

1

Introduction to Wastewater Treatment and Process Analysis

1-1	EVOLUTION OF WASTEWATER TREATMENT	4
	<i>Treatment Objectives</i>	<i>5</i>
	<i>Current Health and Environmental Concerns</i>	<i>5</i>
	<i>Sustainability Considerations</i>	<i>5</i>
1-2	EVOLUTION OF REGULATIONS OF SIGNIFICANCE TO WASTEWATER ENGINEERING	6
	<i>Establishment of the Environmental Protection Agency</i>	<i>6</i>
	<i>Important Federal Laws and Regulations</i>	<i>6</i>
	<i>Other Federal Regulations</i>	<i>9</i>
	<i>State and Regional Regulations</i>	<i>9</i>
1-3	CHARACTERISTICS OF WASTEWATER	9
	<i>Sources of Wastewater</i>	<i>9</i>
	<i>Types of Collection Systems</i>	<i>9</i>
	<i>Wastewater Constituents</i>	<i>10</i>
1-4	CLASSIFICATION OF WASTEWATER TREATMENT METHODS	10
	<i>Physical Unit Processes</i>	<i>10</i>
	<i>Chemical Unit Processes</i>	<i>12</i>
	<i>Biological Unit Processes</i>	<i>12</i>
1-5	APPLICATION OF TREATMENT METHODS	12
	<i>Wastewater Processing</i>	<i>12</i>
	<i>Residuals Processing</i>	<i>13</i>
	<i>Typical Treatment Process Flow Diagrams</i>	<i>13</i>
1-6	STATUS OF WASTEWATER TREATMENT IN THE UNITED STATES	17
	<i>Recent Survey Results</i>	<i>18</i>
	<i>Trends</i>	<i>18</i>
1-7	INTRODUCTION TO PROCESS ANALYSIS	19
	<i>Mass-Balance Analysis</i>	<i>19</i>
	<i>Application of the Mass Balance Analysis</i>	<i>21</i>
1-8	REACTORS USED IN WASTEWATER TREATMENT	22
	<i>Types of Reactors</i>	<i>22</i>
	<i>Hydraulic Characteristics of Reactors</i>	<i>24</i>
	<i>Application of Reactors</i>	<i>25</i>
1-9	MODELING IDEAL FLOW IN REACTORS	26
	<i>Ideal Flow in Complete-Mix Reactor</i>	<i>26</i>
	<i>Ideal Plug-Flow Reactor</i>	<i>27</i>
1-10	INTRODUCTION TO PROCESS KINETICS	29
	<i>Types of Reactions</i>	<i>29</i>
	<i>Rate of Reaction</i>	<i>30</i>

	<i>Specific Reaction Rate</i>	31
	<i>Effects of Temperature on Reaction Rate Coefficients</i>	31
	<i>Reaction Order</i>	33
	<i>Rate Expressions Used in Wastewater Treatment</i>	34
	<i>Analysis of Reaction Rate Coefficients</i>	39
1-11	INTRODUCTION TO TREATMENT PROCESS MODELING	42
	<i>Batch Reactor with Reaction</i>	43
	<i>Complete-Mix Reactor with Reaction</i>	43
	<i>Complete-Mix Reactors in Series with Reaction</i>	44
	<i>Ideal Plug-Flow Reactor with Reaction</i>	47
	<i>Comparison of Complete-Mix and Plug-Flow Reactors with Reaction</i>	48
	<i>Plug-Flow Reactor with Axial Dispersion and Reaction</i>	50
	<i>Other Reactor Flow Regimes and Reactor Combinations</i>	51
	PROBLEMS AND DISCUSSION TOPICS	53
	REFERENCES	55

WORKING TERMINOLOGY

Term	Definition
Batch reactor	A vessel in which flow is neither entering nor leaving during the reaction time.
Biosolids	Sludge from wastewater treatment processes that has been stabilized to meet the criteria in the U.S. EPA's 40 CFR 503 regulations and, therefore, can be used beneficially.
Complete-mix reactor (CMR)	A reactor in which complete mixing occurs instantaneously and uniformly throughout the reactor as fluid particles enter the reactor.
Characteristics, wastewater	General classes of wastewater constituents such as physical, chemical, and biological constituents.
Homogeneous reaction	Reactions that occur uniformly throughout the fluid so that the potential for reaction at any point within the fluid is the same.
Heterogeneous reaction	Reactions that occur between one or more constituents that can be identified with specific sites.
Ideal flow	A flow regime in which all fluid particles are retained in a reactor for a time period equivalent to the theoretical detention time.
Mass-balance analysis	An accounting of mass within a defined boundary before and after reactions and conversions have taken place.
Molecular diffusion, coefficient of	The movement of molecules from a region of higher concentration to a region of lower concentration.
Nonideal flow	A flow regime in which a portion of the fluid particles are held in a reactor for a time other than the theoretical detention time.
Plug-flow reactor (PFR)	A vessel intended to transport fluid particles such that they leave in the same sequence as they entered.
Reaction rate	The rate of change (decrease or increase) in the number of moles of a reactive substance per unit volume per unit time (for homogeneous reactions), or per unit surface area or mass per unit time (for heterogeneous reactions).