

TABLE OF CONTENTS

| | |
|---|----|
| INTRODUCTION | 1 |
| 1. ENVIRONMENTAL LEGISLATION | 3 |
| Toxic Substances Control Act (TSCA) | 3 |
| Resource Conservation and Recovery Act (RCRA): Subtitle C | 4 |
| Clean Water Act | 6 |
| Clean Air Act | 7 |
| Impact of Regulations on Publicly Owned Treatment Works (POTW). | 8 |
| 2. SEWAGE SLUDGE GENERATION | 9 |
| Wastewater Disposal | 9 |
| Wet Stream | 10 |
| Solids Flow | 14 |
| References. | 24 |
| 3. CHARACTERISTICS OF SEWAGE SLUDGE | 25 |
| Sludge Constituents. | 25 |
| Polymer Addition | 26 |
| Ferric Salt and Lime Conditioning | 28 |
| Ash Addition. | 29 |
| Sludge Thermal Conditioning | 29 |
| Oxidation | 31 |
| Sludge Burning | 32 |
| Residue. | 32 |
| Upstream Processing | 33 |
| Sludge Analyses. | 35 |
| References. | 37 |
| 4. SLUDGE DISPOSAL ALTERNATIVES. | 38 |
| Sludge Landfill | 40 |
| Codosposal Landfilling. | 41 |
| Ocean Dumping. | 42 |
| Cropland Application | 42 |



Table of Contents

| | |
|--|------------|
| Land Reclamation | 43 |
| Fertilizer | 43 |
| Other Direct Disposal Methods | 45 |
| Incineration | 46 |
| References | 47 |
| 5. INCINERATOR TYPES | 48 |
| The Incineration Process | 49 |
| The Multiple Hearth Incinerator | 49 |
| Fluid Bed Incineration | 51 |
| The Electric Furnace | 53 |
| Cyclonic Furnace | 56 |
| Flash Drying | 57 |
| 6. INCINERATOR SUBSYSTEMS | 60 |
| Feed and Charging | 60 |
| Weigh Scales | 65 |
| Furnace | 69 |
| Air Pollution Control | 69 |
| Stacks and Flues | 71 |
| Ash Disposal | 75 |
| Air Moving Equipment | 77 |
| Supplemental Fuel System | 86 |
| Water Supply | 89 |
| Alternate Disposal | 89 |
| Other Systems | 89 |
| 7. DESIGN OF A MULTIPLE HEARTH INSTALLATION | 93 |
| Furnace Sizing | 93 |
| Equipment Sizing | 101 |
| Mass Flow | 101 |
| Heat Balance | 103 |
| Supplemental Heat Requirement | 106 |
| Scrubber Operation | 108 |
| Furnace Draft | 111 |
| Furnace Design | 112 |
| 8. DESIGN OF OTHER INCINERATION SYSTEMS | 117 |
| Fluid Bed Furnace | 117 |
| FBF Sizing | 117 |
| FBF Dimensional Requirements | 119 |
| FBF Design | 119 |
| Air Heater Characteristics | 125 |
| Scrubber Parameters—FBF | 125 |
| FBF Fuel Requirement | 128 |
| Radiant Heat Furnace | 128 |
| Sizing the Electric Furnace | 128 |
| Electric Furnace Combustion Parameters | 130 |
| Electric Furnace Design | 130 |
| Electric Furnace Scrubber Requirements | 134 |
| Electric Power Requirements | 135 |

Table of Contents

| | |
|---|----------------|
| 9. ALTERNATIVE SOLIDS INCINERATION | .. 136 |
| Sewage Solids | .. 136 |
| Sewage Solids Generation | .. 139 |
| Analysis of Sewage Solids | .. 140 |
| Handling of Sewage Solids | .. 140 |
| Incineration of Sewage Solids | .. 141 |
| Alternative Solids Burning | .. 143 |
| Pyrolysis | .. 144 |
| Pyrolysis vs Incineration | .. 145 |
| Refuse | .. 145 |
| Codisposal | .. 148 |
| Furnace Conversion to Codisposal | .. 148 |
| References | .. 151 |
| 10. ENERGY RECOVERY | 152 |
| Nature of the Hot Gas Stream | 152 |
| Methods of Energy Recovery | 155 |
| Waste Heat Utilization | 156 |
| Hot Water Generation | 159 |
| Steam Generation | 162 |
| Waste Heat Boiler Steam Production | 165 |
| References | 171 |
| 11. ENVIRONMENTAL CONSIDERATIONS ... | ... 172 |
| Statutory Requirement | ... 172 |
| Gaseous Discharge | ... 173 |
| Metals Discharge | ... 173 |
| Organic Discharge | ... 174 |
| Particulate Generation | ... 174 |
| Particulate Size Distribution | ... 177 |
| Air Pollution Control Equipment Selection | ... 177 |
| Venturi/Tray Scrubber Performance | ... 181 |
| Acid Scrubbing | ... 183 |
| Particulate Monitoring | ... 183 |
| Odor Generation and Detection | ... 184 |
| Odor Control Methods | ... 185 |
| Noise Generation | ... 187 |
| References | ... 190 |
| 12. INCINERATION FACILITY OPERATION | ... 191 |
| Incinerator Operating Parameters | ... 191 |
| Sterile Ash | ... 191 |
| Minimal Air Emissions | ... 192 |
| Minimal Use of Supplemental Fuel | ... 192 |
| Minimal Cost of Operation and Equipment Maintenance | ... 192 |
| Process Control | ... 192 |
| Automation | ... 196 |
| Maintenance | ... 200 |
| Record Keeping | ... 201 |
| Nature of the Work Force | ... 201 |
| Safety | ... 204 |

| | |
|--|-----|
| 13. ECONOMIC ANALYSIS | 206 |
| Federal Participation | 206 |
| State and Local Funding | 207 |
| Cost Projections | 207 |
| Equipment Costs | 207 |
| Incinerator Cost Estimates | 219 |
| Total Cost | 220 |
| References | 221 |
| 14. INCINERATION OVERVIEW | 222 |
| Sludge Incinerator Selection | 222 |
| Multiple Systems | 224 |
| Water Treatment Application—Lime Recalcining | 224 |
| Water Treatment Application—Carbon Regeneration | 224 |
| Future Trends | 226 |
| APPENDIX A: THERMODYNAMICS REFRESHER | 229 |
| Definitions | 229 |
| Subscripts | 229 |
| System Boundary | 230 |
| Gas Equation | 231 |
| Gas Mixture | 231 |
| Flue Gas | 232 |
| Saturated Flue Gas | 234 |
| Heat Transfer | 234 |
| Combustion Calculations | 252 |
| References | 256 |
| APPENDIX B: CALCULATOR PROGRAMS | 257 |
| Combustion Parameters | 257 |
| Heat Transfer, Air Streams | 266 |
| Heat Transfer, Dual Wall | 274 |
| Heat Transfer, Insulated Pipe | 283 |
| Scrubber | 289 |
| Sludge Incinerator | 294 |
| Sludge Incinerator, Electric | 302 |
| Sludge Incinerator, Fluid Bed | 311 |
| Waste Heat Boiler | 319 |
| APPENDIX C: THE CLEAN AIR ACT—CFR 40 EXCERPTS | 328 |
| GLOSSARY | 354 |
| BIBLIOGRAPHY | 373 |
| INDEX | 377 |