POLLUTION PROBLEMS	497
Metal Waste Reclaiming	497
Cyanide Plating Waste Treatment	504
Pulping Process Treatment	506
Stability and Removal of Commercial Dyes from Process Wastewater	511
Combined Treatment from Power Plants	521
Soil Erosion Pollution	523
Dissolved Air Flotation for Treating Industrial Wastes	525
Salt Piling Pollution of Water Supplies	531
Plastic Pipe for Sewers	538
Membrane Pond Liners	542
15. WASTEWATER	549
Vacuum Transport and Collection	549
Neighborhood Treatment Plants	558
16. INSTRUMENTATION—ANALYSIS OF WASTEWATERS	561
Sampling and Monitoring Instrumentation for Water Pollution Control	561
Comparison of Water Pollution Instrumentation	571
pH Control	575
pH Monitoring of Phosphate Removal	580
Measuring Oxygen Demand	581

Planning and Automating for Pollution Control: A Case Study	585
Radio System Monitors	589
Treatment Efficiency Test for Plant Upset	591
17. POLLUTION FROM OIL SPILLS	595
Disposal of Oil Wastes	595
Controlling Oil Spills	599
Oil Spills Measured	604
Treatment of Oily and Metal-Containing Wastewater	610
18. COOLING AND COOLING TOWERS	617
Industrial Cooling Towers—A Use Profile	617
Selecting and Sizing Cooling Towers	620
Cooling Tower Repair and Maintenance	623
FRP for Cooling Towers	627
Sprays for Cooling	630
Spray Nozzles for Pollution Control	633
19. CORROSION	641
Corrosion Resistance of Piping and Construction Materials	641
Analyzing Atmospheric Corrosion	643
Modern Protective Coating Technology	653
Corrosion-Resistant Linings for Stacks and Chimneys	664
20. SOLID WASTES HANDLING METHODS AND MANAGEMENT	671
Industrial Solid Waste Handling and Disposal Equipment	671
Common Industrial Practices for Solid Waste Disposal	681
Analyzing the Cost of Solid Waste Disposal	686
Safely Handling Solid Wastes	692
Solid Waste Handling Conveyors	694
Solid Waste Management—Legal Aspects	704
21. INCINERATION DISPOSAL OF SOLID WASTES	709
Incinerator Emissions: Units, Correction and Conversion	709
Incineration Economics	719
Planning Incineration Without Air Pollution	722
Sludge Incineration	724
Wet Air Oxidation	732
Electric Incineration	736
Fluidized Bed Reactors	737
Removing Coatings with Fluid Bed Reactors	743
Pyrolysis	745
High Alloy Cast Incinerator Components	749
Teepees	752
22. VOLUME REDUCTION OF SOLID WASTES	759
Solid Waste Shredders	759
Milling Refuse—A Case Study	763
Mobile Mulcher	769
Solid Waste Compaction Economics	772
Compactor Sizing and Selection	775

23.	SANITARY LANDFILLING	781
	Applications and Limitations	781
	High Density Landfilling	785
	Composting	789
	Airborne Sensing for Landfill Site Evaluation	793
24.	SOLID WASTE SALVAGE AND RECOVERY	797
	Processing and Reclaiming	797
	Reclaiming Paper Wastes	804
	Magnet Control	808
	Scrap Steel Magnetic Removal	812
	Magnets Salvage Scrap—A Case Study	815
	Getting Rid of Abandoned Cars	817
	Destructive Distillation of Used Tires	820
	Solids Recovery by Spray Drying	827
	On-Site Waste Disposal and Energy Recovery	830
25.	OCEAN DUMPING OF WASTES	839
	Oceanic Pollutants	839
	Ocean Dumping Permits	842
26.	NOISE COMPLIANCE AND ENFORCEMENT	847
	Noise, Laws, Control and the Engineer	847
	Environmental Law—Legal Actions to Control Noise	853
	Assessing Noise Impact on the Environment	858
	Calculating OSHA Noise Compliance	862
	Hearing Conservation Compliance Guide	866
	Buying Guidelines for Noise Control	870
27.	NOISE MEASUREMENT AND PERSONAL PROTECTION	877
	Sound Transmission and Absorption	877
	Velocity of Sound in Gases	881
	Combining Sound Levels and Correcting for Background Noise	883
	Predicting Peak Noise Frequency of Vents to Atmosphere	884
	Noise and its Measurement	886
	Plant Noise Survey Techniques	892
	Industrial Hearing Test Programs	898
	Selecting an Audiometric Room	903
	Personal Hearing Protection Devices	907
	Pointers on Selecting Hearing Protectors	911
	Pollution Engineering Noise Glossary	915
28.	NOISE SOURCES AND CONTROL APPLICATIONS	927
	Techniques for Reducing Machinery Noise	927
	Ground-Borne Vibrations	937
	Lead-Loaded Fabrics Keep Outside Noise Out	940
	Using Glass for Noise Reduction	942
	Noise Control Effects of Rock Wool	946
	Workable Solutions to Common Machinery Noise Problems	948
	Hydrodynamic Control of Valve Noise	953
	Aerodynamic Control of Valve Noise	961
	Silencers for Reciprocating Engine Exhaust	967
	Control of Office Noise	970
	Proper Construction Controls Office Noise	972
	Computers—A White Collar Hazard	975

29. TRAFFIC NOISE	985
Automobile and Traffic Noise	985
Sources of Highway Noise	986
Control of Highway Noises	988
Airport Noise Monitoring—A Case Study	989
30. AIRBORNE RADIOACTIVITY RELEASES FROM NUCLEAR POWER PLANTS	997
Radiation Releases	997
Gaseous Radioactive Waste Treatment Systems	1001
Monitoring Gaseous Effluents	1007
Environmental Surveillance Program	1009
Health Effects from Nuclear Facility Effluents	1011
Summary and Conclusions	1012
Glossary	1012
31. CONVERSION FACTORS	1015
BIBLIOGRAPHY	1031
INDEX	1041

CHAPTER 1

ORGANIZATION AND ADMINISTRATION OF POLLUTION ENGINEERING AND CONTROL

POLLUTION CONTROL INTERRELATIONSHIPS³¹

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 ₂ SO 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	
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 ventilation 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.