DARBHANGA COLLEGE OF ENGINEERING

COURSE FILE OF __INDUSTRIAL POLLUTION _____ (021827)



FACULTY NAME: Mr. Mukesh Kumar Assistant Professor DEPARTMENT OF Mechanical engineering

MECHANICAL ENGINEERING DEPARTMENT

VISION

To bring forth quality engineers embodying societal ethics to serve national and multinational organisations as well as harping on higher studies.

MISSION

- 1. To create a modern teaching-learning ambience focusing on advanced pedagogy and tools for mechanical engineers
- 2. To collaborate with domain industry and research institutes to enhance the skills and knowledge of the graduates.
- 3. To inject necessary professional skills to serve the industry and the nation
- 4. To inculcate humanitarian ethical values in graduates through various social-cultural activities

Program educational objectives(PEO's)

- **1.** The graduates will be able to demonstrate the knowledge and skills of mechanical engineering to obtain solutions to engineering problems.
- **2.** The graduates will be able to apply mechanical engineering concepts while pursuing academic and research activities.
- 3. The graduates will be able to showcase professional skill and expertise.

Program specific outcomes(PSOs)

- 1. Students should be oriented towards research in engineering technologies like Advance manufacturing, 3D Printing, Alternative fuels to contribute the evolving research and development in the field of Mechanical Engineering.
- 2. Students should be able to learn and apply software like AutoCAD, Ansys, Catia for various applications.

TIME TABLE

FACULTY NAME: Mr. Mukesh kumar

Time/Day	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
9:00am-				ENGINEERING		
10:00am				MATERIAL		
10:00am-	INDUSTRIAL				ENGINEERING	ENGINEERING
11.011	POLLUTION(IP)	(IP)			MATERIAL	MATERIAL(T)
11:00am-	ENGINEERING	Γ –	INDUSTRIAL			
12:00pm	MATERIAI		POLLUTION			
			(IP)			
12:00pm-				INDUSTRIAL	INDUSTRIAL	
01:00pm				POLLUTION	POLLUTION	
				IP(T)	IP(T)	
1:00pm-				ПИСН		
_2:00pm						
2:00PM-						
3:00PM						
3:00PM-	WORKSHOP	WORKSHOP		WORKSHOP		WORKSHOP
4:00PM	WORKSHOP	WORKSHOP		WORKSHOP		WORKSHOP
4:00PM-						
5:00PM						

Mr.Mukesh kumar Name of Faculty Mr. Vishnu SINGH Head of Department

SYLLABUS

INDUSTRIAL POLLUTION

L-T-P: 3-1-0

1. Introduction : Environments and Human activities, Environments and Ecology, Consequences of

population growth. Energy problem

2. Population of Air, water and land, Fossil fuel related pollutants in the environment- Lecture : 4

3. Environmental Impacts of Hydro-electric, Nuclear energy and chemicals forwards a solution.

Lecture : 4

4. Air Pollution :Definitions and scales of concentration, classification and properties of air pollutants, Emission an sources and their classification. Air pollution laws and standards, Inversion Ambient air sampling, stack sampling, sampling system, analysis of air pollutants. Air pollution emission control, selection of a particulate: collector, control of gaseous emission, combustion- Lecture : 10

5. Water Pollution :Hydrologic cycle and water quality , origin of waste water and its composition, Type of water pollutants and their effects, water pollution laws: and standards, waste water sampling and analysis water quality standard, waste watertreatment , Biological systems(Aerobic and Facultative ponds), Recovery of material from process effluents.

6. Noise pollution :Different noise environments and their sources, measurement of noise and the equipments Noise pollution lows an, Vibration isolation and noise control in industries. **Lecture : 6**

7. Solid waste management :Sources and classification, Public health aspect, effluent treatment processes and solid waste management: sources and classification. Public health aspect, effluent treatment process and solid waste management, "Solid-Solid separation technique for recovery and reuse.

8. Case study :Modern environmental assessment method, pollution control in steel plants and coal industries. Lecture : 3

Text Book :

1. Managing Industrial Pollution by SC Bhatia

2. Enviromental pollution by HM Dix

3. Chemistry for environmental engineering by SAWYER

Credit : 4

Lecture : 4

COURSE HANDOUT

Institute / College Name :	Darbhanga	College of Engineering	
Program Name	B.Tech Med	chanical	
Course Code	ME021827		
Course Name	Industrial pollution		
Lecture / Lab (per week):	3/0 Course Credits 4		
Course Coordinator Name	MR. Mukesh Kumar		

Course Description

Industrial pollution is of great importance for the protection of the environment in the context of the modern day world. Industrial wastewaters have often very different characteristics from domestic and municipal wastewaters which make it very difficult to successfully treat in a sustainable way. The main objective of this subject is to provide the opportunity for students to understand the principles of industrial wastewater treatment, disposal and reuse in order to minimize pollution in a sustainable manner. To get an in-depth understanding of the treatment and disposal of industrial wastewater, this subject commences with classification, characterization and quantification of industrial wastes. The subject focuses on the principles and mechanisms of pollutant removal, the processes and design of conventional (primary, secondary and tertiary) and advanced (post-treatment) technologies applied in the treatment of industrial effluent.

Course Objectives

- 1. Carry out a complete analysis of industrial wastes (source, characterization and quantification)
- 2. Gain sound and solid understanding of environmental auditing in controlling industrial pollution
- 3. Understand the water recovery and reuse technology and practices in industries and design such processes for industrial wastewater stream.
- 4. Develop technical knowledge and design skills in the treatment and management of industrial wastewater.

COURSE OUTCOMES

- CO1: Understand the various types of pollution occurring in industries.
- CO2: Calculate the pollution level in air, water, soil etc. in environment.
- CO3: Apply the scientific principle and technical information to analyze the existing components in

environment.

CO4: Relate the pollutants with standard air, water, soil, noise etc.

CO5: Define major sources of pollution and also study a case.



Darbhanga college of engineering, Darbhanga

Department: Mechanical engineering

Subject: Industrial pollution (021827)

ASSIGNMENT

- 1. Briefly explain the methods of solid waste management
- 2. What do you understand by solid waste management? Give classification of solid waste.
- 3. Discuss the health hazards and environmental effects of solid waste pollution.
- 4. Explain the concept of an Ecosystem. What are the characteristics of an ideal Ecosystem?
- 5. Describe the energy flow in an Ecosystem.
- 6. Discuss the man- made and natural sources of radioactive pollution
- 7. Briefly explain the main sources, effects and control of Thermal pollution
- 8. Save water campaigns are essential to make people everywhere aware of the dangers of water scarcity. What measures need to be taken for the better management of the world's Water resources?
- 9. What steps should be taken to conserve energy in day to day life?
- 10. Write short notes on any four of the following:
 - I. Acid rain
 - II. Ozone layer deplation
 - III. Air pollution law
 - IV. Pollution due to organic waste Ozone layer depletion
 - V. Chipko movement
- 11. Define pollutant and pollution. Explain briefly the devices used to control air pollution.
- 12. Classify gaseous air pollutants with their sources and effects
- 13. What is noise pollution? state the noise pollution level and its harmful effects.
- 14. State the important indoor and outdoor sources of noise pollution? Mention the method of control for each of them.
- 15. Define water pollution. Explain the major sources of water pollution.
- 16. Write the name of various gaseous particulate control devices. Explain Gravitational settling chamber and Wet scrubbers with neat sketch.
- 17. Discuss about the effluent generated in steel industries and impact of effluents on water bodies. Explain the waste water treatments required for steel industry
- 18. What are the different types of solid wastes?
- 19. Explain inversion. Elaborate on how inversion will affect the dispersion of pollutants.
- 20. Discuss any two aerobic methods available for sludge treatment.

- 21. Discuss the methods used for the collection of solid waste.
- 22. Write short note on sources of Industrial wastes?
- 23. Define hazardous waste. Describe the concept for management of such wastes
- 24. Explain the e-waste and give its impact on environment.
- 25. Briefly explain the waste-water treatment methods
- 26. what are the standards for noise control? what are the various air pollution "control technologies.
- 27. What are the various treatments and control methods for water pollution?
- 28. Discuss Aerobic and Non Aerobic treatment of waste water.
- 29. Write the different pollution control techniques adapted in the treatment of effluents in the sugar or pulp and paper industries.
- 30. Write in detail the identification, characterization, classification, collection and treatment of hazardous wastes in India.

MID SEMESTER QUESTION PAPER

Enroll. No.

DARBHANGA COLLEGE OF ENGINEERING B.Tech – SEMESTER-VIII • MID SEMESTER- EXAMINATION SUBJECT: INDUSTRIAL POLLUTION (ME)

	[DATE: 16-03-2020	TIME: 02:00 PM to 04:00 PM	TOTAL MARKS: 20	
	Ins	tructions: 1. Attempt 2. Figures 3. Assume	any four questions of the following. to the right indicate full marks. suitable data if required.		
Q.	(a)	What is industrial pollu	tion? Explain with suitable examples.		[2.5]
1	(b)	What are pollutants? G	we the example of pollutant.		[2.5]
Q.	(a)	what is air pollution?			[2.5]
2	(b)	What are the causes of	air pollution?		[2.5]
Q.3 (Q.4)	Classif What	y gaseous air pollutants is noise pollution? What	with their sources and effects. are the causes of noise pollution?		[05] [05]
Q.5	Define	e water pollution? Explai	n the major sources of water pollution.		[05]

	Sibaroo	-		·	
d. None of the above		Ę	a. Sewage trea	tment nlant	
(iv) Ozone of found in	wa		h Solid worte	disnosal sites	
	iki	1	D. DUILL WASH	ente mendem	
a. Mesosphere	ıhi	•	c. Thermal pov	ver plant	•
b. Ionosphere	ha		d. All of the ab	ove	•
c. Stratosphere	rco	(ix)	Sound becomes	hazardous noise	e pollution at
d. Exosphere	h	·	decibels:		
(v) The function of automobile catalytic converter is to			A hove 20	2	A hove 30
control emissions of	.,	8	4. 2004000	5 7	00000000
a. carbon dioxide and hydrogen			c. Above IUU	÷	AD0V6 120
h carbon monovide and hydrogen		×	BOD/COD ratio	will always be:	
	wv		a. Equal to 1	þ.	Less than 1
c. carbon monoxide and carbon dioxide	~~~		c More than 1	r	None of them
d. carbon monoxide and nitrogen dioxide	al			; ;	
(vi) The threshold concentraticn of sulphur dioxide in	cut	2. (a)	Define pollutant an	d pollution. Expl	ain briefly the
any industrial activity should not be permitted beyond	, nih:		devices used to contr	rol air pollution.	7
a. 2ppm b. 3ppm	arc	(q)	Classify gaseous air	pollutants with th	eir sources and
c. 4ppm d. Sppm	om		effects.		2
(vii) Which of the following devices is suitable for the		3. (a)	What is noise polluti	on? State the noise	e pollution level
removal of gaseous pollutantis?			and its harmful effec	S	L
a. Cyclone separator		(9	State the important ir	idoor and outdoor	sources of noise
b. Electrostatic precipitat or	v		pollution? Mention	the method of con	ntrol for each of
c Fahric filter			them.	14	7
d Wet scrubber	val	4. (a)	Define water polluti	on. Explain the n	lajor sources of
(viii) Which of the following is a major source of thermal	uhi		water pollution.	, N L	2
pollution in water bodies?	har		200100		DTO
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har.com Code: 021827 B.Tech. 8th Semester Exam., 2017 B.Tech. 8th Semester Exam., 2017 Industrial pollution <i>Time : 3 hours</i> <i>Full Marks : 70</i> <i>Instructions :</i>	 (i) The marks are marke marked in the reguration magnet. (ii) There are Nine questions in this paper. (iii) Attempt Five questions in all. (iv) Questions No. I is compulsory. (iv) Questions No. I is compulsory. 1. Fill in the blanks/select correct answer for any seven of the following: (i) According to WHO, the soft water has 0 to milligram per litre a CaCO, a. 30 (i) b. 60 	 c. 90 d. 120 (ii) The source of Arsenic in water is a. Industrial waste b. Fertilizers a. Industrial waste b. All of the above (iii) The major contributor of Carbon monoxide is a. Motor vehicle b. Industrial processes c. Stationary fuel combustion P.T.0
ww.akubihar.com	www.akubihar.com	www.akubihar.com
 (b) Briefly explain the methods of control of water pollution. 5. (a) What do you understand by solid waste management? 5. (a) What do you understand by solid waste management? (b) Discuss the health hazards and environmental effects of solid waste pollution. (b) Evaluation of an Ecosystem What are the formation the concent of an Ecosystem What are the formation of solid waste pollution. 	 characteristics of an ideal Ecosystem. (b) Describe the energy flow in an Ecosystem. 7. (a) Discuss the man-made and natural sources of radioactive pollution. 7. (b) Briefly explain the main sources, effects and control of Thermal pollution. 8. (a) 'Save water campaigns are essential to make people everywhere aware of the dangers of water scarcity. What measures need to be taken for the better 	 management of the world's water resources? 7 (b) What steps should be taken to conserve energy in day to day life? 7 9. Write short notes on any four of the following: 14 (i) Acid rain (ii) Ozone layer depletion (ii) Ari pollution law (iv) Chipko movement (v) Pollution due to organic waste *** Code : 021827 4

WWW	kuttoihar.com			
d. None of the above	ww	a. Sewage t	reatment plant	
(iv) Ozone of found in	v.ak	b. Solid was	ste disposal sites	2 2
a. Mesosphere	cub	c. Thermal	oower plant	. '
b. Ionosphere	iha	d. All of the	above	
c. Stratosphere	r.co	x) Sound becom	es hazardous noise	pollution
d. Exosphere	om	decibels:	•	•
(v) The function of automobile catalytic converter is to		a Ahove 80	<u>ج</u>	Above 30
control emissions of	in e	a. Above 1	5 T	A have 120
a. carbon dioxide and hydrogen			out of the second se	071 0100T
b. carbon monoxide and hydrogen	v		lo will always be.	
c. carbon monoxide and carbon dioxide	vw	a. Equal to	0.	Less than I
d. carbon monoxide and nitrogen dioxide	w.a	c. More tha	nl d.	None of the
(vi) The threshold concentration of sulphur dioxide in) ci kul	a) Define pollutant	and pollution. Expl	ain briefly t
any industrial activity should not be permitted beyond	oiha	devices used to c	ontrol air pollution.	8 6 83 6
a. 2ppm b. 3ppm	ar.co	b) Classify gaseous	air pollutants with th	eir sources a
c. 4ppm d. 5ppm	om	effects.	•••	
(vii) Which of the following devices is suitable for the	3. (a) What is noise pol	ution? State the noise	pollution lev
removal of gaseous pollutanits?		and its harmful ef	fects.	•
a. Cyclone separator	Ū	b) State the importa	it indoor and outdoor	sources of noi
b. Electrostatic precipitat or	w	pollution? Ment	on the method of cor	trol for each
c. Fabric filter	ww	them.	2	
d. Wet scrubber	v.ak	a) Define water pol	lution. Explain the m	ajor sources
(viii) Which of the following is a major source of thermal	ubil	water pollution.	1 2	8
pollution in water bodies?	nar.		¢	PT(
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DARBHANGA COLLEGE OF ENGINEERING, DARBHANGA

MECHANICAL ENGINEERING DEPARTMENT

Subject:	Industrial pollution
Name of Faculty	Mr. Mukesh kumar
Semester:	8 th
Subject code:	021827

QUESTION BANK

SR. NO.	QUESTIONS
	<u>UNIT 1</u>
1.	Explain the concept of an Ecosystem. What are the characteristics of an ideal Ecosystem?
2.	Discuss the man- made and natural sources of radioactive pollution
3.	Describe the energy flow in an Ecosystem
4.	Save water campaigns are essential to make people everywhere aware of the dangers of water scarcity. What measures need to be taken for the better management of the world's Water resources?
5.	What steps should be taken to conserve energy in day to day life?
6.	Define pollutant and pollution.
7.	Briefly explain the structural and functional component of an eco-system.
8.	Explain fossil fuel related pollutants.
9.	Explain Effect of population growth on environment pollution.
10.	What the energy problem on consequence of pollution.
11.	Which of the following is an example of impact of development activities on the Hydrosphere?a. Air pollutionb. Lithospherec. Hydrosphered. Biosphere
12.	Which of the following is an example of impact of development activities on the Hydrosphere?a. Air pollutionb. Soil pollutionc. Soil erosiond. Water pollution

13	The term ecology wa	s introduced by:				
13.	a. Haeckel	b. Odum	c. Tansely	d. Ramdeo Mishra		
	The study of interaction	ons between living an	d non-living organisms an	nd environment is called		
14						
17,	a. Ecosystem	b. Ecology	c. Phyto-geography	d. Phytosociology		
	An ecosystem consis	ts of				
		• 1				
15.	a. Green plants and	animais				
	c. Producers and co	sumers				
	d. Green plants, anii	nals, decomposers and	d abiotic environment			
		nuis, decomposers un				
	Study of trends in hu	man population growt	h and prediction of future	growth is called		
16						
10.	a. Demograph	b. Biography	c. Kalography	d. Psychology		
	W 71 1 C 41 C 11					
	Which of the following	ng is a problem not as	sociated with population g	rowth?		
17	a. Increased resource consumption					
1/.	c. Food and energy	storages				
	d. None of the abov	e				
		-				
	Population pyramids	are useful to:				
18.	a. Express the population growth rates					
	b. Express the age-sex distribution					
	d Indicate the death	rates				
		Tates				
	Short-term properties	of the atmosphere at	a given place and time is r	referred as:		
19.						
	a. Climate	b. Microclimate	c. Season	d. Weather		
	Global atmogrations t	amperaturas ara litzales	to be increased due to			
		emperatures are likely	to be mereased due to.			
	a Burning of fossil	fuel				
20.	b. Water pollution					
	c. Soil erosion					
	d. None of the abov	e				
		U	<u>NIT 2</u>			
21	Explain different type	es of water pollutants				
<u>~1.</u>		is of water pollutalits.				

22.	What are the adverse effect on receiving water body when these pollutants are discharged in water along with effluents.?				
23.	Describe thermal pollution.				
24.	Describe different types of air pollutants.				
25.	List out any four indoor air pollutants				
26.	Discuss the major soil pollution and their impact.				
27.	Define soil pollution. Describe the various sources of soil pollution				
28.	What is ozone layer deplation.?				
29.	Explain briefly on indian environmental act.				
30.	How is acid rain formed.? Explain its impact on environment.				
	Zone consisting air, water and soil is known as				
31.	a. Hydrosphere b. Atmosphere c. Lithosphere d. Biosphere				
32.	"Greenhouse effect" with respect to global warming refers to- a. Cooling & moist condition b. Warming effect c. Increased rainfall & greenery d. Desertification				
33.	Fossil fuel and metallic minerals are a. Renewable resources b. Non-renewable resources c. Non-renewable resources d. None of these				
34.	Carbon monoxide is a pollutant because a. It react with O2 b. It inhibit its glycolysis c. Make nervous system inactive d. React with haemoglobin				
25	Hydrological cycle provides us				
35.	a. Fresh water b. Nitrogen c. Carbon dioxide d. None of these				
36	Fossil fuels are rich in carbon and				
	a. nitrogen b. hydrogen c. oxygen d. hydrogen				

	Which of the follo	wing is a liquid form of	aerosol?		
37.	a. fume	b. dust	c. mist	d. smoke	
	The minimum siz	e of the smoke particle	is		
38.	a. 0.2µm	b. 1μm	c. 0.8µm	d. 0.5µm	
	The permissible of	concentration of PM 10	in the air is		
39.	a. 60µg/m ³	b. 40µg/m ³	c. 50µg/m ³	d. 20µg/m ³	
40.	Coal is a common a. freshwater alga b. bodies of dead c. marine organis d. tree trunks, lea	fossil fuel is formed fro ae animals sms wes, and freshwater plan	m which of the following	ng types of organic matter.?	
		l	JNIT <u>3</u>		
41.	Explain the effect of nuclear and radiation pollution.				
42.	Discuss various types of incinerators and factor affecting their efficiency.				
43.	What are particulate scrubbers.				
44.	Explain hydro-electric impacts on environment.				
45.	Write short notes on (i) Environmental policy (ii) Kyoto Protocol				
46.	Explain the sources and consequence of air pollutants for the following (i) Sulphur-di-oxide (ii) Ozone (iii) Dust (iv) Fumes				
47.	Explain the effect of nuclear and radiation pollution.				
48.	Discuss the roll of individual in preventing pollution.				
49.	Compare the nuclear power with coal power.				
50.	Discuss the chemi	cal energy effect on env	ironment pollution.		
51.	Power generation facilities have been affected by the concern for the a) Environment b)Availability of resources c) Soaring costs d) Humans				
52.	How many forms a)1 b) 2 c) 3 d) 4	of sulfur exist in the atr	nosphere?		

	Acid rain is caused mainly by				
	a) methane gas				
53.	b) sulphuric acid				
	c) sulfur dioxide				
	d) carbon dioxide				
	Which among the following oxides are major contaminants in the atmosphere?				
5 4	a) Nitrogen oxides				
54.	b) Oxides of carbon				
	d) Particulate matter				
	Carbon dioxide (CO ₂) is largely contributed by				
	a) vehicles				
55.	b) power plants				
	c) humans				
	d) plants				
	By which process can CO ₂ be removed from the atmosphere?				
	a) Pyrolysis				
56.	b) Photosynthesis				
	c) Filtration				
	d) Magnetohydronomics What is TDI stands for in the Thermal pollution field?				
	what is IDI stands for in the Thermal pollution field?				
57	a) Turbocharger direct injection				
57.	b) Toluene Diisocyanate				
	c) Thermal energy discharge integration d) Thermal discharge index				
	d) Thermal discharge index What are the constituents of particulate matter?				
	a) Fluid gases				
58.	b) Smoke and dust				
	c) Flue gas				
	d) Poisonous gases				
	A chemical industry is not a cause of:				
	(a) Air pollution				
59.	(b) Noise pollution (c) Water pollution				
	(d) Nuclear pollution				
	Electronic waste is the adverse effect of:				
	(a) Industry				
	(b) Agriculture				
60.	(b) Agriculture				
	(d) Mining				
	<u>UNII 4</u>				
61	Which of the following is an air pollutant?				
01.	a. Nitrogen b. Carbon dioxide c. Carbon d. Oxygen				
	monooxide				
02.	which of the following is a secondary air pollutant?				

	a. Ozone	b. Carbon dioxide	c. Carbon monooxide	d. Sulphur dioxide			
	During Inversion:						
63.	a. Temperature increa b. Temperature decrea c. Temperature remain d. None of the above	ses with altitude ases with altitude as constant					
	Among the following,	the only secondary poll	utant is:				
64.	a. Sulphur tetraoxide	b. Sulphur dioxide	c. Ozone	d. Sulphur tetraoxide			
65.	Which of the following	groups of plants can be	e used as indicators of S	O pollution of air?			
	a. Epiphytic lichens	b. Ferns	c. Liver worts	d. Horn worts			
66.	Smog 1s: a. A natural phenomenon	b. A combination of smoke and fog	c. Is colourless	d. All of the above			
67.	The major photochemic	cal oxidant is:					
	a. Ozone	b. Hydrogen peroxide	c. Nitrogen oxides	d. Peroxyl Acetyl Nitrate (PAN)			
(0)	Which of the following	devices is suitable for	the removal of gaseous	pollutants?			
08.	a. Cyclone separator	b. Electrostatic precipitator	c. Fabric filter	d. Wet scrubber			
	Which of the following	air pollution control de	evices is suitable for the	removing the finest dust			
69.	from the air?						
	a. Cyclone separator	b. Electrostatic precipitator	c. Fabric filter	d. Wet scrubber			
	Gas leaked in Bhopal tr	ragedy:					
70.	a. Methyl isocyanate	b. Potassium isothoiocynate	c. Ethyl isocyanate	d. Sodium isothiocyanate			
71.	What is air pollution. Describe the man-made sources of air pollution in detail.						
72.	Enumerate the effects of the air pollution on human health and vegetation.						
73.	Discuss the methods of	Discuss the methods of sampling analysis of air pollutants.					
74.	Define air pollution.	Explain primary and s	secondary air pollutan	ts			
75.	Define inversion. Bri sketch.	efly explain the differ	rent types of inversion	with the aid of neat			
76.	Write a short note on photo-chemical smog						

77	With the help of the	neat sketch explain hi	gh volume air sample	r for measurement of		
	particulate matter.					
78.	What is meant by air quality monitoring? Explain any four methods of calculation of					
	air pollution indices for monitoring of air pollutants.					
79.	Explain the factors a	ffecting the selection	of the particulate air c	ontrol devices		
80.	Briefly explain the p	articulate matter remo	val by gravity settler	with the neat sketch.		
		<u>UNIT 5</u>				
81.	Define water pollution	. Explain the major sour	rces of water pollution.			
	Discuss about the efflu	ent generated in steel in	dustries and impact of e	effluents on water		
82.	bodies. Explain the wa	ste water treatments req	uired for steel industry			
83.	Discuss any two aerob	ic methods available for	sludge treatment.			
84.	Briefly explain the waste-water treatment methods					
85.	What are the various treatments and control methods for water pollution?					
86.	Discuss Aerobic and Non Aerobic treatment of waste water.					
87.	Explain the causes, effects and and control measures of water pollution.					
88.	What is meant by BOD & COD.					
89.	Write briefly on the hy	drologic cycle.				
90.	Elaborate on water qua	ality parameters. What a	re point and non-point s	source of water pollution.		
	According to WHO, th	he soft water has 0 to	milligram per lite	er a CaCo _{3.}		
91.	a. 30	b. 60	c. 90	d. 120		
	The source of Arsenic	in water is				
92.						
	a. industrial waste	b. fertilizers	c. phosphate tocks	d. all of these		
	BOD/COD ratio will a	lways be				
93.	a. equal to 1	b. less than 1	c. more than 1	d. none of these		
0.4						
94.	BOD is:					

	a. A measure of the organic matter presents in water	b. Usually less than COD	c. Biochemical oxygen demand	d. All of the above				
95.	Excess fluoride in drinking water is likely to cause:							
	a. Blue baby syndrome	b. Fluorosis c. C	Change in taste and odor	d. Intestinal irritation				
	Which of the following	is a non-point source o	f water pollution?					
96.		h Sewage treatment	c. Urban and					
	a. Factories	plants	suburban lands	d. All of the above				
97.	Septic tank is: a. An aerobic attached growth treatment system b. An aerobic suspended growth biological treatment system c. An anaerobic attached growth biological treatment system d. An anaerobic suspended growth treatment system							
98.	Which of the following	is not a marine polluta	nt?					
	a. Oil	b Plastics	c. Dissolved oxygen	d. All of the above				
99.	Which of the following	is a major source of the	ermal pollution in water	r bodies?				
	a. Sewage treatment plant	b. Solid waste disposal sites	c. Thermal power plant	d. All of the above				
	The highest moisture co	ontent is in:						
100.	a. Garbage	b. Hospital waste	c. Rubbish	d. Agricultural waste				
		Unit 6 noise pol	lution					
101.	What is noise pollution	? state the noise pollution	on level and its harmful	effects.				
102.	State the important inde control for each of then	oor and outdoor sources 1.	s of noise pollution? Me	ention the method of				
103.	Describe the sources an	Describe the sources and effect of noise pollution.						
104.	Write short notes on noise pollution standards							
105.	Distinguish between	Distinguish between loudness and annoyance						
106.	Why does sound cause	Why does sound cause noise pollution.?						
107.	Calculate the equivalan 60 dB, 69 dB, 70 dB an	t sound power level (in d 79 dB	dB) of the four sources	s with the noice levels of				
108.	A noise meter located a a distance of 60 m from	t a distance of 30 m fro the point source would	m a point source record 1 be?	led 74 dB. The reading at				
109.	As per Noise pollution for a residential zone, e	(Regulation and Contro xpressed in dB(A)L _{eq} , i	ol) Rules 2000 of India , s	, the day time noise limit				
110.								

	Noise is: a. Loud sound	b. Sound of high frequency	c. Unwanted sound	d. Unwanted sound		
111	Sound becomes hazardous noise pollution at decibels:					
	a. Above 80	b. Above 30	c. Above 100	d. Above 120		
112	Which pollution cause	hearing loss in organisn	ns?			
112.	a. Air pollution	b. Noise pollution	c. Water pollution	d. Soil pollution		
112	· · · · · ·					
113.	In anaerobic conditions	b. Nitric Acid	c Methane form	d Sulphide form		
		b. Mult Acid	c. Methane form			
114.	Noise pollution effects	marine animal's;				
	a. blood circulation	b. gene pool	c. DNA transposition	d. behaviour		
	Main sources of noise pollution are					
115.	a. Transportation equipment	b. Transportation equipment	c. Heavy machinery	d. A and C both		
	Sounds which are pleasant to our ears are called					
116.	a. noise	b. musical sounds	c. frequency	d. amplitude		
	What is the permissible	e noise limit of 120 db?				
117.	a. 30 minutes	b. 2 minutes	c. 1 minute	d. 30 seconds		
	Level of noise recommended in most countries is					
118.	a. 30-40 dB	b. 95-100 dB	c. 85-90 dB	d. 75-80 dB		
	Sound becomes hazard	ous noise pollution at de	ecibals.			
119.	a. above 80	b. above 30	c. above 100	d. above 120		
	Noise pollution can cau	ise				
120.	a. hypertension	b. hearing loss	c. sleep disturbances	d. all of the above		

		<u>UNIT 7</u>				
121.	Briefly explain the methods of solid waste management					
122.	What do you understar	nd by solid waste manag	gement? Give classificat	tion of solid waste.		
123.	Discuss the health haza	ards and environmental	effects of solid waste p	ollution.		
124.	Discuss the methods us	sed for the collection of	solid waste.			
125.	Write short note on sou	arces of Industrial waste	es?			
126.	Define hazardous wast	e. Describe the concept	for management of suc	h wastes		
127.	Explain the e-waste an	d give its impact on env	vironment.			
128.	Write in detail the iden hazardous wastes in In	tification, characterizat dia.	ion, classification, colle	ction and treatment of		
129.	Write the different pollution control techniques adapted in the treatment of effluents in the sugar or pulp and paper industries.					
130.	The term 'Municipal Solid Waste' is used to describe which kind of solid waste?a. Hazardousb. Toxicc. Non hazardousd. Non toxic					
131.	Why burning waste is a a. Because it is very costly	not an acceptable practi b. Because it requires modern technologies	ce of solid waste manag c. Because it cause several environmental issues	gement? d. Because it requires lot of space		
132.	Problem of solid waste disposal can be reduced through a. Recycling b. Lesser pollution c. More timber d. Population control					
133.	Metals are produced as waste in industries like a. Skiing b. Mining c. Electroplating d. Digging					
	For the survival of fish	in a river stream, the m	ninimum dissolved oxyg	gen is prescribed		
134.	a. 3 PPm	b. 5 PPm	c. 4 PPm	d. 10 PPm		
135.	what is the PH value of	f normal rain?				
	a. 1	b. 5.6	c. 8	d. 7		

136.	Which of the following a. Plastic	g can be recycled many t b. Wood	times? c. Organic materials	d. Aluminum			
137.	How many key characteristics of a municipal sanitary landfill are there?a. oneb. twoc. threed. four						
138.	Why burning waste is n a. Because it is very costly	not an acceptable practic b. Because it requires modern technologies	ce of solid waste manage c. Because it cause several environmental issues	ement? d. Because it requires lot of space			
139.	How many main comp a. one	onents are there in integ b. two	rated waste managemen c. three	t? d. four			
140.	Which of the below is not an idea behind solid waste management? a. Control of waste b. Storage and c. Disposal d. Stop waste generation collection generation						

Introduction

While domestic wastewaters can be consistently classified as to their strength and constituents, industrial wastewaters and domestic/industrial discharges may be highly variable. The latter types of wastewaters are usually a complex rather than a simple misture of constituents. Characterization of the waste stream by flow measurement and chemical analysis is used to identify the undesirable characteristics, to determine the source of these characteristics, and to implement a solution to control them to an acceptable level.

Wastewater characteristics

Wastewaters may contain any material which may be dissolved or suspended in or on water. Wastewater constituents are classified into organic, inorganic, particulate and pathogenic. Tests serve as a first step in determining the treatment requirements for a particular wastewater to preclude potential negative environmental impact.

a. Primary organic parameters. Organic materials in wastewater have traditionally been the major concern in the field of water pollution control. The decrease in dissolved oxygen due to the process of biodegradation is detrimental to the health of the receiving waterways and aquatic life. There are four major tests used to measure organic material in wastewater: the customary pollutant parameter, Biochemical Oxygen Demand (OBD); the noncustomary pollutant parameters Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), and Total Oxygen Demand (TOD).

(1) Biochemical oxygen demand (BOD). The BOD test is an indirect measurement of biodegradable organic material. The test does not measure specific organic materials but indicates the amount of oxygen required to stabilize the biodegradable organic fraction. This test was devised to simulate the impact of a particular wstewaster on the dissolved oxygen level in the receiving waters. Adequate dissolved oxygen must be provided in order to maintain aquatic life. The BOD test measures the oxygen depleted after a period of five days in a closed system which contains a mixture of wastewater and an acclimated seed of microorganisms. The test may also measure a quantity of reduced inroganic materials such as ammonia or sulfites.

(2) Chemical oxygen demand (COD). COD is another indirect measurement of organic material. COD measures the oxygen equivalent of the organic material oxidized by bichromate or permanganate during acid digestion. This parameter was developed in order to substitute for the more time-consuming BOD test.

(3) Total organic carbon (TOC). The TOC test is an indirect measurement of organic material. The test measures the quantity of carbon dioxide liberated during the combustion of the wastewater sample. Thus, TOC is the amount of carbon present in organic molecules contained in the wastewater sample.

(4) Total oxygen demand (TOD). TOD is an indirect method of measuring organic material concentration. However, it is the most direct measurement of oxygen demand. TOD is the difference in the oxygen content of a sample before and after combustion. TOD measures the amount of oxygen required to burn the contaminants in the wastewater sample.

b. Organic parameter relationships. A preliminary step in developing treatment alternatives for a specific wastewater should be an analysis of the organic parameter relationships. This analysis will provide the designer with a general idea of the treatment technologies most likely to be effective on the wastewater.

c. Additional organic parameters. As attention has been focused on the TOD, TOC, COD, and BOD parameters, it is necessary to recognize other important organic evaluations, such as oil and grease content, phenols, organics containing toxic functional groups, etc. Oil and phenol analyses are particularly significant when evaluating unit processes for the treatment of wastes containing petroleum distillates. Quantities of toxic organic compounds, such as pesticides, present in wastewaters entering the environment are extremely significant and require a great deal of effort to control. The need to analyze or treat these organic compounds is site specific. If a substance is used or manufactured in an industrial activity, then the possibility exists that it is present in the wastewater.

(1) Oil and grease. Oil and grease in wastewater is usually a characteristic of petroleum-

unit 5

based chemical manufacturing, machining, vehicle maintenance, kitchen and restaurant wastes and, to a lesser degree, domestic wastewater. Oil and grease is an indirect measurement defined and quantified by an analytical procedure. Oil and grease is an expression of all substances extracted by the organic solvent (Freon) employed in the test procedure. Oil and grease may include hydrocarbons, fatty acids, soaps, fats, waxes, oils and any other Freon extractable substance that will not volatilize during the test procedure. Oil and grease, in large quantities, is a dangerous environmental pollutant. Oil and grease is difficult to remove by conventional treatment processes such as anaerobic or aerobic biological processes and is an interference in most physicalchemical treatment processes. Oil and grease treatment usually consists of removal by skimming or flotation and disposal by reuse, incineration, or landfilling.

(2) Phenol. Phenol is encountered most frequently in the petroleum refining and chemical processing industries, but is present where industrial activities utilize petroleum distillates. Phenol is very soluble in water, oils, carbon disulfide and numerous organic solvents. The wet chemical analysis of phenol measures directly a variety of phenolic compounds. Phenol is a toxic and mutagenic substance in high concentrations and may be absorbed through the skin. Phenols are, for the most part, biodegradable.

(3) Cyanide. Cyanide is found in metal plating, petroleum refining, plastics, and chemicals manufacturing wastewaters. The cyanide ion is highly toxic to aquatic life and humans at very low concentrations. Most cyanide appears as a chemical complex with a metallic compound. As a result, toxicity of cyanide depends upon the nature of the complex. Some cyanide compounds are harmless. Cyanide compounds are usually biodegradable and are otherwise treatable by alternate methods.

(4) Surfactants. Surfactants are found in household and industrial cleaning detergents and many industrial wastewaters. The presence of surfactants is indicated when there are large quantities of foam in the collection or treatment system.

(5) Other organic compounds of significance. Many wastewaters contain U.S. EPA identified toxic organic compounds not identifiable except by direct measurement using specialized analytical techniques such as infrared spectrophotometry, gas chromatography, gel chromatography and mass spectrometry. Other analytical methods may be required depending upon the substance. *d. Wastewater solids.* Wastewater solids are present in nearly all wastewater discharges. Solids occur in wastewater as a result of stormwater runoff, sanitary discharge, chemical precipitation reactions in the waste and direct discharge of solid materials.

(1) Definitions. Waste solids are classified according to gross physical properties and chemical composition. The three basic types of solids include:

-settleable solids,

-suspended solids (TSS), and

-dissolved solids (TDS).

Settleable solids are particles which settle out of a wastewater sample during a 1 hour settling test using an Imhoff cone. Grit and most chemical sludges are settleable solids. They are denser than water and, therefore, cannot remain in suspension. Suspended solids are particles retained by filtering a wastewater sample. The suspended solids test may include settleable solids if the sample is thoroughly mixed. Dissolved solids are basically salts of organic and inorganic molecules and ions that exist in solution.

(2) Testing. Wastewater solids may be classified by direct gravimetric test methods. Suspended and dissolved solids are termed "volatile" if they are vaporized after ignition for 1 hour at $1,022 \pm 122$ degrees F in a furnace. In wastewater treatment, solids are said to be nonfilterable or insoluble if they are retained on the surface of a 0.45 micron filter. The filtrate is said to represent the soluble fraction of the liquid.

e. Significant inorganic parameters. There are many inorganic parameters which are important when assaying potential toxicity, general characterization, or process evaluation. Although special situations require the evaluation of any number of inorganic analyses, it is the intent here to discuss only the more prevalent ones.

(1) Acidity. The acidity of a wastewater is important because a neutral or near neutral water is required before biological treatment can be effective. In addition, regulatory authorities have criteria which establish strict pH limits to final discharges. Acidity is attributable to the nonionized portions of weakly ionizing acids, hydrolyzing salts, and certain free mineral ions. Microbial systems may reduce acidity in some instances through biological degradation of organic acids, or they may increase acidity through vitrification or other biochemical processes. Acidity is expressed as mg/L CaCO₄.

(2) Alkalinity. Alkalinity may be considered the opposite of acidity and it is also expressed as mg/L CaCO₃. Alkalinity is imparted by carbonate, bicarbonate and hydroxide components of natural water supplies. Industrial wastes often contain these species in addition to mineral and organic acids. Alkalinity determinations are useful in determining wastewater neutralization requirements.

(3) PH. pH represents the hydrogen ion (H^{+}) or proton concentration in waters or wastewaters. pH is an extremely important wastewater parameter as it affects the solubilities of metals, salts and organic chemicals, the oxidation-reduction tendency and direction of wastewater components, and the rate of chemical activity in wastewater solutions. Gross wastewater characteristics affected by pH include toxicity, corrosivity, taste, odor, and color. Th pH of pure water is given the value of 7. Acid solutions have a pH below 7 and alkaline or basic solutions have a pH above 7.

(4) Nitrogen. In wastewater treatment, the nitrogen forms of primary concern are:

-Total Kjeldahl nitrogen (TKN),

-Ammonia nitrogen (NH₃-N),

-Nitrate nitrogen (NO₃-N), and

-Nitrite nitrogen (NO_2 -N).

(a) Total Kjeldahl nitrogen represents the organic nitrogen plus ammonia nitrogen indicated in the Kjeldahl test procedure. Following measurement and removal of the ammonia nitrogen, the organic nitrogen in the wastewater sample is converted to ammonia nitrogen by catalyzed acid digestion of the wastewater. The resulting N H_3 -N is then analyzed and reported as the organic nitrogen fraction. Not all organic nitrogen under catalyzed acid digestion. Acrylonitrile and cyanuric acid are examples of compounds that are only partially hydrolyzed by the Kjeldahl test procedure.

(b) Ammonia nitrogen (NH_3-N) as well as organic nitrogen is present in most natural waters in relatively low concentrations. Concentrations as low as 0.5 mg/L have been reported to be toxic to some fish and concentrations as high as 1, 600 mg/L have proved to be inhibitive to biological waste treatment plant microorganisms. The toxicity of ammonia is a function of pH, being highly toxic at an alkaline pH and less toxic at an acidic pH. Ammonia nitrogen is also an essential nutrient in biological waste treatment systems and a slight residual (0.5 to 1.0 mg/L) is recommended for optimum biological activity.

(c) Nitrate nitrogen (NO_3 -N) may appear in wastewaters as dissociated nitric acid, HNO_3 , or may result from the biological vitrification of ammonia to nitrate. Nitrate nitrogen should be

restricted from drinking water supplies because it inhibits oxygen transfer in blood. Maximum NO_3 -N concentrations of 10 mg/L are allowed in drinking water under National Interim Primary Drinking Water Regulations.

(d) Nitrite nitrogen (NO_2-N) is most commonly found in treated wastewaters or natural streams at very low concentrations (0.5 mg/L). Nitrite is a metabolic intermediate in the nitrification process. It is rapidly converted to NO_3-N by nitrifying organisms. Nitrite is an inhibitor to the growth of most microorganisms and for this reason is widely used as a food preservative.

(5) Phosphorus. Phosphorus occurs naturally in rivers and streams as compounds of phosphate. Elemental phosphorus does not persist naturally in aquatic systems as it is quickly oxidized by molecular oxygen to phosphate. Phosphates are commonly found in industrial and domestic wastestreams from sources including corrosion inhibitors, detergents, process chemical reagents, and sanitary wastes. Phosphorus is an essential nutrient in biochemical mechanisms. A residual of 0.5 to 1.0 mg/L total phosphorus is usually required in biological waste treatment systems to ensure efficient waste treatment. Excessive phosphorus in natural waterways, however, can be very harmful resulting in algal blooms and eutrophication.

(6) Sulfur. Sulfur occurs naturally in rivers and streams as compounds of sulfur. Elemental sulfur does not persist naturally in aquatic systems as it is oxidized by molecular oxygen to sulfate. Due to the cathartic effect of sulfate upon humans, the drinking water limit for sulfate has been placed at 250 mg/L in waters intended for human consumption.

(a) In some industrial waste streams sulfate and sulfur compounds are present in high concentrations and may be a major component of TDS and conductivity. Sulfates can cause odor and corrosion of sewer pipes under the proper conditions. The malodorous gas, hydrogen sulfide, is produced by the anaerobic biological reduction of sulfate to hydrogen sulfide. As pH is increased, the chemical equilibrium favors the ionization of sulfate (H_2S). As pH is decreased, the formation of H_2S is favored.

(b) Crown corrosion of sewers occurs when the H_2S gas is released and rises to the crown of the sewer. At the crown, condensed water and H_2S form sulfuric acid which dissolves concrete.

(7) Chlorine. Chlorine is widely used as a disinfectant for drinking water supplies and for treated sanitary discharges. Chlorine is toxic to

all forms of life in the proper concentrations but does not persist in aquatic systems. These two qualities have helped promote the use of chlorine as a disinfectant. However, chlorine does react with other chemical compounds such as ammonia and certain hydrocarbons to form the toxic chloramines and potentially toxic or mutagenic chlorinated hydrocarbons. For this reason, chlorination is not recommended for certain industrial and combined domestic/industrial waste streams.

(8) Chlorides occur in all natural water systems and many industrial waste streams. Seawaters are very high in chlorides. Chlorides are relatively harmless to humans in low concentrations. At a concentration of 250 mg/L, drinking water is found to have an objectionable taste. In some cases, water containing concentrations of chloride up to 1,000 mg/L are consumed without ill effects. Chloride concentrations of 8,000 to 15,000 mg/L have been reported to affect adversely biological waste treatment systems.

(9) Heavy metals. Some of the heavy metals of interest are copper (Cu), chromium (Cr), cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and mercury (Hg). These materials may be measured directly. These elements may be inhibitive or toxic to aquatic and terrestrial organisms and the microorganisms employed in biological waste treatment systems.

(a) Copper. The primary sources of copper in industrial wastewaters are metal process pickling baths and plating baths. Copper may also be present in wastewaters from a variety of chemical manufacturing processes employing copper salts or a copper catalyst. Copper is an essential nutrient for most organisms including humans. Copper can impart a bitter taste to water in concentrations above 1 mg/L. Copper salts are used to control algae growth in reservoirs and farm ponds.

(b) Chromium. Chromium is found in metal plating and anodizing wastes, tannery wastes, and in certain textile processing wastewaters. Chromium commonly appears in the hexavalent (+6) and the trivalent (+3) valence states and also exists in less soluble complexes. Hexavalent chromium is highly toxic to microorganisms.

(c) Cadmium. Cadmium is present in wastewaters from metallurgical alloying, ceramics, electroplating, photography, pigment works, textile printing, chemical industries and lead mine drainage. Cadmium is relatively abundant in the earth's crust and the metal and its salts are highly toxic.

(d) Zinc. Zinc is present in wastewater streams from steel works, rayon manufacture,

battery manufacture, sodium hydrosulfite manufacture and other chemical production. Zinc is a nutritional trace element but is toxic at higher concentrations.

(e) Lead. Lead is present in wastewaters from storage battery manufacture, drainage from lead ore mines, paint manufacture, munitions manufacture, and petroleum refining. Lead is toxic in high concentrations.

(f) Nickel. Nickel is present in wastewaters from metal processing, steel foundry, motor vehicle and aircraft, printing and chemical industries. Nickel may cause dermatitis upon exposure to the skin, and gasrointestinal distress upon ingestion.

(g) Mercury. Mercury is used in the electrical and electronics industries, photographic chemicals, and the pesticides and preservatives industries. Power generation is a large source of mercury release into the environment through the combustion of fossil fuel. Mercury in its methylated form is a highly toxic compound. In its elemental form, it is readily absorbed by inhalation, skin contact and ingestion.

f. Additional wastewater characteristics.

(1) Temperature. Temperature is a very important wastewater characteristic. The chemical equilibrium of complex wastewaters is very temperature dependent. Different reactions may be found at higher temperatures as compared to lower temperatures. Waste treatment system efficiency is affected by extremes in temperature. At low temperatures (39 degrees F), biochemical and chemical reaction rates are extremely slow, and waste treatment operations are often severely limited. At temperatures greater than 100 degrees F, many waste treatment plants experience operating difficult y. Biological processes are impaired, air and oxygen volubility becomes limited, and other physical properties such as sludge density and settling rate affect overall waste treatment.

(2) Tastes and odors. Tastes and odors in water are generally associated with dissolved inorganic salts of iron, zinc, manganese, copper, sodium, and potassium. Phenolics are a special nuisance in drinking water supplies especially after chlorination because of their very low taste and odor threshold concentration (less than 0.2 parts per billion). Petrochemical discharges and liquid wastes from the paper and synthetic rubber industries often cause taste and odor problems. Sulfides from these sources cause odors in concentrations of less than a few hundredths of a part per million. Tastes and odors may also be associated with decaying organic matter, living algae and other microorganisms containing essential oils and other odorous compounds, specific organic chemicals such as phenols and mercaptans, chlorine and its substituted compounds, and many other chemical materials.

(3) Color. Color in water and wastewaters may result from the presence of metallic ions such as chromium, platinum, iron, or manganese from humus and peat materials such as tannin and algae. Color caused by suspended matter is said to be "apparent color". Color caused by colloidal or soluble materials is said to be "true color". True color is the parameter by which color is evaluated. An arbitrary standard is employed to evaluate color. The color produced by 1 mg/L of cobalt-platinum reagent is taken as one color unit. Dilutions of cobalt-platinum reagent are made in the O to 70 unit range and placed in special comparison tubes. Water samples are then compared and matched between the cobaltplatinum standard dilutions.

(4) Radioactivity. Regulatory agencies have established standards for the maximum allowable concentrations of radioactive materials in surface waters. It is possible to differentiate between the following three types of radioactivity:

—alpha rays.

—beta rays.

-gamma rays.

(a) Alpha rays consist of a stream of particles of matter (doubly charged ions of helium with a mass of four) projected at high speed from radioactive matter. Once emitted in air at room temperature, alpha particles do not travel much more than 4 inches. These particles are stopped by an ordinary sheet of paper.

(b) Beta rays consists of a stream of electrons moving at speeds ranging from 30 to 90 percent of the speed of light, their power of penetration varying with their speed. These particles normally travel several hundred feet in air and may be stopped with aluminum sheeting a tenth of an inch thick.

(c) Gamma rays are true electromagnetic radiation which travel with the speed of light, and are similar to x-rays but have shorter wave lengths and greater penetrating power. Proper shielding from gamma rays requires an inch or more of lead or several feet of concrete. The unit of gamma radiation is the photon.

(d) Radioactive materials commonly used in tracer studies in research in biology, chemistry, and medicine are the isotopes of carbon (C^{14}) and iodine (125). In sewers and waste treatment plants certain isotopes, such as radioiodine and radiophosphorus, accumulate in biological slimes and sludges.

(5) Toxicity. Toxicity is most often related to aquatic organisms such as fish, arthropods, shell-fish, and microorganisms. The toxicity bioassay test has been developed to evaluate the relative toxicities of individual wastewaters. The purpose of the test is to determine the lethal concentration of pollutant that will kill 50 percent of the test organisms (LC_{50}) in a given period of time. The LC_{50} is an indirect method of measuring toxicity.

(6) Pathogens. Wastewaters that contain pathogenic bacteria can originate from domestic wastes, hospitals, livestock production, slaughterhouses, tanneries, pharmaceutical manufacturers, and food processing industries. The major pathogens of concern include certain bacteria, viruses, and parasites.

(a) The coliform group of bacteria has been used to indicate the bacterial pollution of water and wastewater. Generally used test parameters employed as water quality indicators are total coliform and fecal coliform. The total coliform test includes organisms other than those found in the gastrointestinal tracts of mammals.

(b) The fecal coliforms are differentiated from the total coliforms by incubation at an elevated temperature in a different, growthspecific medium.

(c) Fecal Streptococci are non-coliform bacteria which are widely used as indicators of pollution. Streptococci are particularly useful in that they are commonly found in heavily polluted streams and almost always absent from nonpolluted waters. Other pathogenic bacteria of concern and related diseases are listed in table 3-1.

 Table 3-1. Common enteric pathogenic bacteria

 and related disease

Bacteria	Disease
Salmonella typhosa	Typhoid fever
Salmonella paratyphi	Paratyphoid fever
Salmonella typhimurium	Salmonellosis
Shigella sonnie, S. flexneri	Shigellosis
Vibrio chlorea	Cholera
Pseudomonas aeruginosa	Enteric infection
Klebsiella sp.	Enteric infection
Diplococcus pneumonia	Infectious pneumonia
Clostridium botulinum	Botulism
Brucella sp.	Brucellosis

(d) Viruses are submicroscopic obligate parasites which can only replicate in a host cell. However, viruses can survive for weeks, even months outside a host cell awaiting the opportunity to reinfect another host. Viruses cause a large number of diseases including the common cold, measles, poliomyelitis, mumps, hepatitis,

Table 3-2. Common parasites and related disease

Organi sm	Di sease	Reservoir(s)	Range(s)
Protozoa			
Balantidium coli	Bal anti di asi s	Man, swine	Worl dwi de
Entamoeba histolytica	Amebiasis	Man	Worl dwi de
Giardia lamblia	Gi ardi asi s	Man, animals	Worl dwi de
Toxoplasma qondii	Toxopl asmosi s	Cat, mammals, birds	Worl dwi de
Nematodes (Roundworms)	·		
Ascaris lumbricoides	Ascari asi s	Man, swi ne	Worldwide-Southeastern USA
Ancylostoma duodenale	Hookworm	Man	Tropical-Southern USA
Necator americanus	Hookworm	Man	Tropical-Southern USA
<u>Ancylostoma braziliense</u> (cat hookworm)	Cutaneous Larva Migrans	Cat	Southeastern USA
Ancylostoma caninum (dog hookworm)	Cutaneous Larva Migrans	Dog	Southeastern USA
Enterobius vermicularis (pinworm)	Enterobi asi s	Man	Worl dwi de
Stronglyoides stercoralis (threadworm)	Strongyl oi di asi s	Man, dog	Tropical-Southern USA
<u>Toxocara cati</u> (cat roundworm)	Visceral Larva Migrans	Cani vores	Probably Worldwide
<u>Toxocara</u> canis (dog roundworm)	Visceral Larva Migrans	Cani vores	Sporadić in USA
Trichuris trichiura (whipworm)	Tri churi asi s	Man	Worl dwi de
Cestodes (Tapeworms)			
<u>Taenia</u> saginata (beef tapeworm)	Taeni asi s	Man	Worl dwi de-USA
Taenia solium (pork tapeworm)	Taeni asi s	Man	Rare in USA
<u>Hymenolepis nana</u> (dwarf tapeworm)	Taeni asi s	Man, rat	Worl dwi de
Echinococcus granulosus (dog tapeworm)	Hydatid Disease	Dog	Far North-Alaska
Echinococcus multilocularis	Aleveolar Hydatid Disease	Doğ	Rare in USA

and distemper, to name only a few. The viruses of most concern found in wastewaters are of the Hepatitis, Coxsackie, Echo, Adeno and Arbo groups.

(e) Parasites and protozoa are widely found in sanitary wastewaters of the United States. Few of these organisms directly cause death but some do weaken the host and promote the possibility of contracting infectious disease. Table 3-2 lists the protozoans and multicellular parasites (nematodes and cestodes) of major concern.

Sources of industrial and sanitary wastewater

a. Industrial waste waters. Industrial wastewaters may be defined as all wastewaters other than those resulting from sanitary discharge or storm runoff. Industrial discharges include source from water treatment operations, vehicle wash racks, metal plating, motorpool and equipment maintenance shops, hospitals, laundries, x-ray and photographic and chemical laboratory operations. Discharges classified as industrial wastes often contain significant quantities of oils, soluble organic compounds, solid matter, dissolved metals, and other substances. Industrial wastes often require treatment operations not normally employed for domestic wastes are quite different from domestic wastes. This section of the manual discusses sources of sanitary and industrial wastewaters.

b. Sanitary discharges. Sanitary discharges originate from the use of restrooms, food preparation, clothes washing, and other domestic sources. When these activities are conducted on a large scale, they become an industrial source. Sanitary or domestic wastewater is commonly referred to as sewage. Table 3-3 summarizes average sanitary discharge loadings and sources from a typical domestic household of four members. Table 3-4 summarizes typical sewage volume and BOD for various services.

Table 3-3. Average pollutant loading and waste water	
volume from domestic household (four members) (100)	

Ν	Jumbe	Water er Volume	Total Water E	BOD, in S	Suspended Solids, in
Wastewater	Per	Per Use in	n Use ir	n Pounds	Pounds
Event	Day	Gallons	Gallons	Per Day	Per Day
Toilet	16	5	80	0.208	0.272
Bath/Shower	2	25	50	0.078	0.050
Laundry	1	40	40	0.085	0.065
Dishwashin	g 2	7	14	0.052	0.026
Garbage	0				
disposal	3	2	6	0.272	0.384
Total			190	0.695	0.797

c. Industrial discharges. Industrial wastewaters vary considerably in strength and composition

among military installations. This is due to differences in installation size and the type of site operations. Sources of industrial discharge common to many military posts are discussed below.

(1) Water treatment. Water treatment plants commonly employ chemical precipitation, sand filtration, carbon adsorption and chlorination as purifying operations. Sludges produced from the precipitation operation have high concentrations of minerals such as calcium, iron, and aluminum. These sludges vary in solids content from 2 percent to 25 percent and are most often handled in one of three manners:

- -discharge to a municipal sewage treatment plant.
- -discharge to an industrial waste treatment plant.
- -dewater and landfill.

(2) Boiler water treatment blowdown. Boiler blowdown is required to control suspended and dissolved solids concentration. Boiler water is treated with chemicals, notably sodium and phosphate, to prevent scaling and corrosion. Boiler blowdown is typically high in pH, temperature, suspended and dissolved solids, and water treatment chemicals.

(3) Cooling water. Cooling water originates from air conditioning systems and cooling towers. Most air conditioning cooling water is oncethrough water which is not recovered or reused. Occasionally, air conditioning cooling water is treated with biocides to prevent slime growth in the plumbing and the condenser heat exchangers. Cooling towers are used to cool process waters and vessels, and allow reuse of utility water. Cooling towers are treated with organic and inorganic biocides to control slime growth in the tower. Severe contamination of cooling tower discharges may occur when the heat exchangers leak process chemicals into the cooling water. In general, however, non-contact cooling water is very low in chemical strength.

(4) Aircraft and vehicle wash racks.

(a) Nearly all military installations have vehicle wash racks to clean vehicles returning from field exercise and for normal maintenance. The wash waters contain grit, soil, oil and detergents.

(b) Centralized Vehicle Wash Facility (CVWF) are being constructed at Army facilities which are complete recycle systems with no discharge to wastewater facilities.

(5) Motor pools.

(a) Motor pools have a variety of waste sources. These include: engine cleaning, spilled hydraulic engine and transmission oils, battery

Type	Volume (oal/capita/day)	BOD (Lb/capita/day)
AI rports Each employee	15	0.11
Each passenger	5	0.11
Bars	0	0.04
Each employee	15	0.11
Plus each customer	2	0.02
Luxury resorts	100	0.00
Summer camps	100	0.39
Construction camps	50	0.33
Domestic sewage		0.00
Luxury homes	100	0.44
Better subdivisions	90	0.44
Low-cost bousing	80 70	0.39
Summer cottages, etc.	70 50	0.39
Apartment houses	75	0. 29
(Note: if garbage		
grinders installed,		
factors by 1.5.)		
Factories (exclusive of		
industrial and		
cafeteria wastes)	15	0.11
Hospitals	150.000	
Hotels motels trailer	150-300	0.67
courts, boarding		
houses (not including		
restaurants or bars)	50	0.33
MIIK plant wastes	100-225 gal/	1.24 to 3.65/
Off ices	1,000 ID OT MILK	I,000 ID OT MILK
Restaurants		
Each employee	15	0. 13
Plus each meal served	3 (per meal)	0.07 (per meal)
If garbage GFI NGEF	1 (nor mool)	0.07 (por mod)
School s	r (per mear)	0.07 (per mear)
Day schools (each		
person, student		
or statt)	15	0.00
High School	15 20	0.09
Boarding Schools	75	0.39
Add per person if		
cafeteria has		0.00
garbage grinder Swimming pools		0.02
(Employees plus	10	0.07
customers)		
Theaters	-	
Urive-in, per stall Movie, per seat	5 E	0.04
μ	0	0.04

Table 3-4. Sewage volume and BOD for various services (126)

maintenance, spray booths, radiator cleaning and floor wash. Engine cleaning is frequently performed with a decreasing agent in conjunction with steam and detergent cleaning or, in modernized facilities with high-pressure hot water, eliminating solvents and detergents. Although most spent oils are recycled, spills in engine maintenance areas are frequently sent to floor drains.

(b) Scheduled maintenance platforms (SMP) have been provided to modernize some facilities. These will be covered to minimize wastewater and will include oil removal. High-pressure hot water has replaced steam cleaning, eliminating use of solvents and detergents.

(6) Laboratories. Hospital laboratories usually incinerate pathological solid and semi-solid waste products. Liquid waste may be disinfected prior to discharge to the sanitary sewer. X-ray and photographic laboratories commonly pretreat fixing solutions to recover silver prior to discharge (DOD Div. 4160.21-M). X-ray finishing and washing solutions are discharged directly to the sewer.

(7) Laundries. Laundry washwaters are a significant source of BOD and flow. Wastewater is usually filtered through a lint screen and sometimes cooled for heat recovery prior to discharge into the sewer. Dry cleaning solvents are normally recycled but a small volume may enter the sanitary sewer system.

(8) Coal pile runoff. Coal pile runoff wastewater results from the passage of water through coal deposits where disulfides, usually pyrites, are exposed to the oxidizing action of air, water and bacteria. Coal piles exposed to air and moisture will result in sulfide oxidizing to ferrous sulfate (copperas) (FeSO₄) and sulfuric acid (H₂SO4). The major characteristics of this runoff flow include a high suspended solids concentration and turbidity, mainly from coal, a low pH and high H₂SO₄ and FeSO₄ concentrations. Major treatment and disposal methods involve settling, froth flotation and drainage control.

(9) Paint stripping. There are several paint stripping methods in use today: mechanical, chemical or molten salts. Chemical or solvent stripping uses either a hot or a cold method. Cold strippers may be further classified by material used into:

-Organic solvents.

-Emulsion type.

-Acid type.

-Combination of types.

Organic solvent stripping processes of modern paints, involving spray-on/spray-off stripping procedures, have exhibited high levels of phenolic compounds in the associated wastewater. Older paints are removed by strippers containing mostly methylene chloride and hexavalent chromium with additional surfactants, thickening and wetting agents. High levels of lead compounds can be expected when stripping lead based paints. Viable treatment alternatives for phenolic waste include hydrogen peroxide oxidation and/or carbon adsorption.

(10) Metal plating. Metal plating process wastewater is defined as all waters used for rinsing, alkaline cleaning, acid pickling, plating and other metal finishing operations; it also includes waters which result from spills, batch dumps and scrubber blowdown. The cleaning, pickling and processing solutions may contain a variety of chemical compounds, most of which at very low concentrations have a toxic potential to aquatic life. At higher concentrations, they may also be toxic to humans. The suspended solids concentration is elevated due to components such as precipitated metal hydroxides, tumbling and burnishing media, metallic chips and paint solids. Treatment methods commonly used include batch treatment for cyanide destruction, continuous flow-through treatment for cyanide and chromium contaminated rinse waters and an integrated treatment system for cyanide and chi-omit acid process solutions. Lime precipitation can be used for the removal of other metals. When clarification of the treated rinse water containing precipitated metal hydroxide is required, it normally is accomplished with settling tanks or clarifiers or filtration using pressure filters.

(11) Munitions manufacturing. Propellants and explosives are materials which, under the influence of thermal or mechanical shock, decompose rapidly and spontaneously with the evoluation of a great deal of heat and much gas. Some of the most common industrial and military propellants and explosives include gunpowder, nitrocellulose, nitroglycerin, ammonium nitrate, trinitrotoluene (TNT), picric acid, ammonium picrate, RDX, HMX, and lead azide. When these compounds are manufactured, the associated wastewater is an acidic, odorous flow sometimes containing metals, organic acids and alcohols, oils and soaps. Major treatment methods include flotation, chemical precipitation, biological treatment, aeration, chemical oxidation neutralization and adsorption.

Comparison of domestic and industrial wastewaters

a. Composition and concentration. All wastewaters differ in composition and concentration.



Figure 3-1. Comparison of domestic wastewater with selected military industrial wastewater.

For this reason comparison between domestic and industrial wastes is made on a case-by-case basis. However, some general conclusions may be drawn from the major differences between domestic and industrial wastes.

(1) First, a major portion of the BOD in domestic sewage is present in colloidal or suspended form while BOD in industrial wastewaters is usually soluble in character. The non-degradable COD in domestic sewage is low (usually less than 200 mg/L) while industrial wastewaters may have a non-degradable COD level in excess of 500 mg/L. Domestic sewage has a surplus of nutrients, nitrogen and phosphorus, relative to the BOD present. Many industrial wastewaters are deficient in nitrogen and phosphorus.

(2) Total dissolved solids (TDS) in domestic sewage primarily reflect the concentration of the carrier water, while many industrial activities substantially increase the TDS through the process areas. Certain industrial wastes contain parameters of special significance such as phenol _{or} cyanide. Figure 3-1 schematically illustrates a comparison between domestic sewage and military industrial type wastewaters. Figure 3-1 and table 3-5 present a comparison between domestic sewage characteristics, aircraft stripping wastewater, and vehicle washrack discharges.

Table 3-5. Comparison of domestic waste water characteristics with selected military industrial wastewater (mg/L unless noted otherwise)

	Sanitary Wastewater	Aircraft Stripping Wastewater	Washrack Wastewater
pH (units)	6.8-7.5	6.2-7.5	7.0
BOD	75-276	375-478	10-29
COD	195-436	5,388-18,946	105-1.620
TSS	83-258	34-76	180-12,390
Phenol	Nil	71-2,220	Nil

b. Characteristics of domestic wastewaters. Domestic sewage is composed of organic matter

present as soluble, colloidal, and suspended solids. The pollutant contribution in sewage is usually expressed as a per capita contribution. A study of data reported by 73 cities in 27 states in the United States (96) during the period 1958-1964 showed a sewage flow of 135 gal/capita-day and a BOD and suspended solids content of 0.20 lb/capita/day and 0.234 lb/capita/day, respectively. The average composition of domestic sewage is shown in table 3-6. It should be recognized that the presence of industrial wastes in a domestic system may radically alter these concentrations. These levels may be expected to vary by about a ratio of 3 over a 24-hour period. Flow and BOD loadings generally peak between 1400 and 1900 hours. The lowest loadings generally occur between 0300 and 0500 hours.

 Table 3-6. Average characteristics of domestic sewage

 (mg/L unless noted otherwise)

Parameter	High	Average	Low
BOD	350	200	100
COD	800	400	200
pH (units)	7.5	7.0	6.5
Total Solids	1,200	700	400
Suspended, total	350	200	100
Fixed	100	50	25
Volatile	250	150	75
Dissolved, total	850	500	300
Fixed	500	300	200
Volatile	350	200	100
Settleable Solids (mL/liter)	20	10	5
Total Nitrogen (as N)	60	40	20
Free Ammonia (as NH ₃)	30	15	10
Total Phosphorus (as P)	20	10	5
Chlorides (as Cl)	150	100	50
Sulfates (as SO.)	40	20	10
Alkalinity (as CaCO ₃)	350	225	150
Grease	150	100	50

c. Characteristics of industrial wastewater. Industrial wastes vary widely in composition and quantity. The purpose of this section is to describe the characteristics of major industrial discharges and particularly those discharges found on military installations. The major portion of wastewaters from most military installations are domestic in nature. However, military industrial wastewaters are produced from operations such as photographic processing, metal plating, laundry, maintenance, and munitions manufacturing.

(1) Aircraft and vehicle washing.

(a) Ground equipment is routinely washed to remove any accumulated oil film, grease, metal oxides, salts and dirt. This is normally accom-

plished by pressure spraying with water or cleaning compounds to remove surface films, followed by scrubbing with brushes and cleaners to loosen foreign matter, and finally rinsing thoroughly with water to remove emulsified oils and dirt. An alkaline, water-based cleaner normally is used. Wastewater flows and concentrations are highly variable. This is due primarily to the type vehicle being washed, type of washing operation, amount of water used, inclusion or exclusion of storm water, variation in type of cleaning agents, and sampling procedures used. Automobile and ground vehicle washing requires 30 to 50 gal of water per vehicle. Washwater characteristics determined from ground vehicles are presented in table 3-7. Principal wastewater constituents include free and emulsified oils, suspended dirt and oxides, phosphates, detergents, and surfactants.

(b) Aircraft are routinely washed to remove foreign material from the aircraft surface. The survey results indicate significantly higher waste loads than those experienced during ground vehicle washing. BOD values ranging from less than 100 to several thousand mg/L and oil and grease levels of less than one to several thousand have been observed.

(2) Wastes from paint stripping operations. Aircraft and other vehicles are stripped of paint periodically as routine maintenance in preparation for repairs or overhaul. Aircraft are usually repainted every three or four years to prevent corrosion of metallic surfaces. The paint-stripper is brushed on and allowed to set on the painted surfaces, causing the paint to swell and blister. This loosened paint is then removed with a high pressure water spray. Modern paints are stripped with a phenolic paint remover, while the older paints are removed by strippers containing mostly methylene chloride (dichloromethane) and hexavalent chromium with additional surfactants. thickeners, and wetting agents. Flows and characteristics are highly variable. For example, approximately 3,350 gallons of paint-stripper, 715 gallons of which is phenolic paint-stripper, are used for large aircraft; while smaller aircraft may require some 300 gallons of stripper. It is estimated that from 45 to 75 gallons of water are required to rinse each gallon of paint-stripper. The principal pollutants from a phenolic aircraft paint-stripping wastewater and the ranges of concentration are presented in table 3-8.

TABLE 3-7

Summary of Wastewater Quality From Maintenance and Exterior C eaning Activities

	Grease and Oil (mg/L)	Suspended Solids (mg/L)	Settleable Solids (mg/L)	Total Dissolved Solids (mg/L)	BOD mg/L	((mg/L) <i>F</i>	Vika nity	Hd	Orthcphosphate mg/L
Yakima Firing Center Maintenance Exterior	37-1,448	1.72-10,900	1-25						
Fort Stewart Exterior - Old	0.5-86.4	3.2-2,390	6.5-32		10.36	100-1,620			
Fort Polk Maintenance Exterior	174	4,780	22	1,720	340	156	82		
Fort Lewis TMP Maintenance Exterior	9-13	65-454				24-32			
Fort Lewis Maintenance - New	20-,673	92-1,060							
Maintenance Exterior	5-110	25-1,420	.1-4.5	71-346	1.8-20	20-356		60-8.1	
Fort Lewis Maintenance - New	553-18,855	957-2,260	.25-6.2	135-160		1,020-1,800		7.5-8.(0
Fort Knox Exterior Old	.6-32.9	3,559	4.3			117.5		0.8	0.07
Fort Hood Exterior Old	1,467-16.1 (PPM)	2,864 (PPM)	60	175-230 (PPM)		336-829 (PPM)	131.0 (PPM)	8.1-8.	m

TABLE 3-7 Cent'd.

Summary of Wastewater Quality From Maintenance and Exterior Cleaning Activities

	Grease and Oil (mg/L)	Suspended Solids (mg/L)	Settleable Solids (mg/L)	Total Dissolved Solids (mg/L)	BOD (mg/L)	COD (mg/L)	Al kal i ni	ty pH	Orthophosphate mg/L
Fort Drum Maintenance Exterior	4-22 5.9-268.5	1,500-10,000 603-1,100	1.6-4.0	15.5-43.8		20-1,200 110-289	65-137	7.1-7.4	0.8-2.6
Fort Carson Maintenance Exterior	. 1-3, 096	2-7, 844			3-1,078	1-3, 366			
Fort Carson Maintenance Exterior	25-3, 096	30-15, 700		8-1, 078				7. 0-8. 1	

Source: U.S. Army Corps of Engineers, Construction Engineering Research Laboratory
Table 3-8. Characteristics of phenolic aircraft				
paint-stripping waste water				
(mg/L unless	noted otherwise)			
Parameter	Concentration			
Phenols	1,000-3,000			
Methylene Chloride	1,000-3,000			
COD	5,000-30,000			
Chromium	50-200			
Suspended Solids	100-1,000			
Oils	100-2,000			
pH (units) 8.5-8.5				

(3) Wastes from machine shops. The machining of metal parts for aircraft, ground vehicles, and large guns is an operation where the major water flows are used for cooling purposes. However, there are large amounts of both lubricating and cooling oils which eventually must be wasted. This operation is often incorporated in a large equipment rebuilding and maintenance depot but may be present in tactical posts. The major pollutants are soluble, emulsified, and free oils; and metal ions, shavings, and flakes.

(4) Wastes from vehicle mechanical maintenance. Engine maintenance on military installations can result in a number of wastewater flows. Waste sources from engine maintenance areas include: steam cleaning condensate, spilled hydraulic, engine and transmission oils, battery maintenance, radiator cleaning, and fuel tank cleaning. A major source of contamination from maintenance shops is solvents, especially petroleum distillates.

(5) Laundry wastes. Most military installations have a large central laundry facility to clean uniforms and work clothes. Wastewaters from laundries vary in composition due to the type of laundry operation, the type of detergents used, the use of dyes, and the condition of the clothing being laundered. Table 3-9 lists typical laundry waste characteristics. TM 5-842-2 indicates wastewater flows and characteristics will vary depending on the type of laundering operations used, the type of detergents used and the condition of the incoming laundry.

 Table 3-9. Typical laundry waste characteristics

 (mg/L unless noted otherwise)

Parameter	Maximum	Average	Minimum
pH (units)	11	8	5.1
Temperature (degrees F)	140	100	50
BOD	3,810	700	45
Grease and Oil	1,410	800	150
Total Solids	3,310	1,700	120
Suspended Solids	784	160	15
Detergents (as ABS)	126	55	3
Phosphates	430	150	1
Free Ammonia	_	3	_

(6) Photographic laboratory wastes. Most military bases have one or more photographic laboratories on site. Photographic wastes normally represent a very small fraction of a facility waste load. However, separate treatment of photographic wastes is sometimes required to remove toxic materials or to recover silver.

(a) There are a number of different types of photochemical processes and each results in a different type of wastewater. Color processes produce more pollutants than black and white processes. Photographic wastes are a combination of spent process chemicals and washwater. Some spent process chemicals, notably fixing agents, are often treated separately for silver recovery. The three most common types of silver recovery processes are: metal replacement, electrodeposition, and precipitation. Metal replacement involves passing the wastewater through a fine steel wool screen. The iron in the steel wool replaces the silver in solution resulting in a settled silver-rich sludge. Electrodeposition involves plating nearly pure silver on the cathode of an electrolytic cell. Precipitation of silver is usually achieved by the addition of chlorine and sulfide to form insoluble silver chloride or sulfide.

(b) The other constituents of a typical combined photographic wastewater are listed in table 3-10. This analysis represents the combined process chemical and wash wastewaters. The toxic chemicals of concern include silver, chromium, cyanide, and boron.

Table 3-10.	Analysis of photographic processing	g
	waste water discharge	

Constituent	Concentration
	(mg/L)
COD	2,234
Dissolved Solids	5,942
Suspended Solids	70
Oils and Grease	22
Surfactants (as LAS)	13
Phenols	0
Nitrates	48
Phosphates	380
Nitrates	1.100
Sulfates	260
Cyanides	6.70
Silver	1.96
Iron	0.20
zinc	0.08
Copper	0.05
Manganese	0.05
Chromium	0.05
Lead	0.05
Cadmium	0.01

(c) Silver ion is highly toxic to aquatic organisms. However, silver in photographic wastes is largely precipitated as silver chloride or silver sulfide and in these forms represents minimal risk of toxicity.

(d) Chromium is present in the hexavalent form (Cr^{*6}) in some bleach solutions. However, hexavalent chromium is reduced to the trivalent form (Cr^{*3}) by strong reducing agents present in photographic wastewaters.

(e) Cyanide is present in bleaching solutions as potassium ferrocyanide. After chemical action by other reducing agents and by oxidation of silver, complex insoluble cyanide compounds are formed. These cyanide complexes are potentially dangerous as their degradation releases toxic cyanides.

(f) Boron is present in photographic wastes in small quantities and is usually precipitated as calcium borate.

(7) Metal plating wastes. Metals are plated onto both metallic and nonmetallic surfaces for decoration, corrosion inhibition, increased wear resistance, or improved hardness. Commonly plated metals are copper, cadmium, chromium, nickel, tin, and zinc. The surface to be plated serves as a cathode. An electrode made of the metal being deposited in most instances acts as the anode. With some metals, such as in chromium plating, an inert anode is used and the plating bath supplies the metal deposited. Nonmetallic surfaces to be plated must be made conductive by application of a conductive material such as graphite. Metal stripping, cleaning, pickling, and phosphatizing are preparation steps for the actual plating operation. Anodizing of aluminum in a chromate bath is considered a related operation since it produces a waste similar in characteristics to plating waste.

(a) A wide range of processing steps is used in the plating operation. Selection of such steps is based on the type of material receiving the plated layer, the type of metal being plated, individual plating technique preferences, and various final product requirements. A typical plating operation will include the following steps:

- -Cleaning by solvent decreasing and/or alkaline cleaner.
- -Rinsing.
- -Acid cleaning or pickling.
- -Rinsing.
- -Surface preparation such as phosphatizing.

–Flash plating.

- -Principal plating.
- -Rinsing.
- -Drying.

(b) The major waste sources are rinse water overflow; fume-scrubber water; batch-dumps of spent acid, alkali, or plating bath solutions; and spills of the concentrated solutions. Important parameters include pH, cyanides, emulsifying and wetting agents, and heavy metals. Cyanide is converted to highly toxic hydrogen cyanide gas at low pH; therefore, cyanide-plating solutions must not be mixed with acid-cleaning or acid-plating solutions.

(8) Wastes from munitions manufacture. Wastes generated from munitions manufacture originate from manufacturing areas as well as loading, assembling, and packing (LAP) areas. Wastewaters are generated from the manufacture and use of explosive chemicals such as trinitrotoluene (TNT), nitroglycerine, cyclonite (RDX), HMX, and tetryl. The amount and composition of munitions wastewaters varies with the explosive being produced.

(a) TNT $(CH_3C_6H_2(NO_2)_3)$. In TNT manufacture, toluene is reacted with nitric acid in a three-step process, using fuming sulfuric acid as a catalyst and drying agent. Excess acids are washed away from the crude TNT, forming in a waste stream known as "yellow water". Unwanted beta- and gamma-TNT isomers are selectively removed from the desired alpha-TNT in a solution of sodium sulfite (sellite). This purification step generates a dark red-colored waste known as "red water". The purified TNT is then recrystallized, dried and flaked. TNT contains up to 0.4 percent dinitrotoluene (DNT) which also is an explosive and considered hazardous. The washdown water from processing areas contains suspended TNT and is known as "pink water". Originally, production was a batch-type operation, however nearly all plants have been converted to continuous-type systems, as shown in figure 3-2. The continuous operations normally employ chemical recycle and result in a smaller quantity of more concentrated waste than the batch-type operations. Typical wastewater characteristics from both types of operations are presented in table 3-11.



Figure 3-2. Typical TNT production process.

Table 3-11. Typical TNT was	ste water characteristics
(mg/L unless note	ed otherwise)

	Continuous-Type Process			
	24-Hour	Grab	Batch-Type	
Parameter	Composite Sample	e Sample	Process	
TNT	20.3	145	—	
pH (units)	2.5	2.05	2.6	
COD	64	274	673	
Nitrate (as N)	213	53	107	
Sulfate (as SO ₄)	1,821	842	638	
Color (units)	161	228	6,700	
Total Solids	2,792	1,160	2,048	
Volatile Solids	1,377	960	850	
Suspended Solids	619	224	98	
Temperature				
(degree F)	95		_	
Flow (gal/lb of TNT)	-		11.2	

(b) Nitroglycerine $(CHNO_3(CH_2NO_3)_2)$. Nitroglycerine is produced by mixing glycerine with concentrated nitric and sulfuric acids, similar to the TNT manufacturing process. The acids are then decanted, and the nitroglycerine is washed with water and soda ash to remove any residual acids. The two principal wastewaters are the waste acid and the soda ash washwaters; and both contain nitroglycerine. Typical wastewater characteristics are presented in table 3-12.

 Table 3-12. Typical nitroglycerine waste water characteristics (mg/L unless noted otherwise)

Parameter	Maximum	Minimum
Nitroglycerine	315	0
pH (units)	9.9**	1.7
COD	340	10
Nitrate (as N)	1,920	0.5
Sulfate (as SO ₄)	470	15
Color (units)	80	5
Total Solids	25,000	110
Suspended Solids	40	1
Temperature (degrees F)	80	50
Flow (mgd)	0.17	0.04

**High values indicate a dump of the soda ash washing solution.

(c) HMX and RDX, HMX (($(CH_2N_2O_2)_4$) and RDX ($CH_2N_2O_2)_3$) are very similar chemical compounds and are manufactured by essentially the same process, except for different operating temperatures and raw material feed ratios. Hexamine, acetic anhydride, nitric acid, and ammonium nitrate are fed into a reactor, forming crude HMX or RDX; which is then aged, filtered, decanted, and washed with water. Wastewaters result from spillage of raw materials or product, discharge of cooling water, washwater and filtered water; and flows from equipment and floor cleanup operations. HMX and RDX wastes typically have a BOD of 900 to 2,000 mg/L and a pH ranging from 1.6 to 6.0. Analysis of wastewater must be made to determine specific treatment needs.

(d) Nitrocellulose $(C_{6}H_{7}O_{5}(NO_{2})_{3})$. To produce nitrocellulose, purified cellulose in the form of cotton-linters or wood-cellulose is treated with a mixture of sulfuric acid, nitric acid and water. The nitrated cellulose is then purified by a combination of centrifugation, boiling, macerating, solvent extraction or washing operations. The nitrocellulose ("green powder") is then combined with other explosive materials to be processed into various propellants. Waste materials generated include the cellulose- and nitrocellulosecontaminated acid waters from the vitrification and purification steps, alcohol and ether solvents, and other waste material from the refining and processing steps. Accidental fires caused by processing of nitrocellulose into propellants are often extinguished by automatic sprinklers, generated highly contaminated wastewater.

(e) Black powder. The industrial classification used by the Bureau of Mines defines black blasting powder as all black powder having sodium or potassium nitrate as a constituent. Black powder and similar mixtures were used in incendiary compositions and in pyrotechnic devices for amusement and for war, long before there was any thought of applying their energy usefully for the production of mechanical work. Where smoke is no objection, black powder is probably the best substance that is available for communicating fire and for producing a quick hot flame. It is for these purposes that it is now principally used in the military. (129)

(f) Nitroguanidine (NO,NHC(NH)NH,). Nitroguanidine exists in two forms. The alphaform invariably results when guanidine nitrate is dissolved in concentrated sulfuric and the solution is poured into water. This is the form which is commonly used in the explosive industry. When alpha-nitroguanidine is decomposed by heat, a certain amount of beta-nitroguanidine is found among the products. Beta-nitroguanidine is produced in variable amounts, usually along with some of the alpha-compound. This is accomplished through nitration of the mixture of guanidine sulfate and ammonium sulfate which is formed from the hydrolysis of dicyanodiamide with sulfuric acid. Nitroguanidine on reduction is converted first into nitrosoguanidine and then into aminoguanidine (or guanylhydrazine). The latter substance is used in the explosives industry for the preparation of tetracene.

(g) Lead azide (PbN₆). Lead azide is manufactured by treating sodium azide with lead acetate or nitrate. Sodium azide is formed from sodium amide and nitrous oxide. Lead azide is used where it is desired to produce, either from flame or from impact, an initiatory shock for the detonation of a high explosive such as found in compound detonators and in the detonators of artillery fuzes. The commercial preparation of the azides is carried out either by the interaction of hydrazine with a nitrite or by the interaction of sodium amide with nitrous oxide.

(h) Lead styphnate $(PbC_6H O_2(NO_2)_3)$. Lead styphanate is commonly prepared by adding a solution of magnesium styphnate to a well-stirred solution of lead acetate at 158 degrees F. Dilute nitric acid is added with stirring to convert the basic to the normal salt, and the stirring is continued while the temperature drops to about 86 degrees F. The product consists of reddishbrown, short, rhombic crystals. Lead styphnate is a poor initiator, but it is easily ignited by fire or by a static discharge. It is used as an ingredient of the priming layer which causes lead azide to explode from a flash. (132)

(i) Projectiles and casings. The manufacture of the lead slugs, bullet jackets, and shell casings generates wastewaters different in composition than those from explosives manufacture. Waste constituents include heavy metals, oils and grease, soaps and surfactants, solvents, and acids. Lead slugs are manufactured by extruding lead wire, then cutting and forming the lead for insertion in the bullet jacket. Alkaline cleaners, soluble oils, and cooling waters constitute the wastewater flow. Typical characteristics include high pH of about 11 and a moderate COD of 286 mg/L. Small arms bullet jackets and casings are normally brass (copper and zinc alloy), although either may be made of steel for certain applications. The larger artillery shells are generally steel. The manufacturing processes used for both brass and steel are essentially the same, consisting of stamping out plugs from metal sheets, then drawing, trimming, tapering, and shaping the plugs into either a shell, bullet jacket, or casing. Conventional metal conditioning operations, such as alkaline cleaning, pickling, phosphatizing, and metal coating occur between steps. One quality control check involves the use of a mercurous nitrate solution, creating an opportunist y for mercury pollution. Total wastes have widely fluctuating pH with heavy metals (mercury, copper, zinc, and iron), oils and surfactants. Table 3- 13 indicates typical munitions metal parts wastewater characteristics.

Table 3-13. Typical munitions metal parts
waste water characteristics
(mg/L unless noted otherwise)

Parameter	Maximum	Average	
Temperature (degree F)	120	65	
pH (units)	9.2	3.3	
Alkalinity (as CaCO ₃)	370	0	
Total Solids	5,000	650	
Suspended Solids	725	27	
Zinc	18	7	
Copper	32	0.6	
Lead	less than 0.2	_	
Iron	21	less than 3.0	
Oil	168	0	

(*j*) Loading, assembling and packing (LAP). The main LAP operations are explosives receiving and melting operations, cartridge and shell-filling operations and shell-renovation. Figure 3-3 is a schematic of a typical shell-filling and renovating facility showing major waste flows. Wastewater is generated from the four following sources:

- air-scrubbing.
- shell-filling.
- -shell-washout water.
- -cleanup water.

Dust from the unloading operation and fumes from the molten explosives are scrubbed from the air with water. When the shells are being filled with explosives, any spillage or over-filling will contaminate the water bath unless the water is covered. The washout water from rejected or renovated shells is heavily contaminated with explosives. The metal-cleaning and metal-treating rinse waters are contaminated with alkali soaps and surfactants, as well as dissolved copper. A complete washdown of all areas and equipment which could be contaminated with explosives is usually performed at least weekly, resulting in large flows of highly contaminated water. Table 3-14 indicates typical total wastewater characteristics.

Table 3-14. Typical LAP facility industrial waste water characteristics (mg/L unless noted otherwise)

Parameter	Maximum Average		Minimum
pH (units)	8.4	7.9	6.8
Total Solids	1,790	1,401	903
Suspended Solids	336	138	22
Total Volatile Solids	956	548	426
Total (Kjeldahl) Nitrogen	25	17	10
TNT	235	178	156
RDX	180	145	88

(k) Coal pile runoff. Large quantities of coal are used at many military facilities for power generation. The coal that is stored for this purpose is maintained in large outdoor storage piles. Rain infiltration generates a coal pile runoff



flow which must be treated due to its elevated TSS and turbidity, as well as an increased $FeSO_4$ and H_2SO_4 concentration resulting from the coal oxidizing environment. Construction of a retaining curb surrounding the area of potential contamination, as well as a collection sump for short

term storage, will allow for complete collection and routing of this flow to the wastewater treatment system. Construction of a coal pile cover, where applicable, would negate the need for flow collection as well as protect the coal from environmental influences and degradation.

4 Overview of wastewater treatment systems

4.1 WASTEWATER TREATMENT LEVELS

In planning studies for the implementation of the wastewater treatment, the following points must be clearly addressed:

- environmental impact studies on the receiving body
- treatment objectives
- treatment level and removal efficiencies

The environmental impact studies that are necessary for the evaluation of the compliance with the receiving body standards were detailed in Chapter 3. The requirements to be reached for the effluent are also a function of the specific legislation that defines the quality standards for the effluent and for the receiving body. The legislation was also covered in Chapter 3.

The removal of pollutants during treatment in order to reach a desired quality or required discharge standard is associated with the concepts of *treatment level* and *treatment efficiency*.

Wastewater treatment is usually classified according to the following levels (see Tables 4.1 and 4.2):

- Preliminary
- Primary

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Level	Removal			
Preliminary	• Coarse suspended solids (larger material and sand)			
Primary	 Settleable suspended solids Particulate (suspended) BOD (associated to the organic matter component of the settleable suspended solids) 			
Secondary	 Particulate (suspended) BOD (associated to the particulate organic matter present in the raw sewage, or to the non settleable particulate organic matter, not removed in the possibly existing primary treatment) Soluble BOD (associated to the organic matter in the form of dissolved solids) 			
Tertiary	 Nutrients Pathogenic organisms Non-biodegradable compounds Metals Inorganic dissolved solids Remaining suspended solids 			

Table 4.1. Wastewater treatment levels

Note: depending on the treatment process adopted, the removal of nutrients (by biological processes) and pathogens can be considered an integral part of secondary treatment.

- Secondary
- Tertiary

The objective of **preliminary treatment** is only the removal of coarse solids, while **primary treatment** aims at removing settleable solids and part of the organic matter. *Physical* pollutant removal mechanisms are predominant in both levels. In **secondary treatment** the aim is the removal of organic matter and possibly nutrients (nitrogen and phosphorus) by predominantly *biological* mechanisms. The objective of **tertiary treatment** is the removal of specific pollutants (usually toxic or non-biodegradable compounds) or the complementary removal of pollutants that were not sufficiently removed in the secondary treatment. Tertiary treatment is rare in developing countries.

The *removal efficiency* of a pollutant in the treatment or in a treatment stage is given by the formula:

$$E = \frac{C_o - C_e}{C_o}.100$$
(4.1)

where:

E = removal efficiency (%)

 $C_o = influent$ concentration of the pollutant (mg/L)

 $C_e = effluent \text{ concentration of the pollutant (mg/L)}$

	Treatment level ⁽¹⁾					
Item		Preliminary		Primary		Secondary
Pollutants removed	•	Coarse solids	•	Settleable solids Particulate BOD	• • •	Non-settleable solids Fine particulate BOD Soluble BOD Nutrients ⁽⁴⁾ Pathogens ⁽⁴⁾
Removal efficiencies			•	SS: 60–70% BOD: 25–40% Coliforms: 30–40%	•	SS: 65–95% BOD: 60–99% Coliforms: 60–99% ⁽³⁾
Predominant treatment mechanism	•	Physical	•	Physical	•	Biological
Complies with usual discharge standards? ⁽²⁾	•	No	•	No	•	Usually yes
Application	•	Upstream of pumping stations Initial treatment stage	•	Partial treatment Intermediate stage of a more complete treatment	•	More complete treatment (for organic matter)

Table 4.2. Characteristics of the main wastewater treatment levels

Notes:

(1) A secondary level WWTP usually has preliminary treatment, but may or may not have primary treatment (depends on the process).

(3) The coliform removal efficiency can be higher if a specific removal stage is included.

(4) Depending on the treatment process, nutrients and pathogens may be removed in the secondary stage.

4.2 WASTEWATER TREATMENT OPERATIONS, PROCESSES AND SYSTEMS

The treatment methods are composed by unit operations and processes, and their integration makes up the treatment systems.

The concepts of unit operations and unit process are frequently used interchangeably, because they can occur simultaneously in the same treatment unit. In general, the following definitions can be adopted (Metcalf & Eddy, 1991):

• **Physical unit operations:** treatment methods in which *physical forces* are predominant (e.g. screening, mixing, flocculation, sedimentation, flotation, filtration)

⁽²⁾ Discharge standard as stated in the legislation. The environmental agency may authorise other values, if environmental studies demonstrate that the receiving body is able to assimilate a higher loading.

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- Chemical unit processes: treatment methods in which the removal or the conversion of the contaminants occurs by the addition of *chemical products* or due to *chemical reactions* (e.g. precipitation, adsorption, disinfection).
- **Biological unit processes:** treatment methods in which the removal of the contaminants occurs by means of *biological activity* (e.g. carbonaceous organic matter removal, nitrification, denitrification)

Various mechanisms can act separately or simultaneously in the removal of the pollutants, depending on the process being used. The main mechanisms are listed in Table 4.3.

Table 4.4 lists the main processes, operations, and treatment systems frequently used in the treatment of *domestic sewage*, as a function of the pollutant to be removed. These methods are employed in the **liquid phase** (or liquid lines), which corresponds to the main flow of the liquid (sewage) in sewage treatment works. On the other hand, the **solid phase** (covered in Section 5) is associated with the solid by-products generated in the treatment, notably sludge. The present text concentrates on the *biological treatment* of wastewater, which is the reason why physical – chemical treatment systems are not covered (these depend on the addition of chemical products and are used more frequently for the treatment of industrial wastewaters).

Table 4.5 presents a summary of the main secondary level domestic sewage treatment systems. The technology of wastewater treatment has various other processes and variants, but the present book addresses only the most frequently used systems in warm-climate countries. The flowsheets of the systems described in this table are presented in Figures 4.1a–f. The integration between the various operations and processes listed in Table 4.5 can be seen in the flowsheets. In all flowsheets, besides going to the receiving water body, the effluent may be reused (agricultural / industrial / other) if conditions so permit.

In order to allow a better understanding of the main wastewater treatment systems, the remainder of the chapter is devoted to a preliminary description of them. Further details may be found in various chapters throughout this book.

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Pollutant	Subdivision	ivision Main removal mechan		
Solids	Coarse solids $(> \sim 1 \text{ cm})$	Screening	Retention of the solids with dimensions greater than the spacing between the bars	
	Suspended solids (>~1 μm)	Sedimentation	Separation of the particles with a density greater than the sewage	
	Dissolved solids (< ~1 μm)	Adsorption	Retention on the surface of biomass flocs or biofilms	
Organic matter	BOD in suspension	Sedimentation	Separation of the particles with a density greater than the sewage	
	(particulate BOD) $(> \sim 1 \text{ um})$	Adsorption	Retention on the surface of biomass flocs or biofilms	
	(* 1 µm)	Hydrolysis	Conversion of the BOD in suspension into soluble BOD by means of enzymes, allowing its stabilisation	
		Stabilisation	Utilisation by biomass as food, with conversion into gases, water and other inert compounds.	
	Soluble BOD (< ~1 μm)	Adsorption	Retention on the surface of biomass flocs or biofilms	
		Stabilisation	Utilisation by biomass as food, with conversion into gases, water and other inert compounds.	
Pathogens	Larger dimensions and/or with protective layer (protozoan cysts and helminth eggs)	Sedimentation	Separation of pathogens with larger dimensions and density greater than the sewage	
		Filtration	Retention of pathogens in a filter medium with adequate pore size	
	Lower dimensions (bacteria and viruses)	Adverse environmental conditions	Temperature, pH, lack of food, competition with other species, predation	
		Ultraviolet radiation	Radiation from the sun or artificial	
		Disinfection	Addition of a disinfecting agent, such as chlorine	

Table 4.3. Main mechanisms for the removal of pollutants in wastewater treatment

(Continued)

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Pollutant	Subdivision	Main removal mechanisms		
Nitrogen	Organic nitrogen	Ammonification	Conversion of organic nitrogen into ammonia	
	Ammonia	Nitrification	Conversion of ammonia into nitrite, and the nitrite into nitrate, by means of nitrifying bacteria	
		Bacterial assimilation	Incorporation of ammonia into the composition of bacterial cells	
		Stripping	Release of free ammonia (NH ₃) into the atmosphere, under high pH conditions	
		Break-point chlorination	Conversion of ammonia into chloramines, through the addition of chlorine	
	Nitrate	Denitrification	Conversion of nitrate into molecular nitrogen (N_2) , which escapes into the atmosphere, under anoxic conditions	
Phosphorus	Phosphate	Bacterial assimilation	Assimilation in excess of the phosphate from the liquid by phosphate accumulating organisms, which takes place when aerobic and anaerobic conditions are alternated	
		Precipitation	Phosphorus precipitation under conditions of high pH, or through the addition of metallic salts	
		Filtration	Retention of phosphorus-rich biomass, after stage of biological excessive P assimilation	

Table 4.3 (Continued)

Table 4.4. Treatment operations, processes and systems frequently used for the removal of pollutants from domestic sewage

Pollutant	Operation, process or treatment system
Suspended solids	 Screening Grit removal Sedimentation Land disposal
Biodegradable organic matter	 Stabilisation ponds and variants Land disposal Anaerobic reactors Activated sludge and variants Aerobic biofilm reactors
Pathogenic organisms	 Maturation ponds Land disposal Disinfection with chemical products Disinfection with ultraviolet radiation Membranes

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Table 4.4 (Continued)

Pollutant	Operation, process or treatment system
Nitrogen	 Nitrification and biological denitrification Maturation and high-rate ponds Land disposal Physical-chemical processes
Phosphorus	Biological removalMaturation and high-rate pondsPhysical chemical processes

Table 4.5. Summary description of the main biological wastewater treatment systems

STABILISATION PONDS			
Facultative pond	Wastewater flows continuously through a pond especially constructed for wastewater treatment. The wastewater remains in the ponds for many days. The soluble and fine particulate BOD is aerobically stabilised by bacteria which grow dispersed in the liquid medium, while the BOD in suspension tends to settle, being converted anaerobically by bacteria at the bottom of the pond. The oxygen required by the aerobic bacteria is supplied by algae through photosynthesis. The land requirements are high.		
Anaerobic pond – facultative pond	Around 50 to 65% of the BOD is converted in the anaerobic pond (deeper and with a smaller volume), while the remaining BOD is removed in the facultative pond. The system occupies an area smaller than that of a single facultative pond.		
Facultative aerated lagoon	The BOD removal mechanisms are similar to those of a facultative pond. However, oxygen is supplied by mechanical aerators instead of through photosynthesis. The aeration is not enough to keep the solids in suspension, and a large part of the sewage solids and biomass settles, being decomposed anaerobically at the bottom.		
Completely mixed aerated lagoon – sedimentation pond	The energy introduced per unit volume of the pond is high, what makes the solids (principally the biomass) remain dispersed in the liquid medium, in complete mixing. The resulting higher biomass concentration in the liquid medium increases the BOD removal efficiency, which allows this pond to have a volume smaller than a facultative aerated lagoon. However, the effluent contains high levels of solids (bacteria) that need to be removed before being discharged into the receiving body. The sedimentation pond downstream provides conditions for this removal. The sludge of the sedimentation pond must be removed every few years.		
High rate ponds	High rate ponds are conceived in order to maximise algal production, in a totally aerobic environment. To accomplish this, lower depths are employed, allowing light penetration throughout the liquid mass. Therefore, photosynthetic activity is high, leading to high dissolved oxygen concentrations and pH levels. These factors contribute to the increase of the pathogens die-off and to the removal of nutrients. High rate ponds usually receive a high organic load per unit surface area. Usually a moderate agitation in the liquid is introduced, caused by a low-power mechanical equipment.		

(Continued)

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Maturation ponds	The main objective of maturation ponds is the removal of pathogenic organisms. In maturation ponds prevail environmental conditions which are adverse to these organisms, such as ultraviolet radiation, high pH, high DO, lower temperature (compared with the human intestinal tract), lack of nutrients and predation by other organisms. Maturation ponds are a post-treatment stage for BOD-removal processes, being usually designed as a series of ponds or a single-baffled pond. The coliform removal efficiency is very high.
	LAND DISPOSAL
Slow rate system	The objectives may be for (a) wastewater treatment or (b) water reuse through crop production or landscape irrigation. In each case, design criteria are different. Wastewater is applied to the soil, supplying water and nutrients necessary for plant growth. Part of the liquid evaporates, part percolates into the soil, and the largest fraction is absorbed by the plants The surface application rates are very low. The liquid can be applied by sprinkling, graded-border, furrow and drip irrigation.
Rapid infiltration	Wastewater is applied in shallow basins. The liquid passes through the porous bottom and percolates into the soil. The evaporation loss is lower in view of the higher application rates. Vegetation may or may not be used. The application is intermittent, which provides a rest period for the soil. The most common types are: application for groundwater recharge, recovery using underdrains and recovery using wells.
Subsurface infiltration	Pre-settled sewage (usually from septic tanks) is applied below the soil surface. The infiltration trenches or chambers are filled with a porous medium, which provides transportation, storage and partial treatment, followed by the infiltration itself.
Overland flow	Wastewater is distributed in the upper part of vegetated slopes, flows over the slopes and is collected by ditches at the lower part. Treatment occurs in the root-soil system. The application is intermittent. Distribution of wastewater may be by high-pressure sprinklers, low-pressure sprays and gated or perforated pipes or channels.
Constructed wetlands	While the former systems are land-based systems, these are aquatic-based systems. The systems are composed by shallow basins or channels in which aquatic plants grow. The system can be of free-water surface (water level above ground level) or subsurface flow (water level below ground level). Biological, chemical and physical mechanisms act on the root–soil system.
	ANAEROBIC SYSTEMS
Upflow anaerobic sludge blanket reactor (UASB)	BOD is converted anaerobically by bacteria dispersed in the reactor. The liquid flow is upwards. The upper part of the reactor is divided into settling and gas collection zones. The settling zone allows the exit of the clarified effluent in the upper part and the return of the solids (biomass) by gravity to the system, increasing its concentration in the reactor. Amongst the gases formed is methane. The system has no primary sedimentation tank. The sludge production is low, and the excess sludge wasted is already thickened and stabilised.

Table 4.5 (Continued)

Anaerobic filter	BOD is converted anaerobically by bacteria that grow attached to a support medium (usually stones) in the reactor. The tank works submerged and the flow is upwards. The system requires a primary sedimentation tank (frequently septic tanks). The sludge production is low and the excess sludge is already stabilised.
Anaerobic reactor – post-treatment	UASB reactors produce an effluent that has difficulty in complying with most existing discharge standards. Therefore, some form of post treatment is frequently necessary. The post treatment may be biological (aerobic or anaerobic) or physical-chemical (with the addition of coagulants). Practically all wastewater treatment processes may be used as a post treatment of the anaerobic reactors. The global efficiency of the system is usually similar to the one that would be obtained if the process were being applied for raw wastewater. However, land, volume and energy requirements are lower. Sludge production is also lower.
	ACTIVATED SLUDGE
Conventional activated sludge	The biological stage comprises two units: aeration tank (reactor) and secondary sedimentation tank. The biomass concentration in the reactor is very high, due to the recirculation of the settled solids (bacteria) from the bottom of the secondary sedimentation tank. The biomass remains in the system longer than the liquid, which guarantees a high BOD removal efficiency. It is necessary to remove a quantity of the sludge (biomass) that is equivalent to what is produced. This excess sludge removed needs to be stabilised in the sludge treatment stage. The oxygen supply is done by mechanical aerators or by diffused air. Upstream of the reactor there is a primary sedimentation tank to remove the settleable solids from the raw sewage.
Activated sludge (extended aeration)	Similar to the previous system, but with the difference that the biomass stays longer in the system (the aeration tanks are bigger). With this, there is less substrate (BOD) available for the bacteria, which makes them use their own cellular material as organic matter for their maintenance. Consequently, the removed excess sludge (bacteria) is already stabilised. Primary sedimentation tanks are usually not included.
Intermittently operated activated sludge (sequencing batch reactors)	The operation of the system is intermittent. In this way, the reaction (aerators on) and settling (aerators off) stages occur in different phases in the same tank. When the aerators are turned off, the solids settle, which allows the removal of the clarified effluent

(supernatant). When the aerators are turned on again, the settled solids return to the liquid mass, with no need of sludge

recirculation pumps. There are no secondary sedimentation tanks. It can be in the conventional or extended aeration modes.

The biological reactor incorporates an anoxic zone (absence of

upstream and/or downstream of the aerated zone. The nitrates formed in the nitrification process that takes place in the aerobic zone are used in the respiration of facultative microorganisms in the anoxic zones, being reduced to gaseous molecular nitrogen,

oxygen, but presence of nitrates). The anoxic zone can be

which escapes to the atmosphere.

Activated sludge with biological nitrogen removal

Table 4.5 (Continued)

(Continued)

Activated sludge with biological nitrogen and phosphorus removal	Besides the aerobic and anoxic zones, the biological reactor also incorporates an anaerobic zone, situated at the upper end of the tank. Internal recirculations make the biomass to be successively exposed to anaerobic and aerobic conditions. With this alternation, a certain group of microorganisms absorbs phosphorus from the liquid medium, in quantities that are much higher than those which would be normally necessary for their metabolism. The withdrawal of these organisms in the excess sludge results in the removal of phosphorus from the biological reactor.
	AEROBIC BIOFILM REACTORS
Low rate trickling filter	BOD is stabilised aerobically by bacteria that grow attached to a support medium (commonly stones or plastic material). The sewage is applied on the surface of the tank through rotating distributors. The liquid percolates through the tank and leaves from the bottom, while the organic matter is retained and then further removed by the bacteria. The free spaces permit the circulation of air. In the low rate system there is a low availability of substrate (BOD) for the bacteria, which makes them undergo self-digestion and leave the system stabilised. Sludge that is detached from the support medium is removed in the secondary sedimentation tank. The system requires primary sedimentation.
High rate trickling filter	Similar to the previous system but with the difference that a higher BOD load is applied. The bacteria (excess sludge) need to be stabilised within the sludge treatment. The effluent from the secondary sedimentation tank is recirculated to the filter in order to dilute the influent and to guarantee a homogeneous hydraulic load.
Submerged aerated biofilter	The submerged aerated biofilter is composed by a tank filled with a porous material (usually submerged), through which sewage and air flow permanently. The air flow is always upwards, while the liquid flow can be downward or upward. The biofilters with granular material undertake, in the same reactor, the removal of soluble organic compounds and particulate matter. Besides being a support medium for biomass growth, the granular material acts also as a filter medium. Periodic backwashings are necessary to eliminate the excess biomass accumulated, reducing the head loss through the medium.
Rotating biological contactor (biodisc)	The biomass grows adhered to a support medium, which is usually composed by a series of discs. The discs, partially immersed in the liquid, rotate, exposing their surface alternately to liquid and air.

Table 4.5 (Continued)

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WASTE STABILISATION POND SYSTEMS



Figure 4.1a. Flowsheet of stabilisation pond systems (liquid phase only).

LAND DISPOSAL SYSTEMS



Figure 4.1b. Flowsheet of soil-based land treatment systems (liquid phase only).

CONSTRUCTED WETLANDS



Figure 4.1c. Flowsheet of aquatic-based land treatment systems (liquid phase only).

ANAEROBIC SYSTEMS



UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR

Figure 4.1d. Flowsheet of anaerobic reactors (liquid phase only).



ACTIVATED SLUDGE SYSTEMS

Figure 4.1e. Flowsheet of activated sludge systems (liquid phase only).

AEROBIC BIOFILM REACTORS

LOW RATE TRICKLING FILTER



Figure 4.1f. Flowsheet of aerobic biofilm reactors (liquid phase only).

(already stabilised in case the primary sedimentation tank is a septic tank)

solid phase

solid phase

4.3 PRELIMINARY TREATMENT

Preliminary treatment is mainly intended for the removal of:

- Coarse solids
- Grit

The basic removal mechanisms are of a *physical* order. Besides the coarse solids removal units, there is also a *flow measurement* unit. This usually consists of a standardised flume (e.g. Parshall flume), where the measured liquid level can be correlated with the flow. Weirs (rectangular or triangular) and closed-pipe measurement mechanisms can also be adopted. Figure 4.2 presents a typical flowsheet of the preliminary treatment.

PRELIMINARY TREATMENT





The removal of *coarse solids* is frequently done by *screens* or racks, but static or rotating screens and comminutors can also be used. In the screening, material with dimensions larger than the spaces between the bars is removed (see Figure 4.3). There are coarse, medium, and fine screens, depending on the spacing between the bars. The removal of the retained material can be manual or mechanised.

The main objectives of the removal of coarse solids are:

- protection of the wastewater transport devices (pumps and piping)
- protection of the subsequent treatment units
- protection of the receiving bodies

The removal of *sand* contained in the sewage is done through special units called *grit chambers* (see Figure 4.4). The sand removal mechanism is simply by sedimentation: the sand grains go to the bottom of the tank due to their larger dimensions and density, while the organic matter, which settles much slower, stays in suspension and goes on to the downstream units.

There are many processes, from manual to completely mechanised units, for the removal and transportation of the settled grit. The basic purposes of grit removal are:

- to avoid abrasion of the equipment and piping
- to eliminate or reduce the possibility of obstructions in piping, tanks, orifices, siphons, etc
- to facilitate the transportation of the liquid, principally the transfer of the sludge in its various phases

SCREEN

Figure 4.3. Schematics of a screen



Figure 4.4. Diagram of a grit chamber

4.4 PRIMARY TREATMENT

Primary treatment aims at the removal of:

- settleable suspended solids
- floating solids

After passing the preliminary treatment units, sewage still contains non-coarse suspended solids, which can be partially removed in sedimentation units. A significant part of these suspended solids is comprised of organic matter in suspension. In this way, its removal by simple processes such as sedimentation implies a reduction in the BOD load directed to the secondary treatment, where its removal is more expensive.

The sedimentation tanks can be circular (Figure 4.5) or rectangular. Sewage flows slowly through the sedimentation tanks, allowing the suspended solids with a greater density than the surrounding liquid to slowly settle to the bottom. The mass of solids accumulated in the bottom is called raw *primary sludge*. This sludge is removed through a single pipe in small sized tanks or through mechanical scrapers and pumps in larger tanks. Floating material, such as grease and oil, tends to have a lower density than the surrounding liquid and rise to the surface of the sedimentation tanks, where they are collected and removed from the tank for subsequent treatment.

The efficiency of primary treatment in the removal of suspended solids, and, as result, BOD, may be enhanced by the addition of coagulants. This is called *advanced primary treatment* or *chemically enhanced primary treatment* (CEPT).

PRIMARY SEDIMENTATION TANK



Figure 4.5. Schematics of a circular primary sedimentation tank

Coagulants may be aluminium sulphate, ferric chloride or other, aided or not by a polymer. Phosphorus may be also removed by precipitation. More sludge is formed, resulting from the higher amount of solids removed from the liquid and from the chemical products added. The primary sludge may be digested by conventional digesters, but in some cases it may also be stabilised by lime (simplifying the flowsheet, but further increasing the amount of sludge to be disposed of).



Figure 4.6. Schematics of a single-chamber septic tank

Septic tanks are also a form of primary treatment (Figure 4.6). The septic tanks and their variants, such as Imhoff tanks, are basically sedimentation tanks, where the settleable solids are removed to the bottom. These solids (sludge) remain at the bottom of the tanks for a long period of time (various months) which is sufficient for their digestion. This stabilisation occurs under anaerobic conditions.

4.5 SECONDARY TREATMENT

4.5.1 Introduction

The main objective of secondary treatment is the removal of *organic matter*. Organic matter is present in the following forms:

- *dissolved organic matter* (soluble or filtered BOD) that is not removed by merely physical operations, such as the sedimentation that occurs in primary treatment;
- organic matter in suspension (suspended or particulate BOD), which is largely removed in the occasionally existing primary treatment, but whose solids with slower settleability (finer solids) remain in the liquid mass.

The secondary treatment processes are conceived in such a way as to accelerate the decomposition mechanisms that naturally occur in the receiving bodies. Thus, the decomposition of the degradable organic pollutants is achieved under controlled conditions, and at smaller time intervals than in the natural systems.

The essence of secondary treatment of domestic sewage is the inclusion of a *biological stage*. While preliminary and primary treatments have predominantly physical mechanisms, the removal of the organic matter in the secondary stage is carried out through biochemical reactions, undertaken by microorganisms.

A great variety of microorganisms take part in the process: bacteria, protozoa, fungi and others. The basis of the whole biological process is the effective contact between these organisms and the organic matter contained in the sewage, in such a way that it can be used as food for the microorganisms. The microorganisms convert the organic matter into carbon dioxide, water and cellular material (growth and reproduction of the microorganisms) (see Figure 4.7). This biological decomposition of the organic matter requires the presence of oxygen as a fundamental component of the aerobic processes, besides the maintenance of other favourable environmental conditions, such as temperature, pH, contact time, etc.

BACTERIAL METABOLISM



Figure 4.7. Simplified diagram of bacterial metabolism

Secondary treatment generally includes preliminary treatment units, but may or may not include primary treatment units. There exists a large variety of secondary treatment processes, and the most common ones are:

- Stabilisation ponds
- Land disposal systems
- Anaerobic reactors
- Activated sludge systems
- *Aerobic biofilm reactors*

These processes have been summarised in Table 4.5, and a simplified description is presented below. In Section 4.7.2, there is a general comparison between all the processes described, including basic data (efficiencies, land requirements, power requirements, costs, sludge production, etc.), together with qualitative comparisons and a list of advantages and disadvantages.

4.5.2 Stabilisation ponds

The following variants of stabilisation ponds are described briefly in this section:

- Facultative ponds
- Anaerobic pond facultative ponds systems
- Facultative aerated lagoons
- Complete-mix aerated lagoon sedimentation pond systems
- High rate ponds
- Maturation ponds

a) Facultative ponds

Stabilisation ponds are units specially designed and built with the purpose of treating sewage. However, the construction is simple and is principally based on earth movement for digging, filling and embankment preparation.

When facultative ponds receive raw sewage, they are also called *primary* ponds (a secondary pond would be the one which would receive its influent from a previous treatment unit, such as anaerobic ponds – see item b in this section).

Amongst the stabilisation ponds systems, the process of facultative ponds is the simplest, relying only on natural phenomenon. The influent enters continuously in one end of the pond and leaves in the opposite end. During this time, which is of the order of many days, a series of events contribute to the purification of the sewage.

Part of the organic matter in suspension (*particulate BOD*) tends to settle, constituting the bottom sludge. This sludge undergoes a decomposition process by anaerobic microorganisms and is converted into carbon dioxide, methane and other compounds. The inert fraction (non-biodegradable) stays in this bottom layer.

The dissolved organic matter (*soluble BOD*), together with the small-dimension organic matter in suspension (*fine particulate BOD*), does not settle and stays dispersed in the liquid mass. Its decomposition is through **facultative** bacteria that have the capacity to survive, either in the presence or in the absence of free oxygen (but presence of nitrate), hence the designation of facultative, which also defines the name of the pond. These bacteria use the organic matter as energy source, which is released through respiration. The presence of oxygen is necessary in aerobic respiration, and it is supplied to the medium by the photosynthesis carried out by the algae. There is an equilibrium between consumption and the production of oxygen and carbon dioxide (see Figure 4.8).



Figure 4.8. Simplified diagram of a facultative pond

A light energy source, in this case represented by the sun, is necessary for photosynthesis to occur. For this reason, locations with high solar radiation and low cloudiness are favourable for the implementation of facultative ponds.

Photosynthesis is higher near the water surface, as it depends on solar energy. Typical pond depths are between 1.5 and 2.0 m. When deep regions in the pond are reached, the light penetration is low, what causes the predominance of oxygen consumption (*respiration*) over its production (*photosynthesis*), with the possible absence of dissolved oxygen at a certain depth. Besides, photosynthesis only occurs during the day, and during the night the absence of oxygen can prevail. Owing to

these facts, it is essential that the main bacteria responsible for the stabilisation of the organic matter are facultative, so that they can survive and proliferate, either in the presence or in the absence of oxygen (but only under anoxic, and not strict anaerobic conditions).

The process of facultative ponds is essentially natural, as it does not require any equipment. For this reason, the stabilisation of the organic matter takes place at lower rates, implying the need of a long detention time in the pond (usually greater than 20 days). To be effective, photosynthesis needs a large exposure surface area to make the most of the solar energy by the algae, also implying the need of large units. As a result, the total area required by facultative ponds is the largest within all the wastewater treatment processes (excluding the land disposal processes). On the other hand, because the process is totally natural, it is associated to a high operational simplicity, which is a factor of fundamental importance in developing countries.

Figure 4.9 presents a typical flowsheet of a facultative pond system.



Figure 4.9. Typical flowsheet of a facultative pond system

b) Anaerobic pond - facultative ponds systems

The process of facultative ponds, in spite of having a satisfactory efficiency, requires a large area that is often not available in the locality in question. There is therefore, the need to find solutions that could imply the reduction of the total area required. One of these solutions is the system of anaerobic ponds followed by facultative ponds. In this case, the facultative pond is also called a *secondary* pond, since it receives the influent from an upstream treatment unit, and not the raw sewage.

The raw sewage enters a pond that has smaller dimensions and is deeper (around 4 to 5 m). Owing to the smaller dimensions of this pond, photosynthesis practically does not occur. In the balance between oxygen consumption and production, consumption is much higher. Therefore, anaerobic conditions predominate in this first pond, which is consequently called an *anaerobic pond*.

Anaerobic bacteria have a slower metabolic and reproduction rate than the aerobic bacteria. For a detention time of only 2 to 5 days in the anaerobic pond, there is only partial decomposition of the organic matter. However, the BOD removal of the order of 50 to 70%, even if insufficient, represents a large contribution, substantially reducing the load to the facultative pond that is situated downstream.

The facultative pond receives a load of only 30 to 50% of the raw sewage load, which therefore allows it to have smaller dimensions. The overall area requirement

(anaerobic + facultative pond) is such, that land savings in the order of 1/3 are obtained, compared with just a single facultative pond.

The working principles of this facultative pond are exactly as described in item a. Figure 4.10 shows a typical flowsheet of a system of anaerobic ponds followed by facultative ponds.



Figure 4.10. Typical flowsheet of a system of anaerobic ponds followed by facultative ponds

The efficiency of the system is similar or only slightly higher than that of a single facultative pond. The system is also conceptually simple and easy to operate. However, the existence of an anaerobic stage in an open unit is always a cause for concern, due to the possibility of the release of malodours. If the system is well balanced, then the generation of bad smells should not occur. However, occasional operational problems could lead to the release of hydrogen sulphide, responsible for a bad smell. For this reason, this system should, whenever possible, be located far from residences.

c) Facultative aerated lagoon

If a predominantly aerobic system is desired, with even smaller dimensions, a *facultative aerated lagoon* can be used. The main difference in relation to a conventional facultative pond is regarding the form of the oxygen supply. While in facultative ponds the oxygen is mainly obtained from photosynthesis, in the case of facultative aerated lagoons the oxygen is supplied by mechanical equipment called *aerators*.

The most commonly used mechanical aerators in aerated ponds are those with a vertical axis that rotates at a high speed, causing great turbulence in the water. This turbulence favours the penetration of atmospheric oxygen into the liquid mass, where it is then dissolved. A greater oxygen introduction is achieved, in comparison with the conventional facultative pond, which leads to a faster decomposition of the organic matter. Because of this, the detention time of the wastewater in the pond can be less (in the order of 5 to 10 days for domestic sewage). Consequently, the land requirements are much smaller.

The pond is called *facultative* by the fact that the level of energy introduced by the aerators is only sufficient for the oxygenation, but not to maintain the solids (biomass and wastewater solids) in suspension in the liquid mass. In this way, the

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solids tend to settle and constitute a sludge layer at the bottom of the pond, to be decomposed anaerobically. Only the soluble and fine particulate BOD remains in the liquid mass, undergoing aerobic decomposition. Therefore, the pond behaves like a conventional facultative pond (see Figure 4.11).

FACULTATIVE AERATED LAGOON



Figure 4.11. Typical flowsheet of a system of facultative aerated lagoons

Aerated lagoons are less simple in terms of operation and maintenance, when compared with the conventional facultative ponds, owing to the introduction of mechanisation. Therefore, the reduction of the reduction of the land requirements is achieved with a certain rising in the operational level, along with the introduction of electricity consumption.

d) Complete-mix aerated lagoon - sedimentation pond systems

A way of reducing the aerated pond volume even further is to increase the aeration level per unit volume of the lagoon, thus creating a turbulence that, besides guaranteeing oxygenation, allows all the solids to be maintained in suspension in the liquid medium. The denomination of *complete mix* is because of the high degree of energy per unit volume, which is responsible for the total mixing of all the constituents in the pond. Amongst the solids maintained in suspension and in complete mixing are the biomass, besides the organic matter of the raw sewage. There is, therefore, a larger concentration of bacteria in the liquid medium as well as a larger organic matter – biomass contact. Consequently, the efficiency of the system increases and allows the volume of the aerated pond to be greatly reduced. The typical detention time in an aerated pond is in the order of 2 to 4 days.

However, in spite of the high efficiency of this lagoon in the removal of the organic matter originally present in the sewage, a new problem is created. The biomass stays in suspension in all the volume and thus leaves with the pond effluent. This biomass is, in a way, also organic matter (particulate BOD), even if of a different nature of the BOD of the raw sewage. If this new organic matter were discharged into the receiving body, it would also exert an oxygen demand and cause a deterioration in the water quality.

Therefore, it is important that there is a unit downstream in which the suspended solids (predominantly the biomass) can settle and be separated from the liquid

(final effluent). This unit is a *sedimentation pond*, with the main purpose of permitting the settling and accumulation of the solids.

The sedimentation pond is designed with short detention times, around 2 days. In this period, the solids will go to the bottom where they will undergo digestion and be stored for a period of some years, after which they will be removed. There are also sedimentation ponds with continuous removal of the bottom sludge, using, for instance, pumps mounted on rafts.

The land required for this pond system is the smallest within the pond systems. The energy requirements are similar to or only slightly higher than those in the facultative aerated lagoons. However, the aspects related to sludge handling can be more complicated, due to the fact that there is a smaller storage period in the pond compared with the other systems. If the sludge is removed periodically, this will take place with an approximate frequency of around 2 to 5 years. The removal of the sludge is a laborious and expensive task.

Figure 4.12 illustrates the flowsheet of the system.



Figure 4.12. Typical flowsheet of a system of complete-mix aerated lagoons – sedimentation ponds

e) High rate ponds

High rate algal ponds are conceived to maximise the production of algae in a totally aerobic environment. To accomplish this, the ponds are shallow (less than 1.0 m depth), thus guaranteeing the penetration of light in all the liquid mass. Consequently, the photosynthetic activity is high, leading to high dissolved oxygen concentrations and an increase in pH (consumption of carbonic acid in the photosynthesis). These factors contribute to the increase in the death rate of the pathogenic microorganisms and the removal of nutrients, which is the main objective of the high rate ponds.

Ammonia removal occurs by stripping of the free ammonia (NH₃), since in high pH conditions the ammonia equilibrium shifts in the direction of free ammonia (with a reduction in the concentration of the ammonium ion NH_4^+). The increase in the NH₃ concentration leads to its release to the atmosphere.

Phosphorus removal also occurs as a result of the high pH, which causes the precipitation of the phosphates into the form of hydroxyapatite or struvite.

The high rate ponds receive a high organic load per unit surface area. There is usually the introduction of moderate agitation in the pond, which is achieved by means of a horizontal-axis rotor or equivalent equipment. Its function is not





Figure 5.10. Typical set up of a belt press system for sludge dewatering

in series, the sludge is progressively compressed between two screens with the objective of releasing the interstitial water. Finally, scrapers remove the sludge and high-pressure water jets wash the screens. Figure 5.10 presents a typical set up of a belt press system.

Low acquisition costs and reduced energy consumption are the main advantages. However, since the equipment is open, the belt press may have the following disadvantages: aerosol emissions, high level of noise and eventual unpleasant odours (depending on the sludge type). Another large disadvantage of the belt press is the high number of rollers (40–50), which require operational attention and regular substitution.

5.8 SLUDGE DISINFECTION

The objective of introducing a sludge disinfection stage in the sewage treatment works is to guarantee a low level of pathogens in the sludge, such that, when it is disposed of on land, will not cause health risks to the population and to the workers that will handle it and also negative impacts to the environment. However, the need to include a complementary sludge disinfection system will depend on the final disposal alternative to be adopted.

The application of sludge in public parks and gardens or its recycling in agriculture implies a higher sanitary level than other disposal alternatives, such as landfills. These requirements can be met by a sludge disinfection process or by temporary restrictions to public use and access.

INDUSTRIAL POLLUTION

<u>UNIT 2</u>

Pollution of Air, water and land, Fossil fuel related pollutants in the environment (Continue) Lecture-4

SOIL(land) POLLUTION

Introduction: We can no more manufacture a soil with a tank of chemicals than we can invent a rain forest or produce a single bird. We may enhance the soil by helping its processes along, but we can never recreate what we destroy. The soil is a resource for which there is no substitute. (Environmental historian Donald Worster reminds us that fertilizers are not a substitute for fertile soil).

Soil is a thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air and water that together support the growth of plant life. Several factors contribute to the formation of soil from the parent material. This includes mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichens. Climate and time are also important in the development of soils. Extremely dry or cold climates develop soils very slowly while humid and warm climates develop them more rapidly. Under ideal climatic conditions soft parent material may develop into a centimetre of soil within 15 years. Under poor climatic conditions a hard parent material may require hundreds of years to develop into soil.

Mature soils are arranged in a series of zones called soil horizons. Each horizon has a distinct texture and composition that varies with different types of soils. A cross sectional view of the horizons in a soil is called a soil profile.

The top layer or the surface litter layer called the O horizon consists mostly of freshly fallen and partially decomposed leaves, twigs, animal waste, fungi and other organic materials. Normally it is brown or black.

The uppermost layer of the soil called the A horizon consists of partially decomposed organic matter (humus) and some inorganic mineral particles. It is usually darker and looser than the deeper layers. The roots of most plants are found in these two upper layers. As long as these layers are anchored by vegetation soil stores water and releases it in a trickle throughout the year instead of in a force like a flood. These two top layers also contain a large amount of bacteria, fungi, earthworms and other small insects that form complex food webs in the soil that help recycle soil nutrients and contribute to soil fertility.

The B horizon often called the subsoil contains less organic material and fewer organisms than the A horizon. The area below the subsoil is called the C horizon and consists of weathered parent material. This parent material does not contain any organic materials. The chemical composition of the C-horizon helps to determine the pH of the soil and also influences the soil's rate of water absorption and retention.

Soils vary in their content of clay (very fine particles), silt (fine particles), sand (medium size particles) and gravel (coarse to very coarse particles). The relative amounts of the different sizes and types of mineral particles determine soil texture. Soils with approximately equal mixtures of clay, sand, silt and humus are called loams.

Causes of soil degradation

Erosion

Soil erosion can be defined as the movement of surface litter and topsoil from one place to an-other. While erosion is a natural process often caused by wind and flowing water it is greatly accelerated by human activities such as farming, construction, overgrazing by livestock, burning of grass cover and deforestation. Loss of the topsoil makes a soil less fertile and reduces its water holding capacity. The topsoil, which is washed away, also contributes to water pollution clogging lakes, increasing turbidity of the water and also leads to loss of aquatic.

life. For one inch of topsoil to be formed it normally requires 200-1000 years depending upon the climate and soil type. Thus if the topsoil erodes faster than it is formed the soil becomes a non-renewable resource.

Thus it is essential that proper soil conservation measures are used to minimize the loss of top soil. There are several techniques that can protect soil from erosion. Today both water and soil are conserved through integrated treatment methods. Some of the most commonly employed methods include the two types of treatment that are generally used.

- Area treatment which involves treating the land
- Drainage line treatment which involves treating the natural water courses (nalas)

Continuous contour trenches can be used to enhance infiltration of water reduce the run-off and check soil erosion. These are actually shallow trenches dug across the slope of the land and along the contour lines basically for the purpose of soil and water conservation. They are most effective on gentle slopes and in areas of low to medium rainfall. These bunds are stabilized by fast growing tree species and grasses. In areas of steep slopes where the bunds are not possible, continuous contour benches (CCBs) made of stones are used for the same purpose.

Gradonies can also be used to convert waste-lands into agricultural lands. In this narrow trenches with bunds on the downstream side are built along contours in the upper reaches of the catchment to collect runoff and to conserve moisture from the trees or tree crops. The area between the two bunds is use for cultivation of crops after development of fertile soil cover.

Some of the ways in which this can be achieved are:

Live check dams which barriers created by planting grass, shrubs and trees across the gullies can be used for this purpose.

A **bund constructed out of stones** across the stream can also be used for conserving soil and water.

Area Treatment

Purpose	Treatment Measure	Effect
Reduces the impact of rain drops on the soil	Develop vegetative cover on the non arable land	Minimum disturbance and displacement of soil particles
Infiltration of water where it falls	Apply water infiltration measures on the area	In situ soil and moisture conservation
Minimum surface run off	Store surplus rain water by constructing bunds, ponds in the area	Increased soil moisture in the area, facilitate ground water recharge
Ridge to valley sequencing	Treat the upper catchment first and then proceed towards the outlet	Economically viable, less risk of damage and longer life of structures of the lower catchments

Drainage line treatment

Purpose	Treatment measure	Effect
Stop further deepening of gullies and retain sediment run-off	Plug the gullies at formation	Stops erosion, recharges groundwater at the upper level.
Reduce run-off velocity, pass cleaner water to the downstream side	Crate temporary barriers in nalas	Delayed flow and increased groundwater recharge
Minimum sedimentation in the storage basins	Use various methods to treat the catchments	
Low construction cost	Use local material and skills for constructing the structures	Structures are locally maintained

An Earthen check bund is constructed out of local soil across the stream to check soil erosion and flow of water.

A Gabion structure is a bund constructed of stone and wrapped in galvanized chain-link.

A Gabion structure with Ferro cement impervious barrier has a one-inch-thick impervious wall of Ferro cement at the centre of the structure which goes below the ground level up to the hard strata. This Ferro cement partition sup-ported by the gabion portion is able to retain the water and withstand the force of the runoff water.

An Underground bandhara is an under-ground structure across a nalla bed to function as a barrier to check the ground water movement.
Excess use of fertilizers: Approximately 25 percent of the world's crop yield is estimated to be directly attributed to the use of chemical fertilizers. The use of chemical fertilizers has in-creased significantly over the last few decades and is expected to rise even higher. Fertilizers are very valuable as they replace the soil nutrients used up by plants. The three primary soil nutrients often in short supply are potassium, phosphorus and nitrogen compounds. These are commonly referred to as macronutrients. Certain other elements like boron, zinc and manganese are necessary in extremely small amounts and are known as micronutrients. When crops are harvested a large amount of macronutrients and a small amount of micronutrients are re-moved with the crops. If the same crop is grown again depleted levels of thee nutrients can result in decreased yields. These necessary nutrients can be returned to the soil through the application of fertilizers. In addition to fertilizers a large amount of pesticides (chemicals used to kill or control populations of unwanted fungi, animals or plants often called pests) are also used to ensure a good yield. Pesticides can be subdivided into several categories based on the kinds of organisms they are used to control unwanted fungal growth. Mice and rats are killed by *rodenticides* while plant pests are controlled by *herbicides*.

Problems with pesticide use

Pesticides not only kill the pests but also a large variety of living things including humans. They may be persistent or non-persistent. Persistent pesticides once applied are effective for a long time. However, as they do not break down easily they tend to accumulate in the soil and in the bodies of animals in the food chain.

For example, DDT which was one of the first synthetic organic insecticide to be used was thought to be the perfect insecticide. During the first ten years of its use (1942-1952) DDT is estimated to have saved about five million lives primarily because of its use to control disease carrying mosquitoes. However, after a period of use many mosquitoes and insects became tolerant of DDT, thus making it lose its effective-ness. DDT in temperate regions of the world has a half-life (the amount of time required for half of the chemical to decompose) of 10 to 15 years. This means that if 100 kilograms of DDT were to be sprayed over an area, 50 kilograms would still be present in the area 10 to 15 years later. The half-life of DDT varies according to the soil type, temperature, kind of soil organ-isms present and other factors. In tropical parts of the world the half-life may be as short as six months. The use of DDT has been banned in some countries. India still however permits the use of DDT though for purposes of mosquito-control only. Persistent pesticides become attached to small soil particles which are easily moved by wind and water to different parts thus affecting soils elsewhere. Persistent pesticides may also accumulate in the bodies of animals, and over a period of time increase in concentration if the animal is unable to flush them out of its system thus leading to the phenomenon called bioaccumulation. When an affected animal is eaten by another carnivore these pesticides are further concentrated in the body of the carnivore. This phenomenon of acquiring increasing levels of a substance in the bodies of higher trophic level organisms is known as bio magnification. This process especially in the case of insecticides like DDT have been proved to be disastrous. DDT is a well-known case of bio magnification in ecosystems. DDT interferes with the production of normal eggshells in birds making them fragile.

Other problems associated with insecticides is the ability of insect populations to become resistant to them thus rendering them useless in a couple of generations. Most pesticides kill beneficial as well as pest species. They kill the preda-tor as well as the parasitic insects that control the pests. Thus the pest species increase rapidly following the use of a pesticide as there are no natural checks to their population growth. The short term and the long-term health effects to the persons using the pesticide and the public that consumes the food grown by using the pesticides are also major concerns. Exposure to small quantities of pesticides over several years can cause mutations, produce cancers, etc.

Thus the question that comes to mind is that if pesticides have so many drawbacks then why are they used so extensively and what are the substitutes for them? There are three main rea-sons for the use of pesticides. Firstly, the use of pesticides in the short term has increased the amount of food that can be grown in many parts of the world as the damage by pests is de-creased. The second reason for its extensive use is based on an economic consideration. The in-creased yields more than compensates the farmer for cost of pesticides. Thirdly current health problems especially in developing countries due to mosquitoes are impossible to con-troll without insecticides.

However, more and more farmers are increasingly opting to replace chemical fertilizers and use different methods of controlling pests with-out affecting their yield. Thus several different approaches that have slightly varying and over-lapping goals have been developed. Alternative agriculture is the broadest term that is used that includes all non-traditional agricultural methods and encompasses sustainable agriculture, organic agriculture, alternative uses of traditional crops, alternative methods for raising crops, etc.

Sustainable agriculture advocates the use of methods to produce adequate safe food in an economically viable manner while maintaining the state of the ecosystem. Organic agriculture advocates avoiding the use of chemical fertilizers and pesticides. A wide variety of techniques can be used to reduce this negative impact of agriculture. Leaving crop residue on the soil and incorporating it into the soil reduces erosion and increase soil organic matter. Introduction of organic matter into the soil also makes compaction less likely. Crop rotation is an effective way to enhance soil fertility, reduce erosion and con-troll pests. There have been arguments both for and against organic farming. Critics argue that organic farming cannot produce the amount of food required for today's population and it is economically viable only in certain conditions. However, supporters for organic farming feel that of the hidden costs of soil erosion and pollution are taken into account it is a viable approach. Besides organic farmers do not have to spend on fertilizers and pesticides and also get a premium price for their products thus making it financially viable for them.

Another way to reduce these impacts is through the use of *integrated pest management*. This is a technique that uses a complete understanding of all ecological aspects of a crop and the particular pests to which it is susceptible to establish pest control strategies that uses no or few pesticides. IPM promotes the use of bio pesticides. Bio pesticides are derived from three sources: microbial, botanical and bio-chemical. Microbial pesticides are micro-organ-isms such as bacteria, fungus, virus or protozoa that fight pests through a variety of ways. They produce toxins specific to the pests and produce diseases in them. Biochemical pesticides contain several chemicals that affect the reproductive and digestive mechanisms of the pests. The most commonly used biopesticides are *Bacillus thuringiensis (Bt)*, neem (*Azadirachta indica*) and trichogramma. Although they are available in the market they are yet to become market favourites.

Excess salts and water

Irrigated lands can produce crop yields much higher than those that only use rainwater. How-ever this has its own set of ill effects. Irrigation water contains dissolved salts and in dry climates much of the water in the saline solution evaporates leaving its salts such as sodium chloride in the topsoil. The accumulation of these salts is called salinization, which can stunt plant growth, lower yields and eventually kill the crop and render the land useless for agriculture. These salts can be flushed out of the soil by using more water. This practice however increases the cost of crop production and also wastes enormous amounts of water. Flushing salts can also make the downstream irrigation water saltier.

Another problem with irrigation is water logging. This occurs when large amounts of water are used to leach the salts deeper into the soil. However, if the drainage is poor this water accumulates underground gradually raising the water table. The roots of the plants then get enveloped in this saline water and eventually die.

Thus in the long run it is better for us to adopt sustainable farming practices so as to prevent the degradation of soil.

INDUSTRIAL POLLUTION

<u>Unit 1</u>

Introduction: Environments and Human activities, Environments and Ecology, Consequences of population growth. Energy problem

INTRODUCTION

Together with many social and economic benefits of urbanization, there are also environmental problems. Cities comprise less than 3% of the Earth's surface, but there is an extraordinary concentration of population, industry and energy use, leading to a massive local pollution and environmental degradation. In the cities, approximately 78% of carbon emissions are due to human activities. The ecological footprints of cities go (through emissions, consumption and other human activities) far beyond their urban boundaries to forests, agriculture, water and other surfaces, which supply their residents so that they have an enormous impact on the surrounding rural, regional and global ecosystem.

Cities are therefore centers of consumption (energy, materials, ...), greenhouse gas production, waste and emissions of pollutants in water and air. Ecological and sociological footprints of cities have expanded over increasingly large areas and created urban - rural continuum of communities, who share similar aspects of individual lifestyles. There are less and less areas in the world which are not under the influence of the dynamics of cities.

The world faces enormous environmental challenges in terms of climate change, resource use and protection of the natural environment. Urban areas have a high environmental impact that can be felt globally, as well as within its own borders.

ECOLOGICAL FOOTPRINT

The environmental impacts of modern cities go beyond their surrounding regions. Size, rate, and connections of the modern metropolis show a global impact. The ecological footprint is one measure of these effects. The ecological footprint of cities is defined as the total amount of productive land needed to maintain current activities and the removal of waste. The ecological footprint of cities such as New York and Tokyo are hundreds of times larger than their actual size and are also faced with problems such as acid rain, reduction of the ozone layer and global warming.

DEVELOPING COUNTRIES

In the cities of the developing world, where population growth is outpacing the ability to provide the necessary infrastructure and services, the most serious environmental problems are expected in the immediate vicinity, with serious economic and social impacts on the urban population. Inadequate water supply to households, the accumulation of waste and unhygienic conditions require large claims in terms of unnecessary deaths and illness of one billion of the world population who lives in slums. Cities in developing countries are also faced with the worst urban air pollution in the world, which occurs as a result of rapid industrialization and increased motorized traffic. It is estimated that worldwide urban air pollution is cause of one million premature deaths each year and costs 2% of the GDP in developed countries and 5% in developing countries

DEVELOPED COUNTRIES

The urban population of developed countries, which is characterized by some of the highest rates of per capita consumption in the world is largely responsible for the resulting trends. US city with 650,000 inhabitants requires approximately 30,000 km2 to meet their needs, similarly big, but a less wealthy city in India requires only 2,800 km2. Similarly, the urban population of the developed world produces six times more waste than urban dwellers in countries. However, developing accurtices are becoming richer and urbaner, and their levels of

However, developing countries are becoming richer and urbaner, and their levels of consumption are close to those in developed countries. As a result, they rapidly and significantly contribute to the global problem of resource depletion and climate change. The need to change the cities into more efficient and less polluted areas is, therefore, more necessary than ever.

While cities of developed countries have adopted policies and technologies to improve many of their local environmental problems, it is growing recognition that human activities in urban areas have significant impacts at the global level. In fact, cities of the world represent 75% of global energy consumption and 80% of greenhouse gas emissions and a disproportionate share of resource use.

ENVIRONMENTAL PROBLEMS OF MODERN CITIES

Urban environmental problems are mostly inadequate water supply, wastewater, solid waste, energy, loss of green and natural spaces, urban sprawl, pollution of soil, air, traffic, noise, etc. All these problems are particularly serious in developing countries and countries with economic transition, where there is a conflict between the short-term economic plan and the protection of the environment.

Pollution of the urban environment and its components is the total resultant of an excessive burden on the environment and the self-cleaning capacity. Environmental problems in urban areas are growing especially in cities in developing countries. Of greatest concern are the state of air quality, noise, and congestion. In cities of economically developed countries, the environmental problems related to industrial production, lodging, and basic infrastructure are reduced, however, the problems of consumption (increasing waste) and traffic problems have increased. Cities consume increasing amounts of natural resources, produce more and more waste and emissions, and all this have an impact on the regional and planetary environment. Air and water pollution and waste are the main environmental problems in most cities. The underlying causes of air pollution of the city are the processes that are associated with the burning of fossil fuels (production and consumption of energy for heating buildings, industrial activities, traffic). Noise is also a special form of pollution, which burdens the urban population. Urbanization causes numerous effects on water resources; these effects can change the hydrology, water quality and availability of aquatic habitats. Deterioration in the quality of ground and river water in the cities is mainly due to the water consumption of the population and industry. Contamination is usually caused by industrial activity as well as the disposal of waste, so in cities is dominated water pollution from municipal and industrial

wastewater. The city is marked by large inputs of energy, water, food and a variety of raw materials, resulting in large quantities of goods, as well as waste, which means a huge loss of natural resources in the form of raw materials and energy. Urban ecosystems are indicated by a very high energy consumption and large amounts of solid waste that accumulate in certain places. In this way, they represent landscape degradation factor and adversely affect the quality of water resources and urban air.

<u>Nature</u>

In most cities, a man transformed nature, vegetation was replaced with concrete, asphalt, and other surfaces, transformed or buried riverbeds, caused city climate and created huge artificial transfers of energy, water, and various substances. Growing cities are changing hydrological relationships and thereby influence the size and frequency of floods. Knowledge of urban hydrology and geomorphology is not only a key to good urban planning but should be available to each resident.

<u>Climate</u>

Cities have little direct impact on the global balance of radiation, but inside urban climate, generated by absorption and subsequent re-radiation of heat from built-up areas and emissions of artificial heat through combustion, creates the effect of the urban heat island. Cities are warmer at night than the surrounding countryside and often, especially in the higher latitudes, even during the day. In Tokyo, anthropogenically generated heat increases the temperature of the urban surface by about $1.5 \degree C$ in summer and $2.5 \degree C$ in winter, the effect of urban land-use raises the temperature by about $1 \degree C$ in both halves of the year.

Water

Even the hydrological cycle is increasingly under the influence of a man who uses water for different purposes and returns it to the water cycle contaminated. These changes are in urban areas so profound that we can speak of urban hydrology. Built-up areas create artificial impervious surfaces that reduce surface water supplies, infiltration is gone, surface flow, permeability, and erosion are increased, evaporation is reduced. In a wider range, it comes not only to qualitative but also quantitative consequences (regulation, dams, ...). However, human activity is reflected in the quality of water resources. The major problem presents urban waste water and residues of pesticides and biocides, which pass through the surface and groundwater. Freshwater resources in urban areas are also threatened by the waste from transport, tourism, military activities.

<u>Soil</u>

Human activities have a negative impact on pedosphere; this is reflected in the increasing chemisation and mechanization of agriculture and in the cities, however, especially as poisoning the soil through contaminated air and precipitation and changes in the quality of land use for sealing.

CONSEQUENCES AND EFFECTS OF URBANIZATION

Knowing the problems of urbanization is not enough, it is necessary to understand their implications and the degree of social preparedness to deal with them. Consequences and

effects of urbanization depend on many other factors and are operating in all segments of human activity and the environment. They can be divided into several groups:

1. Environmental problems due to the production and consumption:

increasing energy consumption, which results in a reduction of non-renewable resources

problems of infrastructure that does not follow the spread of urbanization

high consumption of drinking water, which affects the lowering of groundwater levels

excessive use of space

2. Pollution problems from major manufacturers and emissions problems due to the dispersed agents:

pollution of water, air, soil due to industry and agriculture

problems of waste disposal sites, particularly radioactive

the problem of the concentration of population (air pollution, groundwater ...)

a dense network of roads and increase in traffic (air pollution, noise, ...)

3. Social and environmental problems and the consequences of urbanization (differences between population groups, stress loads, accidents, disease, crime, ...)

4. The economic component of the effects of urbanization (accidents, the cost of building infrastructure, road network damage as a result of an interaction of a large number of factors which by themselves would not have negative effects on the environment, ...).

INDUSTRIAL POLLUTION

<u>unit 2</u>

Pollution of Air, water and land, Fossil fuel related pollutants in the environment

POLLUTION:

Pollution is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. This occurs when only short-term economic gains are made at the cost of the long-term ecological benefits for humanity. No natural phenomenon has led to greater ecological changes than have been made by mankind. During the last few decades we have contaminated our air, water and land on which life itself depends with a variety of waste products.

Pollutants include solid, liquid or gaseous sub-stances present in greater than natural abundance produced due to human activity, which have a detrimental effect on our environment. The nature and concentration of a pollutant determines the severity of detrimental effects on human health. An average human requires about 12 kg of air each day, which is nearly 12 to15 times greater than the amount of food we eat. Thus even a small concentration of pollutants in the air becomes more significant in comparison to the similar levels present in food. Pollutants that enter water have the ability to spread to distant places especially in the marine ecosystem.

From an ecological perspective pollutant can be classified as follows:

Degradable or non-persistent pollutants: These can be rapidly broken down by natural pro-cesses. E.g.: domestic sewage, discarded vegetables, etc.

Slowly degradable or persistent pollutants: Pollutants that remain in the environment for many years in an unchanged condition and take de-cades or longer to degrade. E.g.: DDT and most plastics.

Non-degradable pollutants: These cannot be degraded by natural processes. Once they are released into the environment they are difficult to eradicate and continue to accumulate. Eg: toxic elements like lead or mercury.

CAUSES, EFFECTS AND CONTROL MEA-SURES OF POLLUTION

1.Air Pollution

History of air pollution: The origin of air pollution on the earth can be traced from the times when man started using firewood as a means of cooking and heating. Hippocrates has mentioned air pollution in 400 BC. With the discovery and increasing use of coal, air pollution became more pronounced especially in urban areas. It was recognized as a problem 700 years ago in London in the form of smoke pollution, which prompted King Edward I to make the first antipollution law to restrict people from using coal for domestic heating in the year 1273. In the year 1300 another Act banning the use of coal was passed. Defying the law led to imposition of capital punishment. In spite of this air pollution became a serious problem in London during the industrial revolution due to the use of coal in industries. The earliest recorded major disaster was the 'London Smog' that occurred in 1952 that resulted in more than 4000 deaths due to the accumulation of air pollutants over the city for five days.

In Europe, around the middle of the 19th century, a black form of the Peppered moth was noticed in industrial areas. Usually the normal Peppered moth is well camouflaged on a clean lichen covered tree. However, the peppered pat-tern was easily spotted and picked up by birds on the smoke blackened bark of trees in the industrial area, while the black form remained well camouflaged. Thus while the peppered patterned moths were successful in surviving in clean non-industrial areas, the black coloured moths were successful in industrial areas. With the spread of industrialization, it has been observed that the black forms are not only see in Peppered moth, but also in many other moths. This is a classic case of pollution leading to adaptation.

Air pollution began to increase in the beginning of the twentieth century with the development of the transportation systems and large-scale use of petrol and diesel. The severe air quality problems due to the formation of photochemical smog from the combustion residues of diesel and petrol engines were felt for the first time in Los Angeles. Pollution due to auto-exhaust re-mains a serious environmental issue in many developed and developing countries including India.

The Air Pollution Control Act in India was passed in 1981 and the Motor Vehicle Act for controlling the air pollution, very recently. These laws are intended to prevent air from being polluted.

The greatest industrial disaster leading to serious air pollution took place in Bhopal where extremely poisonous methyl isocyanides gas was accidentally released from the Union Carbide's pesticide manufacturing plant on the night of December 3rd 1984. The effects of this disaster on human health and the soil are felt even to-day.

Types and sources of Air Pollution

What is air pollution?

Air pollution occurs due to the presence of un-desirable solid or gaseous particles in the air in quantities that are harmful to human health and the environment. Air may get polluted by natural causes such as volcanoes, which release ash, dust, sulphur and other gases, or by forest fires that are occasionally naturally caused by lightning. However, unlike pollutants from human activity, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change.

Pollutants that are emitted directly from identifiable sources are produced both by natural events (for example, dust storms and volcanic eruptions) and human activities (emission from vehicles, industries, etc.). These are called primary pollutants. There are five primary pollutants that together contribute about 90 percent of the global air pollution. These are carbon oxides (CO and CO2), nitrogen oxides, sulphur oxides, volatile organic compounds (mostly hydrocarbons) and suspended particulate matter.

Pollutants that are produced in the atmosphere when certain chemical reactions take place among the primary pollutants are called secondary pollutants. E.g.: sulphuric acid, nitric acid, carbonic acid, etc.

Carbon monoxide is a colourless, odourless and toxic gas produced when organic materials such as natural gas, coal or wood are incompletely burnt. Vehicular exhausts are the single largest source of carbon monoxide. The number of vehicles has been increasing over the years all over the world. Vehicles are also poorly maintained and several have inadequate pollution control equipment resulting in release of greater amounts of carbon monoxide. Carbon monoxide is however not a persistent pollutant. Natural processes can convert carbon monoxide to other compounds that are not harmful. There-fore the air ean-be cleared of its carbon monoxide if no new carbon monoxide is introduced into the atmosphere.

Sulphur oxides are produced when sulphur containing fossil fuels are burnt. Nitrogen oxides are found in vehicular exhausts. Nitrogen oxides are significant, as they are involved in the production of secondary air pollutants such as ozone.

Hydrocarbons are a group of compounds consisting of carbon and hydrogen atoms. They either evaporate from fuel supplies or are remnants of fuel that did not burn completely. Hydrocarbons are washed out of the air when it rains and run into surface water. They cause an oily film on the surface and do not as such cause a serious issue until they react to form secondary pollutants. Using higher oxygen concentrations in the fuel-air mixture and using valves to prevent the escape of gases, fitting of catalytic converters in automobiles, are some of the modifications that can reduce the release of hydrocarbons into the atmosphere.

Particulates are small pieces of solid material (for example, smoke particles from fires, bits of asbestos, dust particles and ash from industries) dispersed into the atmosphere. The effects of particulates range from soot to the carcinogenic (cancer causing) effects of asbestos, dust particles and ash from industrial plants that are dispersed into the atmosphere. Repeated exposure to particulates can cause them to accumulate in the lungs and interfere with the ability of the lungs to exchange gases.

Lead is a major air pollutant that remains largely unmonitored and is emitted by vehicles. High lead levels have been reported in the ambient air in metropolitan cities. Leaded petrol is the primary source of airborne lead emissions in Indian cities.

Pollutants are also found indoors from infiltration of polluted outside air and from various chemicals used or produced inside buildings. Both indoor and outdoor air pollution are equally harmful.

Types of particulates

Term	Meaning	Examples
		Sprays from pressurized
Aerosol	General term for particles suspended in air	cans
Mist	Aerosol consisting of liquid droplets	Sulphuric acid mist
	Aerosol consisting of solid particles that are blown	
Dust	into	Dust storm
	the air or are produced from larger particles by	
	grinding	
	them down	
	Aerosol consisting of solid particles or a mixture of	
Smoke	solid	Cigarette smoke, smoke
	and liquid particles produced by chemical reaction	
	such	from burning garbage
	as fires	
	Generally means the same as smoke but often	
Fume	applies	Zinc/lead fumes
	specifically to aerosols produced by condensation of	
	hot	
	Vapours of metals.	
	Geometrical shape or form of the smoke coming out	
Plume	of	
	a chimney	
Fog	Aerosol consisting of water droplets	
Smog	Term used to describe a mixture of smoke and fog.	

What happens to pollutants in the atmosphere?

Once pollutants enter the troposphere they are transported downwind, diluted by the large volume of air, transformed through either physical or chemical changes or are removed from the atmosphere by rain during which they are attached to water vapour that subsequently forms rain or snow that falls to the earth's surface. The atmosphere normally disperses pollutants by mixing them in the very large volume of air that covers the earth. This dilutes the pollutants to acceptable levels. The rate of dispersion how-ever varies in relation to the following aspects:

Topography

Normally as the earth's surface becomes warmed by sunlight the layer of air in contact with the ground is also heated by convection. This warmer air is less dense than the cold air above it, so it rises. Thus pollutants produced in the surface layer are effectively dispersed.

However, on a still evening, the process is re-versed. An hour or two before sunset after a sunny day, the ground starts to lose heat and the air near the ground begins to cool rapidly. Due to the absence of wind, a static layer of cold air is produced as the ground cools. This in turn induces condensation of fog. The morning sun cannot initially penetrate this fog layer. The cold air being dense cannot rise and is trapped by the warm air above. It cannot move out of the area due to the surrounding hills. The topographic features resemble a closed chemical re-actor in which the pollutants are trapped. This condition often continues through the cool night and reaches its maximum intensity before sun-rise. When the morning sun warms the ground the air near the ground also warms up and rises within an hour or two. This may be broken up by strong winds. In cold regions this situation can persist for several days. Such a situation is known as smog (smoke + fog).



The most wellknown example is that of the 'London Smog' that occurred in 1952. The city used large quantities of sulphur containing coal for domestic heating that released smoke, along with smoke from thermal power plants and

other industrial establishments. This used to lead to the generation of high levels of smoke containing sulphur oxides. Due to a sudden adverse meteorological condition air pollutant like smoke and sulphur oxides started to build-up in the atmosphere. The white fog accumulated over the city turned black forming a 'pea-soup' smog with almost zero visibility. Within two days of the formation of this smog, people started suffering from acute pulmonary disorders which caused irritation of bronchi, cough, nasal dis-charges, sore throat, vomiting and burning sen-sations in the eyes. This event lead to several deaths.

Meteorological conditions

The velocity of the wind affects the dispersal of pollutants. Strong winds mix polluted air more rapidly with the surrounding air diluting the pollutants rapidly. When wind velocity is low mixing takes place and the concentration of pollutants remains high.



When sulphur dioxide and nitrogen oxides are transported by prevailing winds they form secondary pollutants such as nitric acid vapour, droplets of sulfuric acid and particles of sulphate and nitrate salts. These chemicals descend on the earth's surface in two forms: wet (as acidic rain, snow, fog and cloud vapour) and dry (as acidic particles). The resulting mixture is called acid deposition, commonly called acid rain.

Acid deposition has many harmful effects espe-cially when the pH falls below 5.1 for terrestrial systems and below 5.5 for aquatic systems. It contributes to human respiratory diseases such as bronchitis and asthma, which can cause pre-mature death. It also damages statues, buildings, metals and car finishes. Acid deposition can damage tree foliage directly but the most serious effect is weakening of trees so they be-come more susceptible to other types of dam-age. The nitric acid and the nitrate salts in acid deposition can lead to excessive soil nitrogen levels. This can over stimulate growth of other plants and intensify depletion of other important soil nutrients such as calcium and magnesium, which in turn can reduce tree growth and vigour.

Effects of air pollution on living organisms

Our respiratory system has a number of mechanisms that help in protecting us from air pollution. The hair in our nose filters out large particles. The sticky mucus in the lining of the upper respiratory tract captures smaller particles and dissolves some gaseous pollutants. When the upper respiratory system is irritated by pollutants sneezing and coughing expel contaminated air and mucus. Prolonged smoking or exposure to air pollutants can overload or break-down these natural defences causing or contributing to diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Elderly people, infants, pregnant women and people with heart disease, asthma or other respiratory diseases are especially vulnerable to air pollution.

Cigarette smoking is responsible for the greatest exposure to carbon monoxide. Exposure to air containing even 0.001 percent of carbon monoxide for several hours can cause collapse, coma

and even death. As carbon monoxide re-mains attached to haemoglobin in blood for a long time, it accumulates and reduces the oxy-gen carrying capacity of blood. This impairs perception and thinking, slows reflexes and causes headaches, drowsiness, dizziness and nausea. Carbon monoxide in heavy traffic causes head-aches, drowsiness and blurred vision.

Sulphur dioxide irritates respiratory tissues. Chronic exposure causes a condition similar to bronchitis. It also reacts with water, oxygen and other material in the air to form sulphur contain-ing acids. The acids can become attached to particles which when inhaled are very corrosive to the lung.

Nitrogen oxides especially NO2 can irritate the lungs, aggravate asthma or chronic bronchitis and also increase susceptibility to respiratory infections such as influenza or common colds.

Suspended particles aggravate bronchitis and asthma. Exposure to these particles over a long period of time damages lung tissue and con-tributes to the development of chronic respiratory disease and cancer.

Many volatile organic compounds such as (benzene and formaldehyde) and toxic particulates (such as lead, cadmium) can cause mutations, reproductive problems or cancer. Inhaling ozone, a component of photochemical smog causes coughing, chest pain, breathlessness and irritation of the eye, nose and the throat.

Effects on plants

When some gaseous pollutants enter leaf pores they damage the leaves of crop plants. Chronic exposure of the leaves to air pollutants can break down the waxy coating that helps prevent excessive water loss and leads to damage from diseases, pests, drought and frost. Such expo-sure interferes with photosynthesis and plant growth, reduces nutrient uptake and causes leaves to turn yellow, brown or drop off altogether. At a higher concentration of sulphur dioxide majority of the flower buds become stiff and hard. They eventually fall from the plants, as they are unable to flower.

Prolonged exposure to high levels of several air pollutants from smelters, coal burning power plants and industrial units as well as from cars and trucks can damage trees and other plants.

Effects of air pollution on materials

Every year air pollutants cause damage worth billions of rupees. Air pollutants break down exterior paint on cars and houses. All around the world air pollutants have discoloured irreplaceable monuments, historic buildings, marble statues, etc.

Effects of air pollution on the stratosphere

The upper stratosphere consists of considerable amounts of ozone, which works as an effective screen for ultraviolet light. This region called the ozone layer extends up to 60 kms above the surface of the earth. Though the ozone is present up to 60 kms its greatest density remains in the region between 20 to 25 kms. The ozone layer does not consist of solely ozone but a mix-ture of other common atmospheric gases. In the most dense ozone layer there will be only one ozone molecule in 100,000 gas molecules. Therefore even small changes in the ozone concentration can produce dramatic effects on life on earth.

The total amount of ozone in a 'column' of air from the earth's surface upto an altitude of 50 km is the total column ozone. This is recorded in Dobson Units (DU), a measure of the thickness of the ozone layer by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. This means that 100 DU=1mm of pure ozone gas at normal temperature and pressure at sea level.

Ozone is a form of oxygen with three atoms instead of two. It is produced naturally from the photodissociation of oxygen gas molecules in the atmosphere. The ozone thus formed is constantly broken down by naturally occurring pro-cesses that maintain its balance in the ozone layer. In the absence of pollutants, the creation and breakdown of ozone are purely governed by natural forces, but the presence of certain pollutants can accelerate the breakdown of ozone. Though it was known earlier that ozone shows fluctuations in its concentrations which may be accompanied sometimes with a little ozone depletion, it was only in 1985 that the large scale destruction of the ozone also called the Ozone Hole came into limelight when some British researchers published measurements about the ozone layer.

Soon after these findings a greater impetus was given to research on the ozone layer, which convincingly established that CFC's were leading to its depletion. These CFCs (chloro-fluro-carbons) are extremely stable, non-flammable, non-toxic and harmless to handle. This makes them

ideal for many industrial applications like aerosols, air conditioners, refrigerators and fire extinguishers. Many cans, which give out foams and sprays, use CFCs. (eg: perfumes, room fresheners, etc.) CFCs are also used in making foams for mattresses and cushions, disposable Styrofoam cups, glasses, packaging material for insulation, cold storage etc. However, their stability also gives them a long life span in the atmosphere.

Halons are similar in structure to the CFCs but contain bromine atoms instead of chlorine. They are more dangerous to the ozone layer than CFCs. Halons are used as fire extinguishing agents as they do not pose a harm to people and equipment exposed to them during firefighting.

The CFCs and the halons migrate into the up-per atmosphere after they are released. As they are heavier than air they have to be carried by air currents up to just above the lower atmosphere and then they slowly diffuse into the upper atmosphere. This is a slow process and can take as long as five to fifteen years. In the stratosphere unfiltered UV-radiation severs the chemical bonds releasing chlorine from the rest of the CFC. This attacks the ozone molecule resulting in its splitting into an oxygen molecule and an oxygen atom.

Despite the fact that CFCs are evenly distribute over the globe, the ozone depletion is especially pronounced over the South Pole due to the extreme weather conditions in the Antarctic atmosphere. The presence of the ice crystals makes the Cl-O bonding easier. The ozone layer over countries like Australia, New Zealand, South Africa and parts of South America is also depleted.

India has signed the Montreal Protocol in 1992, which aims to control the production and consumption of Ozone Depleting Substances.

Ozone depletion-What does it do?

Changes in the ozone layer have serious implications for mankind.

Effects on human health: Sunburn, cataract, aging of the skin and skin cancer are caused by increased ultra-violet radiation. It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

Food production: Ultra violet radiation affects the ability of plants to capture light energy during the process of photosynthesis. This reduces the nutrient content and the growth of plants. This is seen especially in legumes and cabbage.

Plant and animal planktons are damaged by ultra-violet radiation. In zooplanktons (microscopic animals) the breeding period is shortened by changes in radiation. As planktons form the basis of the marine food chain a change in their number and species composition influences fish and shell fish production.

Effect on materials: Increased UV radiation damages paints and fabrics, causing them to fade faster.

Effect on climate: Atmospheric changes induced by pollution contribute to global warming, a phenomenon which is caused due to the increase in concentration of certain gases like carbon dioxide, nitrogen oxides, methane and CFCs. Observations of the earth have shown beyond doubt that atmospheric constituents such as water vapour, carbon dioxide, methane, nitrogen oxides and Chloro Fluro Carbons trap heat in the form of infra-red radiation near the earth's surface. This is known as the 'Green-house Effect'. The phenomenon is similar to what happens in a greenhouse. The glass in a greenhouse allows solar radiation to enter which is absorbed by the objects inside. These objects radiate heat in the form of terrestrial radiation, which does not pass out through the glass. The heat is therefore trapped in the greenhouse increasing the temperature inside and ensuring the luxuriant growth of plants.



There could be several adverse effects of global warming.

- With a warmer earth the polar ice caps will melt causing a rise in ocean levels and flooding of coastal areas.
- In countries like Bangladesh or the Maldives this would be catastrophic. If the sea level rises by 3m., Maldives will disappear completely beneath the waves.
- The rise in temperature will bring about a fall in agricultural produce.
- Changes in the distribution of solar energy can bring about changes in habitats. A previously
 productive agricultural area will suffer severe droughts while rains will fall in locations that
 were once deserts. This could bring about changes in the species of natural plants, agricultural
 crops, insects, live-stock and micro-organisms.
- In the polar regions temperature rises caused by global warming would have disastrous effects. Vast quantities of methane are trapped beneath the frozen soil of Alaska. When the permafrost melts the methane that will be released can accelerate the process of global warming.

Control measures for air pollution

Air pollution can be controlled by two fundamental approaches: preventive techniques and effluent control.

One of the effective means of controlling air pollution is to have proper equipment in place. This includes devices for removal of pollutants from the flue gases though scrubbers, closed collection recovery systems through which it is possible to collect the pollutants before they escape, use of

dry and wet collectors, filters, electrostatic precipitators, etc. Providing a greater height to the stacks can help in facilitating the discharge of pollutants as far away from the ground as possible. Indus-tries should be located in places so as to minimize the effects of pollution after considering the topography and the wind directions. Substitution of raw material that causes more pollution with those that cause less pollution can be done

Air pollution in India

The World Health Organization (WHO) which rates only mega cities of the world has rated Delhi the fourth most polluted city ion the world. However, compared to other cities in India, Delhi is not at the top of the list of polluted cities. Our country has several pollution hotspots. The re-cent release from the Central Pollution Control Board (CPCB), Parivesh, January 2003 states that Ahmedabad's air is most noxious flowed by Kanpur, Solapur and Lucknow with small particulate levels (PM10) 3-4 times the standard of 60 microgram per cubic meter (mg/m3). The re-port has ranked 29 cities according to Respirable Particulate Matter (RSPM) levels recorded during the year 2000. This report thus confirms the fact that Indian cities show high particulate pollution with 14 cities hitting critical levels.

Nitrogen dioxide levels in most major cities are generally close to the acceptable annual standard of 60 mg/m3. However sharp increases have been noticed in a few cities with heavy vehicular traffic and density as in a few locations in Kolkata and Delhi indicating stronger impact of traffic. The CPCB indicates vehicles as one of the predominant sources of air pollution. How-ever the impact of hard measures implemented in Delhi over the last few years such as introduction of Euro II standards, lowering the sulphur content in fuel to 500 ppm and implementing Compressed Natural Gas program has succeeded in improving the quality of air. Rapid urbanization of smaller cities especially those situated near the big commercial centers have an enormous increase in traffic load especially in the most polluted segment such as two and three wheelers and diesel vehicles combined with poor quality fuel contribute to the deteriorating air quality in a big way.

It is alarming to note that residential locations in India are fast outpacing industrial locations in air pollution implying that vehicular fumes are responsible for this trend. The Supreme Court's order of April 5, 2002 has directed the Central Government for an action plan for other pol-luted cities. Absence of any local initiatives for action and delay in air pollution control mea-sures will only make the situation worse.

The Supreme Court also played a vital role protecting the Taj Mahal. Being exposed to sulphur dioxide and suspended particulate matter, the Taj had contracted 'marble cancer', a fungal growth that corroded its surface giving it a yellowish tinge. The SPM deposits blackened it. Shri MC Mehta an environmental lawyer filed a public interest litigation in 1984 expressing concern over the havoc the polluting units in Agra were wreaking on the Taj Mahal. Twelve years later the Supreme Court ordered 292 industries in the vicinity to either adopt pollution control measures or shut down. It also made it mandatory for these units to either switch over to eco-friendly fuels like natural gas or shift out of the area.

Air quality monitoring

India does not presently have a well-established system of monitoring air pollution. When air quality monitoring began in India in the late 1960s planners focused only on a few pollutants namely sulphur dioxide, nitrogen oxides and suspended particulate matter. Other pollutants such as carbon monoxide and lead were monitored only on a limited scale. The threat from other air toxins such as benzene, ozone, other small particulates is not known as these are not monitored at all. A database on ambient air quality in Indian cities has been prepared by the monitoring networks of the National Environ-mental Engineering Research Institute (NEERI), Nagpur. The Central Pollution Control Board (CPCB) initiated its own national Ambient Air Quality Monitoring (NAAQM) program in 1985.

Ambient air quality standards in India developed by the Central Pollution Control Board

Area Category	SPM µg/m3	SO2 µg/m3	Co µg/m3	NOx µg/m3
Industrial and mixed use	500	120	5000	120
Residential and rural	200	80	2000	80
Sensitive	100	3	1000	30

Data to the NAAQM is supplied by the respective state pollution control boards, which is then transmitted to the CPCB. Experts feel that the present air quality-monitoring network cannot capture the true profile of urban air pollution due to the lack of adequate monitoring stations. Moreover, critical toxins have still not been included in the list of pollutants to be monitored.

Legal aspects of air pollution control in India The Air (Prevention and Control of Pollution) Act was legislated in 1981. The Act provided for prevention, control and abatement of air pollution. In areas notified under this Act no industrial pollution causing activity could come up without the permission of the concerned State Pollution Control Board. But this Act was not strong enough to play a precautionary or a corrective role. After the Bhopal disaster, a more comprehensive Environment Protection Act (EPA) was passed in 1986. This Act for the first time conferred enforcement agencies with necessary punitive powers to restrict any activity that can harm the environment. To regulate vehicular pollution the Central Motor Vehicles Act of 1939 was amended in 1989. Following this amendment the exhaust emission rules for vehicle owners were notified in 1990 and the mass emission standards for vehicle manufacturers were enforced in 1991 for the first time. The mass emission norms have been further revised for Air quality management as a well-defined pro-gram has yet to emerge in India. We need a much more strengthened air quality management with continuous monitoring of air if we are to have a better quality of air. This would also need an integrated approach with strict air pollution control laws. Some of the suggestions for doing this include:

- Putting a greater emphasis on pollution prevention rather than control
- Reducing the use of fossil fuels
- Improving the quality of vehicular fuel

Increasing the use of renewable energy

Industrial pollution

<u>UNIT 4</u>

Inversion Ambient air sampling, stack sampling, sampling system, analysis of air pollutants.

Introduction

Most frequently occurring pollutants in an urban environment are particulate matters (suspended particulate matter i.e. SPM and respirable suspended particulate matter i.e. RSPM), carbon monoxide (CO), hydrocarbons (HC), sulfur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3) and photochemical oxidants.



The recommended criteria for siting the monitoring stations

- The site is dependent upon the use/purpose of the results of the monitoring programs.
- The monitoring should be carried out with a purpose of compliance of air quality standards.
- Monitoring must be able to evaluate impacts of new/existing air pollution sources.
- Monitoring must be able to evaluate impacts of hazards due to accidental release of chemicals.
- Monitoring data may be used for research purpose.

Type of ambient monitoring stations

Station type	Description
Туре А	Downtown pedestrian exposure station- In central business districts, in congested areas, surrounding by buildings, many pedestrians, average traffic flow > 10000 vehicles per day. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Туре В	Downtown neighbor hood exposure stations- In central business districts but not congested areas, less high rise buildings, average vehicles < 500 vehicles per day. Typical locations like parks, malls, landscapes areas etc. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Туре С	Residential population exposure station – In the midst of the residential areas or sub- urban areas but not in central business districts. The station should be more than 100 m away from any street.
Type D	Mesoscale stations – At appropriate height to collect meteorological and air quality data at upper elevation; main purpose to collect the trend of data variations not human exposure.
Туре Е	Non-urban stations – In remote non-urban areas, no traffic, no industrial activity. Main purpose to monitor trend analysis. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Туре F	Specialized source survey stations – to determine the impact on air quality at specified location by an air pollution source under scrutiny. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.

Frequency of data collection

- Gaseous pollutants: continuous monitoring
- Particulates: once every three days



Number of stations

- Minimum number is three.
- The location is dependent upon the wind rose diagram that gives predominant wind directions and speed.
- One station must be at upstream of predominant wind direction and other two must at downstream pre dominant wind direction.
- More than three stations can also be established depending upon the area of coverage.

Components of ambient air sampling systems

Four main components are:

Inlet manifold

- Air mover
- collection medium
- flow measurement device

Inlet manifold transports sampled pollutants from ambient air to collection medium or analytical device in an unaltered condition. The manifold should not be very long. Air mover provides force to create vacuum or lower pressure at the end of sampling systems. They are pumps. The collection mediums are liquid or solid sorbent or dissolving gases or filters or chamber for air analysis (automatic instruments). The flow device like rotameters measure the volume of air sampled.

Characteristics for ambient air sampling systems

Five main characteristicss are:

- collection efficiency
- sample stability
- recovery
- minimal interference
- understanding the mechanism of collection

The first three must be 100% efficient. For e.g. for SO2, the sorbent should be such that at ambient temperature it may remove the SO2 from ambient atmosphere 100%. Sample must be stabled during the time between sampling and analysis. Recovery i.e. the analysis of particular pollutant must be 100% correct.

Basic considerations for sampling

- Sample must be representative in terms of time, location, and conditions to be studied.
- Sample must be large enough for accurate analysis.
- The sampling rate must be such as to provide maximum efficiency of collection.
- Duration of sampling must accurately reflect the fluctuations in pollution levels i.e. whether 1-hourly, 4-hourly, 6-hourly, 8-hourly, 24-hourly sampling.
- Continuous sampling is preferred.
- Pollutants must not be altered or modified during collection.

Errors in sampling by HVS

- Particulates may be lost in sampling manifold so not too long or too twisted manifold must be used.
- If 'isokinetic' conditioned are not maintained, biased results may be obtained for particulate matters.

Advantages of HVS

- High flow rate at low pressure drop
- High particulate storage capacity
- No moisture regain
- high collection efficiency
- Low coast
- Not appreciable increase in air flow resistance
- Filter is 99% efficient and can collect the particles as fine as 0.3 μm

• Absorption principle is 99% efficient in collecting the gases



Sampling

The sample collected must be representative in terms of time and location.

The sample volume should be large enough to permit accurate analysis. The sampling rate must be such as to provide maximum efficiency of collection. The contaminants must not be modified or altered in the process of collection.





Diagrammatic view of stacksampling

- Impingers are glass bubble tubes designed for the collection of airborne particles into a liquid medium (Figure 1).
- When using an air sampler, a known volume of air bubbles is pumped through the glass tube that contains a liquid specified in the method.
- The liquid is then analyzed to determine airborne concentrations.



Figure 1: Glass Impinger

Selection of sampling location

- The sampling point should be as far as possible from any disturbing influence, such as elbows, bends, transition pieces, baffles.
- The sampling point, wherever possible should be at a distance of 5-10 diameters down-stream from any obstruction and 3-5 diameters up-stream from similar disturbance.



• The size of the sampling point may be made in the range of 7-10 cm, in diameter.

🗡 Traverse points

- For the sample become representative, it should be collected at various points across the stack.
- The number of traverse points may be selected with reference to Table 1.

Table 1: Traverse Points

Cross-section area of stack sq. m	No. of Points
0.2	4
0.2 to 2.5	12
2.5 and above	20

In circular stacks, traverse points are located at the center of equal annular areas across two perpendicular diameters as shown in Figure 2



Figure 2 In case of rectangular stacks, the area may be divided in to 12 to 25 equal areas and the centers for each area are fixed. (Figure 3)





 Isokinetic conditions exist when the velocity in the stack 'Vs' equals the velocity at the top of the probe nozzle 'Vn' at the sample point (Figure 4).







-the reporting and use of the information collected.

- Emissions data collected from point sources are used to determine compliance with air pollution regulations, determine the effectiveness of air pollution control technology, evaluate production efficiencies, and support scientific research.
- The EPA has established ambient air monitoring methods for the criteria pollutants, as well as for toxic organic (TO) compounds and inorganic (IO) compounds.
- The methods specify precise procedures that must be followed for any monitoring activity related to the compliance provisions of the Clean Air Act.
- These procedures regulate sampling, analysis, calibration of instruments, and calculation of emissions.
- The concentration is expressed in terms of mass per unit volume, usually micrograms per cubic meter (μg/m3).

Particulate Monitoring

- Particulate monitoring is usually accomplished with manual measurements and subsequent laboratory analysis.
- A particulate matter measurement uses gravimetric principles. Gravimetric analysis refers to the quantitative chemical analysis of weighing a sample, usually of a separated and dried precipitate.
- In this method, a filter-based high-volume sampler (a vacuum- type device that draws air through a filter or absorbing substrate) retains atmospheric pollutants for future laboratory weighing and chemical analysis. Particles are trapped or collected on filters, and the filters are weighed to determine the volume of the pollutant. The weight of the filter with collected pollutants minus the weight of a clean filter gives the amount of particulate matter in a given volume of air.
- Chemical analysis can be done by atomic absorption spectrometry (AAS), atomic fluorescence spectrometry (AFS), inductively couple plasma (ICP) spectroscopy, and X-ray fluorescence (XRF) spectroscopy.

Atomic Absorption Spectrometry (AAS)

- AAS is a sensitive means for the quantitative determination of more than 60 metals or metalloid elements.
- Principle: This technique operates by measuring energy changes in the atomic state of the analyte. For example, AAS is used to measure lead in particulate monitoring.



Figure: Atomic absorption spectrometry

- Particles are collected by gravimetric methods in a Teflon (PTFE) filter, lead is acid-extracted from the filter.
- The aqueous sample is vaporized and dissociates into its elements in the gaseous state. The element being measured, in this case lead, is aspirated into a flame or injected into a graphite furnace and atomized.
- A hollow cathode or electrode less discharge lamp for the element being determined provides a source of that metal's particular absorption wavelength.
- The atoms in the unionized or "ground" state absorb energy, become excited, and advance to a higher energy level.
- A detector measures the amount of light absorbed by the element, hence the number of atoms in the ground state in the flame or furnace.

- The data output from the spectrometer can be recorded on a strip chart recorder or processed by computer.
- Determination of metal concentrations is performed from prepared calibration curves or read directly from the instrument.

Gaseous pollutant monitoring

- Gaseous pollutant monitoring can be accomplished using various measurement principles.
- Some of the most common techniques to analyze gaseous pollutants include -Spectrophotometry,
 - -Chemiluminescence,

.

- -Gas chromatography-flame ionization detector (GC-FID),
- Gas chromatography-mass spectrometry (GC-MS), and
- Fourier transform infrared spectroscopy (FTIR).
- With all sampling and analysis procedures, the end result is quantitative data.
- The validity of the data depends on the accuracy and precision of the methods used in generating the data.
- The primary quality control measure is calibration.
- Calibration checks the accuracy of a measurement by establishing the relationship between the output of a measurement process and a known input.

Table 1. Methods of Measuring and Analyzing Air Pollutants

Method	Variable Measured	Principle
Gravimetric	PM10, PM2.5	Particles are trapped or collected on filters, and the filters are weighed to determine the volume of the pollutant.
Atomic absorption spectrometry (AAS)	more than 60 metals or metalloid elements (e.g. Pb, Hg, Zn)	This technique operates by measuring energy changes in the atomic state of the analyte. Emitted radiation is a function of atoms present in the sample.
Spectrophotometry	SO2, O3	Measure the amount of light that a sample absorbs. The amount of light absorbed indicates the amount of analyte present in the sample.
Chemiluminescence	SO2, O3	Based upon the emission spectrum of an excited species that is formed in the course of a chemical reaction.
Gas chromatography (GC) - flame ionization detector (FID)	VOC	Responds in proportion to number of carbon atoms in gas sample.
Gas chromatography- mass spectrometry (GC-MS)	VOC	Mass spectrometers use the difference in mass-to-charge ratio (m/z) of ionized atoms or molecules to separate them from each other.
Fourier Transform Infrared Spectroscopy (FTIR)	CO, VOC, CH4	Sample absorbs infrared radiation and difference in absorption is measured.

Spectrophotometry

- A spectrophotometer measures the amount of light that a sample absorbs.
- The instrument operates by passing a beam of light through a sample and measuring the intensity of light reaching a detector.
- Spectrophotometry commonly used to measure sulfur dioxide (SO2) concentrations.
- The amount of light absorbed indicates the amount of sulfur dioxide present in the sample.





Figure: Schematic gas chromatography

- The flame in a flame ionization detector is produced by the combustion of hydrogen and air.
- When a sample is introduced, hydrocarbons are combusted and ionized, releasing electrons.
- A collector with a polarizing voltage located near the flame attracts the free electrons, producing a current that is proportional to the amount of hydrocarbons in the sample.
- The signal from the flame ionization detector is then amplified and output to a display or external device.
- Gas chromatography-mass spectrometry (GC-MS) instruments have also been used for identification
 of volatile organic compounds. Mass spectrometers use the difference in mass-to-charge ratio (m/z) of
 ionized atoms or molecules to separate them from each other. Mass spectrometry is useful for
 quantification of atoms or molecules and also for determining chemical and structural information about
 molecules.

Fourier Transform Infrared Spectroscopy

- FTIR can detect and measure both criteria pollutants and toxic pollutants in ambient air
- FTIR can directly measure more than 120 gaseous pollutants in the ambient air, such as carbon monoxide, sulfur dioxide, and ozone.
- The technology is based on the fact that every gas has its own "fingerprint," or absorption spectrum.



Figure: FTIR can directly measure both criteria pollutants and toxic pollutants in the ambient air.

- The FTIR sensor monitors the entire infrared spectrum and reads the different fingerprints of the gases present in the ambient air.
- Carbon monoxide is monitored continuously by analyzers that operate on the infrared absorption principle.
- Ambient air is drawn into a sample chamber and a beam of infrared light is passed through it.
- CO absorbs infrared radiation, and any decrease in the intensity of the beam is due to the presence of CO molecules.
- This decrease is directly related to the concentration of CO in the air.
- A special detector measures the difference in the radiation between this beam and a duplicate beam passing through a reference chamber with no CO present.
- This difference in intensity is electronically translated into a reading of the CO present in the ambient

air, measured in parts per million.

National Ambient Air Quality Standards

POLLUTANTS	AVERAGE TIME	CONCENTRATION
sulphur dioxide (SO2)	Annual average 24 hour	60 μg/cubic m 80 μg/cubic m
Oxides of Nitrogen (NO2)	A.A 24H	60 μg/cubic m 80 μg/cubic m
Suspended Particulate Matter (SPM)	A.A 24H	140µg/cubic m 200µg/cubic m
Lead	A.A 24H	0.75 μg/cubic m 1.0 μg/cubic m
Carbon Monoxide	A.A 24H	2.0 μg/cubic m 84.0 μg/cubic m
Respirable Particulate Matter (RPM)	A.A 24H	60 μg/cubicm 100 μg/cubic m

NAAQS by USEPA 2006

Pollutant	Primary Stds.	Averaging Times	Secondary Stds.
Carbon Monovido	9 ppm (10 mg/cubic m)	8-hour (1)	None
	35 ppm (40 mg/cubic m)	1-hour (1)	None
Lead	1.5 µg/cubic m	Quarterly Average	Same as Primary
Nitrogen Dioxide	0.053 ppm (100 µg/cubic m)	Annual (Arithmetic Mean)	Same as Primary
Particulate Matter	Revoked(2)	Annual (2) (Arith. Mean)	
(PM10)	150 µg/cubic m	24-hour (3)	
Particulate Matter	15.0 µg/cubic m	Annual (4) (Arith. Mean)	Arith. Mean) Same as Primary
(PM2.5)	35 μg/cubic m	24-hour (5)	
	0.08 ppm	8-hour (6)	Same as Primary
Ozone	0.12 ppm	1-hour (7) (Applies only in limited areas)	Same as Primary
	0.03 ppm	Annual (Arith. Mean)	
Sulfur Oxides 0.14 ppm 24	24-hour (1)		
		3-hour (1)	0.5 ppm (1300 µg/cubic m)

(1)Not to be exceeded more than once per year.

(2)Due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution, the agency revoked the annual PM10 standard in 2006 (effective December 17, 2006).

(3) Not to be exceeded more than once per year on average over 3 years.

(4) To attain this standard, the 3-year average of the weighted annual mean PM2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 μg/cubic metre.

(5) To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 μ g/cubic metre (effective December 17, 2006).

(6) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08

ppm.

(7) (a) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is < 1, as determined by appendix H. (b) As of June 15, 2005 EPA revoked the 1-hour ozone standard in all areas except the fourteen 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

🖊 WHO Air Quality Guidelines Value

POLLUTANTS	AVERAGE TIME	AQG value
Particulate matter PM2.5 PM10	1 year 24 hour(99th percentile) 1 year 24 hour(99th percentile)	 10 μg/cubic metre 25 μg/cubic metre 20 μg/cubic metre 50 μg/cubic metre
Ozone, O3	8 hour, daily maximum	100 µg/cubic metre
Nitrogen dioxide, NO2	1 year 1 hour	40µg/cubic metre 200µg/cubic metre
Sulfur dioxide, SO2	24 hour 10 minute	20 μg/cubic metre 500 μg/cubic metre

Industrial pollution Unit 4 Emission and sources and classification

The air pollution problem can be schematically presented as a system consisting of three basic components:



Emissions is the term used to describe the gases and particles which are put into the air or emitted by various sources.

Major emission sources:

- Transportation;
- Industrial and domestic fuel burning;
- Industrial processes.
- Receptors:
- Humans;
- Animals;
- Plants;
- Materials.
- Atmosphere
- acts as a medium for transport and dispersion,
- physical and chemical transformations

WHAT ARE EMISSIONS?

- The amount of pollutant(s) a source puts into the air during a fixed time.
- Units: mass/time
- Emissions vary making air quality management a challenge!



Emissions classification

- •By pollutant
- •By source type

Classification – by Pollutant

Some general pollutant categories include

- •Criteria air pollutants
- •Criteria Pre-cursor air pollutants
- Hazardous Air Pollutants (HAPs)

Classification – by Source Type

Stationary - sources with a fixed location

-Point: usually a large source, often a stack

-Area: sources that are considered as a group

Mobile - sources that move

-On-road: highway vehicles

-Non-road: non-highway vehicles
Classification – by Source Type

Emissions from source types modeled differently

Point source	Gaussian plume model (e.g. ISC-AERMOD)	
Mobile source	Roadway models (e.g. CALINE, CAL3QHC)	
Area source	Flexible source models (e.g. CALPUFF)	





Emission Classification Nitrogen Oxides (NO_x)

- Passenger vehicles are a major source of NO_x.
- These are mobile (on-road) sources.





Air pollutants can present a real danger to living organisms as well as the wider environment.

- Air pollutants come in the form of gases and finely divided solid and liquid aerosols.
- Aerosols are loosely defined as "any solid or liquid particles suspended in the air" .
- Air pollutants can also be of primary or secondary nature.
- Primary air pollutants are the ones that are emitted directly into the atmosphere by the sources (such as power-generating plants).
- Secondary air pollutants are the ones that are formed as a result of reactions between primary pollutants and other elements in the atmosphere, such as ozone.
- Possibly one of the most important characteristics of air pollutants is their transboundary nature they can easily travel and affect the areas far away from their points of origination.

Gaseous Air Pollutants

Renowned author Jeremy Colls identifies the following three main types of gaseous air pollutants:

- Sulfur dioxide (SO2)
- Oxides of nitrogen (NOx = NO + NO2)
- Ozone (O3)
- Sulfur dioxide and nitric oxide (NO) are the primary air pollutants, and ozone is a secondary pollutant (though there are negligible direct emissions of the gas itself).
- Nitrogen dioxide (NO2) is both a primary and secondary air
- pollutant.
- Other important gaseous pollutants are: ammonia, carbon
- monoxide, volatile organic compounds (VOCs) and persistent

organic pollutants (POPs) which we discuss below. Air Pollutants: Sulfur Dioxide (SO2)

• Sulfur dioxide is a colorless gas with a pungent, suffocating odor. It is a dangerous air pollutant because it is corrosive to organic materials and it irritates the eyes, nose and lungs.

Anthropogenic Sources of Sulfur Dioxide Emissions

• Sulfur is contained within all fossil fuels, and is released in the form of sulfur

dioxide (SO2) during fossil fuel combustion. Fossil fuel combustion accounts

for almost all anthropogenic (human-caused) sulfur emissions.

• Sulfur contents in fossil fuels range between 0.1% and 4% in oil, oil byproducts and coal, and up to 40% in natural gas (when immediately

extracted from the well; however, the sulfur is efficiently removed during the processing of gas before distribution ; therefore, combustion of natural gas is not a major source of sulfur emissions.

• Historically, the use of coal in domestic heating was a major source of sulfur

dioxide emissions but it has declined substantially over time. This trend is possibly true for other industrialized countries as well, though

the US as the most important economy in the world is still a large consumer

of energy derived from coal.

• Below is a breakdown of all the significant sources of sulfur dioxide

emissions :

- Energy Production
- Electric power generation
- Petroleum refining
- Other combustion
- Commercial and residential use
- Combustion for industry use
- Production processes
- Extraction and distribution of fossil fuels
- Transport
- Road transport
- •Other Transport (such as aviation, ships, trains).
- Currently, the most important sources of sulfur dioxide emissions (as a

result of fossil fuel combustion) are electric power generating plants.

• For example, as of 1998, 66% of all sulfur dioxide emissions in the UK came from power plants. In contrast, transport contributions of sulfur dioxide emissions are among the smallest ones.

• The biggest sulfur dioxide emitters: US, China and Russia.

 In fact, you may be surprised to learn that just one Siberian city in Russia – Norilsk – produces 1% of the total global emissions of sulfur dioxide. In 2007, Norilsk was considered to be one of the most polluted places on EarthNatural Sources of Sulfur Dioxide Emissions

There are also significant sulfur emissions generated by natural sources.

The main natural sulfur emissions come in the reduced forms of sulfur compounds such as :

- hydrogen sulfide (H2S)
- carbon disulfide (CS2)
- carbonyl sulfide (COS)
- and in the organic forms of:
- methyl mercaptan (CH3SH)

• dimethyl sulfide (DMS) (CH3SCH3)

• dimethyl disulfide (DMDS) (CH3SSCH3)

Most of these compounds get oxidized to sulfur dioxide or to sulfate aerosols in the atmosphere. Marine phytoplankton produce dimethyl sulfide (DMS) which is then oxidized to SO2 in the atmosphere; decay processes in soil and vegetation produce H2S (as one of sulfur compounds); and SO2 is emitted into the atmosphere by volcanoes.

Around 90% of all natural sulfur emissions come in the form of DMS.

• Most recently the natural sources have been by far surpassed by anthropogenic sources. Natural sources have been estimated to produce around 24% of all sulfur dioxide emissions, whereas human-caused emissions made up around 76%. Effects of Sulfur Dioxide Emissions

- Sulfur dioxide found in the air produces following effects:
- Irritates eyes, nose, throat
- Damages lungs when inhaled
- As part of acid rain:
- acidifies lakes and streams
- •destroys plant and fish life in lakes and streams
- •may deplete mineral nutrients in the soil
- may cause reduction of forest and agricultural yields
- corrodes metals
- •damages surfaces of buildings.

Air Pollutants: Nitrogen Oxides

Author Andrew Farmer points out that oxides of nitrogen are produced by combustion of all fossil fuels including coal- and gas-fired power stations and motor vehicles. Whereas fuel itself can produce some nitrogen (for example, oil and coal contain around 0.5 - 1.5% of nitrogen, and natural gas contains less than that, most of nitrogen oxides' production comes from the reaction of atmospheric nitrogen and oxygen within the combustion chamber.

- The two main nitrogen oxides are nitric oxide (NO), or nitrogen monoxide,
- and nitrogen dioxide (NO2) the sum of which is equal to NOx.
- Nitric oxide (NO) is a colorless gas.
- Nitrogen dioxide (NO2) is a gas of reddish-brown color with a distinct sharp, biting odor.
- Combustion of fuels always produces both NO2 and NO.
- But almost 90% of the NOX combustion product is in the form of NO which is then oxidized to nitrogen dioxide (NO2) in the air .
- Therefore, only a small percentage of NO2 found in the atmosphere is directly emitted there in this form. The rest has been formed as a result of chemical reactions in the atmosphere itself. Anthropogenic Sources of Nitrogen Oxide Emissions
- Road transport (motor vehicles) is by far the largest contributor of nitrogen emissions (in contrast, it contributes a very small proportion to sulfur dioxide emissions, as discussed above).
- Bus Pollution in Guatemala

Photo: Doron Laor

• For example, based on 1998 UK

figures, road transport contributed

nearly half of all nitrogen emissions, followed by contributions from electric power generating plants which only contributed around 20% of total nitrogen emissions.

- Below is a breakdown of the significant sources of emissions of nitrogen oxides :
- Road transport
- Other Transport
- Energy Production
- Electric power generation
- Petroleum refining

• Other combustion: Combustion for industry use; Production processes; Extraction and distribution of fossil fuels. Natural Sources of Nitrogen Oxide Emissions

• Nitric oxide (NO) is also emitted by soils but there is very little data available

for the proper assessment of this area.

• Some estimates suggest that the soil production of NO in the UK may be around 2 – 5% of its production from fossil fuel combustion.

Effects of Nitrogen Dioxide (NO2) Emissions

- When inhaled, nitrogen dioxide becomes a serious air pollutant which may:
- Cause pulmonary edema (accumulation of excessive fluid in the lungs)
- Be part of acid rain (destroying fish and plant life in lakes, damaging surfaces of buildings etc)
- Contribute to photochemical smog. Air Pollutants: Ammonia
- Ammonia is a colorless, pungent, hazardous caustic gas composed of nitrogen and hydrogen. Ammonia emissions are also grouped as NHy which is a sum of NH3 and NH4.

Sources of Ammonia Emissions

• Agriculture is by far the biggest source of ammonia emissions.

• Livestock farming and animal waste account for the biggest percentage of total ammonia emissions which are due to the decomposition of urea from large animal wastes and uric acid from poultry wastes.

• Based on Jeremy Colls' table of global ammonia emissions, below is a breakdown of their major sources:

- Livestock contributes more than 50% of all emissions
- Fertilizer application
- Oceans
- Vegetation
- Biomass burning
- Effects of Ammonia Emissions

• Exposure to very high concentrations of gaseous ammonia in the air may result in lung damage and even death.

Air Pollutants: Carbon monoxide (CO)

- Carbon monoxide is a colorless, odorless gas which is highly toxic to humans.
- The combustion of carbon-based fuels produces carbon dioxide (CO2).
- But not all such combustion is complete, and this leads to the production of carbon

monoxide (CO).

• Motor vehicles and industry are among the largest anthropogenic sources of carbon monoxide emissions.

Effects of Carbon Monoxide Emissions

• Carbon monoxide is the most common type of fatal poisoning in many countries around the world.

- Exposures to carbon monoxide may lead to:
- Toxicity of the central nervous system and heart
- Severe effects on the baby of a pregnant woman
- Headaches and dizziness

• Problems with getting oxygen supplied to some body parts which may be lifethreatening. Air Pollutants: Volatile Organic Compounds (VOCs)

• Volatile organic compounds (VOCs) are defined as organic compounds which easily evaporate and enter the atmosphere.

• VOCs may include a wide range of organic air pollutants, from pure hydrocarbons to partially oxidized hydrocarbons to organic compounds containing chlorine, sulfur, or nitrogen.

• Historically, the definition of VOCs did not include methane compounds (non-methane VOCs: NMVOCs) since the atmospheric concentration of methane was considered to be a stable natural background. But it was ultimately recognized that methane is also an anthropogenic air pollutant that comes from intensive animal and rice production.

• Though some of these compounds can have direct toxic effects, they have been grouped together because of their role in ozone formation.

Anthropogenic Sources of Volatile Organic Compounds

- The major anthropogenic sources of VOCs include:
- Solvent Use (including paints, adhesives, aerosols, metal cleaning and printing)
- Road transport (emissions from fuel / petroleum use)
- Production processes
- Extraction and distribution of fossil fuels
- For example, in the UK the biggest emissions of NMVOCs are due to solvent use and road transport. Substantial NMVOC emissions occur during the following processes :
- Painting (evaporation of solvents)
- Oil production (flaring and venting of gas)
- Oil refining (flaring and fugitive emissions)
- Distribution of oil or refinery products (evaporation from storage, displacement losses when venting tanks)
- Dry cleaning (final drying of clothes)
- Production of alcoholic drinks (breweries and distilleries)
- Arable farming (crop growing, silage manufacture, sludge spreading)

Natural Sources of Volatile Organic Compounds

• Not a lot is known about the natural emissions of VOCs.

• But we know that forests are the primary natural sources of VOC emissions. And tropical forests are estimated to produce about half of all global natural non-methane VOC emissions.

• Plants synthesize many organic molecules and release some VOCs (including a range of terpenes) into the atmosphere.

• In total, around 1000 different compounds (with some of which themselves being families with thousands of their own members) are known to be emitted by natural sources.

INDUSTRIAL POLLUTION

Unit 5(lecture1)

What is the Hydrological Cycle?

Hydrological cycle can be defined as the continuous process of exchange of water from the earth surface to the atmosphere or vice versa by the influence of solar radiation or solar heat.

It is a closed system where the water gets transformed either from one place to other or from one form to other under the action of sun heat. Whatever be the process, the total water in the whole system remains constant. The representation of the hydrological cycle is represented in the figure-1 below.



Fig.1. Hydrological Cycle

The hydrological cycle is involved in the total earth system. The total system can be classified into three important zone: Atmosphere, hydrosphere and lithosphere. Atmosphere forms the gaseous envelope that is above the hydrosphere. Hydrosphere forms the body of water that is covering the surface of the earth. The environment that is below the hydrosphere till the solid rock forms the lithosphere.

What are the basic components of Hydrological Cycle?

The basic components of a hydrological cycle constitute:

- 1. Precipitation
- 2. Runoff
- 3. Evaporation
- 4. Condensation
- 5. Transpiration
- 6. Evapotranspiration
- 7. Infiltration
- 8. Depression Storage
- 9. Interception

1. Precipitation

It is the fall of moisture from the atmosphere to the earth's surface in any form. Example: rain, hail, snow, sleet, glaze, drizzle, snowflakes.

2. Runoff

It is the water flowing over the land making its way towards rivers, lakes, oceans, etc. as surface or subsurface flow.

- 1. Surface runoff: it is the running water over the land and which ultimately discharge water to the sea.
- 2. Subsurface runoff: The water getting infiltrated into pervious soil mass, making its way towards rivers and lakes can be termed as subsurface runoff.

3. Evaporation

It is the conversion of natural liquids like water into gaseous form like air. Evaporation happens in the water bodies

4. Condensation

It is the conversion of a vapour or gas to a liquid. The water vapour evaporates from the water bodies like ocean, sea and river. These vapours after reaching a height around 20km in the sky undergo condensation and forms clouds. These later precipitate as rain, fog etc.

5. Transpiration

It is the evaporation taking place from any plant or greenery. For example, a water droplet on a leaf getting evaporated into the atmosphere.

6. Evapotranspiration

It is the combination of evaporation and transpiration.

7. Infiltration

It is the process of filtration of water to the inner layers of soil based on its structure and nature. Pervious soils go through more infiltration than impervious. Infiltration in soils like sand, gravel and coarser material is more and for finer soil particles like clay and silt, infiltration is less.

Infiltration is inversely proportional to runoff. In soil, if infiltration is less, then the runoff is more. Similarly, more infiltration gives less runoff. Example: bitumen roads have more runoff than metallic red mud roads

8. Depression Storage

It is the part of precipitation required to fill depression zones of land.

9. Interception

Part of precipitation required to wet the surface of soil, buildings and all pervious surfaces is called Interception.

Process of Hydrological Cycle

The Process of the hydrological cycle starts with oceans. Water in oceans, gets evaporated due to heat energy provided by solar radiation and forms water vapor. This water vapor moves upwards to higher altitudes forming clouds.

Most of the clouds condense and precipitate in any form like rain, hail, snow, sleet. And a part of clouds is driven to land by winds. Even during the process of precipitation, some parts of water molecules may evaporate back to atmosphere.

The Portion of water that reaches the ground, enters the earth's surface infiltrating various strata of soil. This process enhances the moisture content as well as the water table.

Vegetation sends a portion of water from the earth's surface back to the atmosphere through the process of transpiration. Once water percolates and infiltrates the earth's surface, runoff is formed over the land, flowing through the contours of land heading towards river and lakes and finally joins into oceans after many years. Some amount of water is retained as depression storage.

Further again the process of this hydrological cycle continues by blowing of cool air over the ocean, carrying water molecules, forming into water vapour then clouds getting condensed and precipitates as rainfall. Similarly, the water percolates into the soil, thus increasing the water table and also the formation of runoff waters heading towards water bodies. Thus the cyclic process continues.

Water balance Equation

As per the water balance equation, the sum of inflow waters = sum of outflow waters. Out of the three processes precipitation, runoff, and evaporation, inflow is precipitation. Runoff and evaporation comes under outflow, then the water balance equation can be written as,

Precipitation – runoff = Evaporation

That gives,

Precipitation (P) = Evaporation (E) + Runoff (R)

INDUSTRIAL POLLUTION

<u>UNIT 2</u>

Pollution of Air, water and land, Fossil fuel related pollutants in the environment (Continue) Lecture-3

Water Pollution

Our liquid planet glows like a soft blue sapphire in the hard-edged darkness of space. There is nothing else like it in the solar sys-tem. It is because of water.

Introduction: Water is the essential element that makes life on earth possible. Without water there would be no life. We usually take water for granted. It flows from our taps when they are turned on. Most of us are able to bathe when we want to, swim when we choose and water our gardens. Like good health we ignore water when we have it.

Although 71% of the earth's surface is covered by water only a tiny fraction of this water is available to us as fresh water. About 97% of the total water available on earth is found in oceans and is too salty for drinking or irrigation. The remaining 3% is fresh water. Of this 2.997% is locked in ice caps or glaciers. Thus only 0.003% of the earth' total volume of water is easily avail-able to us as soil moisture, groundwater, water vapour and water in lakes, streams, rivers and wetlands.

In short if the world's water supply were only 100 litres our usable supply of fresh water would be only about 0.003 litres (one-half teaspoon). This makes water a very precious resource. The future wars in our world may well be fought over water. By the middle of this century, almost twice as many people will be trying to share the same amount of fresh water the earth has today. As freshwater becomes more scarce ac-cess to water resources will be a major factor in determining the economic growth of several countries around the world

Water availability on the planet: Water that is found in streams, rivers, lakes, wetlands and artificial reservoirs is called surface water. Wa-ter that percolates into the ground and fills the pores in soil and rock is called groundwater. Porous water-saturated layers of sand, gravel or bedrock through which ground water flows are called aquifers. Most aquifers are replen-ished naturally by rainfall that percolates down-ward through the soil and rock. This process is called natural recharge. If the withdrawal rate of an aquifer exceeds its natural recharge rate, the water table is lowered. Any pollutant that is discharged onto the land above is also pulled into the aquifer and pollutes the groundwater resulting in polluted water in the nearby wells.

India receives most of her rainfall during the months of June to September due to the sea-sonal winds and the temperature differences between the land and the sea. These winds blow from the opposite directions in the different sea-sons. They blow into India from the surround-ing oceans during the summer season and blow out from the subcontinent to the oceans during the winter. The monsoon in India is usually rea-sonably stable but varies geographically. In some years the commencement of the rains may be delayed considerably over the entire country or a part of it. The rains may also terminate earlier than usual. They may be heavier than usual over one part than over another. All these may cause local floods or drought. However in India even areas that receive adequate rainfall during the monsoon suffer from water shortages in the post monsoon period due to lack of storage facili-ties.

When the quality or composition of water changes directly or indirectly as a result of man's activities such that it becomes unfit for any purpose it is said to be polluted.

Point sources of pollution: When a source of pollution can be readily identified because it has a definite source and place where it enters the water it is said to come from a **point source.** Eg. Municipal and Industrial Discharge Pipes.

When a source of pollution cannot be readily identified, such as agricultural runoff, acid rain, etc, they are said to be **non-point sources** of pollution.



sources of pollution

Causes of water pollution

There are several classes of common water pollutants. These are **disease-causing agents** (pathogens) which include bacteria, viruses, protozoa and parasitic worms that enter water from domestic sewage and untreated human and animal wastes. Human wastes contain concentrated populations of coliform bacteria such as *Escherichia coli* and *Streptococcus faecalis*. These bacteria normally grow in the large intestine of humans where they are responsible for some food digestion and for the production of vita-min K. These bacteria are not harmful in low numbers. Large amounts of human waste in water, increases the number of these bacteria which cause gastrointestinal diseases. Other potentially harmful bacteria from human wastes may also be present in smaller numbers. Thus the greater the amount of wastes in the water the greater are the chances of contracting dis-eases from them.

Another category of water pollutants is **oxy-gen depleting wastes.** These are organic wastes that can be decomposed by aerobic (oxy-gen requiring) bacteria. Large populations of bacteria use up the oxygen present in water to degrade these wastes. In the process this de-grades water quality. The amount of oxygen required to break down a certain amount of organic matter is called the biological oxygen demand (BOD). The amount of BOD in the water is an indicator of the level of pollution. If too much organic matter is added to the water all the available oxygen is used up. This causes fish and other forms of oxygen dependent aquatic life to die. Thus anaerobic bacteria (those that do not require oxygen) begin to break down the wastes. Their anaerobic respiration produces chemicals that have a foul odour and an un-pleasant taste that is harmful to human health.

A third class of pollutants are **inorganic plant nutrients**. These are water soluble nitrates and phosphates that cause excessive growth of algae and other aquatic plants. The excessive growth of algae and aquatic plants due to added nutrients is called eutrophication. They may in-terfere with the use of the water by clogging water intake pipes, changing the taste and odour of water and cause a build-up of organic matter. As the organic matter decays, oxygen levels decrease and fish and other aquatic species die.

The quantity of fertilizers applied in a field is often many times more than is actually required by the plants. The chemicals in fertilizers and pesticides pollute soil and water. While excess fertilizers cause eutrophication, pesticides cause bioaccumulation and bio-magnification. Pesticides which enter water bodies are introduced into the aquatic food chain. They are then absorbed by the phytoplanktons and aquatic plants. These plants are eaten by the herbivorous fish which are in turn eaten by the carnivorous fish which are in turn eaten by the water birds. At each link in the food chain these chemicals which do not pass out of the body are ac-cumulated and increasingly concentrated resulting in bio magnification of these harmful substances.

One of the effects of accumulation of high levels of pesticides such as DDT is that birds lay eggs with shells that are much thinner than normal. This results in the premature breaking of these eggs, killing the chicks inside. Birds of prey such as hawks, eagles and other fish eating birds are affected by such pollution. Al-though DDT has been banned in India for agricultural use and is to be used only for malaria eradication, it is still used in the fields as it is cheap.

A fourth class of water pollutants is **water soluble inorganic chemicals** which are acids, salts and compounds of toxic metals such as mercury and lead. High levels of these chemicals can make the water unfit to drink, harm.



fish and other aquatic life, reduce crop yields and accelerate corrosion of equipment that use this water.

Another cause of water pollution is a variety of **organic chemicals**, which include oil, gasoline, plastics, pesticides, cleaning solvents, detergent and many other chemicals. These are harmful to aquatic life and human health. They get into the water directly from industrial activity either from improper handling of the chemicals in industries and more often from improper and illegal disposal of chemical wastes.

Sediment of suspended matter is another class of water pollutants. These are insoluble particles of soil and other solids that become sus-pended in water. This occurs when soil is eroded from the land. High levels of soil particles sus-pended in water, interferes with the penetration of sunlight. This reduces the photosynthetic activity of aquatic plants and algae disrupting the ecological balance of the aquatic bodies. When the velocity of water in streams and rivers decreases the suspended particles settle down at the bottom as sediments. Excessive sediments that settle down destroys feeding and spawning grounds of fish, clogs and fills lakes, artificial reservoirs etc.

Water soluble radioactive isotopes are yet another source of water pollution. These can be concentrated in various tissues and organs as they pass through food chains and food webs. Ionizing radiation emitted by such isotopes can cause birth defects, cancer and genetic damage.

Hot water let out by power plants and industries that use large volumes of water to cool the plant result in rise in temperature of the local water bodies. Thermal pollution occurs when industry returns the heated water to a water source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity. For efficient functioning of the steam

turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to ab-sorb the heat. This heated water, which is at least 15oC higher than the normal is discharged back into the water body. The warm water not only decreases the solubility of oxygen but changes the breeding cycles of various aquatic organisms.

Oil is washed into surface water in runoff from roads and parking lots which also pollutes groundwater. Leakage from underground tanks is another source of pollution. Accidental oil spills from large transport tankers at sea have been causing significant environmental damage.

Though accidents such as the *Exxon Valdez* get worldwide attention, much more oil is released as a result of small, regular releases from other less visible sources. Nearly two thirds of all marine oil pollution comes from three sources: run-off from streets, improper discharge of lubricating oil from machines or automobile crankcases and intentional oil discharges that occur during the loading and unloading of tankers. Oil tankers often use sea water as ballast to stabilize the ship after they have discharged their oil. This oil contaminated water is then dis-charged back into the sea when the tanker is refilled.

Groundwater pollution: While oil spills are highly visible and often get a lot of media attention, a much greater threat to human life comes from our groundwater being polluted which is used for drinking and irrigation. While groundwater is easy to deplete and pollute it gets renewed very slowly and hence must be used judiciously. Groundwater flows are slow and not turbulent hence the contaminants are not effectively diluted and dispersed as com-pared to surface water. Moreover, pumping groundwater and treating it is very slow and costly. Hence it is extremely essential to prevent the pollution of groundwater in the first place. Ground water is polluted due to:

· Urban run-off of untreated or poorly treated waste water and garbage

- Industrial waste storage located above or near aquifers
- Agricultural practices such as the application of large amounts of fertilizers and pesticides, animal feeding operations, etc. in the rural sector
- Leakage from underground storage tanks containing gasoline and other hazardous substances
- Leachate from landfills
- Poorly designed and inadequately maintained septic tanks
- Mining wastes

Severe cases of arsenic poisoning from contaminated groundwater have been reported from West Bengal in what is known today as the worst case of groundwater pollution. The School of Environmental Sciences, Jadhavpur University, West Bengal has been involved in the task of surveying the magnitude of the arsenic problem in West Bengal for the last fourteen years. According to a report in the Down to Earth (Vol. 11, No.22), arsenic poisoning was first noticed by K C Saha, former professor of dermatology at the School of Tropical Medicine, Kolkata when he began to receive patients with skin lesions that resembled the symptoms of leprosy which was in reality not leprosy. Since all the patients were from the district of 24-Parganas, Saha along with others began to look for the cause and found it to be arsenic toxicity. Thus ground-water arsenic contamination in West Bengal was first reported in a local daily newspaper in December 1983 when 63 people from three villages located in different districts were identified by health officials as suffering from arsenic poisoning.

There are two theories that have been put forth to explain this unusually high content of arsenic in groundwater. One group of researchers suggested that the cause is natural while the other stated that the cause is man-made.

According to the first hypothesis, arsenic probably originates in the Himalayan headwaters of the Ganga and the Brahmaputra rivers and has been lying undisturbed beneath the surface of the region's deltas for thousands of years in the thick layers of fine alluvial mud across the banks of these rivers. Most of the arsenic affected areas of West Bengal lie in the alluvial plains formed in the quarternary period (last 1.6 mil-lion years). The Purulia district of West Bengal is part of the extensive area of the Precambrian era (last 570 million year) having metamorphic rocks and granites with widespread sulphide mineralisation. Researchers from the UK based British Geological Survey (BGS) suggested that their position close to where the river Ganga enters Bangladesh (geologically) may be the primary source of arsenic in the Bengal alluvium. According to David Kinniburgh project leader with BGS the main factor is time. The mud in these areas is thicker, wider and flatter than al-most anywhere else on earth. It can thus take hundreds or thousands of years for underground water to percolate through the mud before reaching the sea and thus it absorbs arsenic for a long period.

Other researchers feel that the excess amount of arsenic in groundwater can be contributed to by the high rate of groundwater extraction. Their hypothesis called the pyrite oxidation the-sis describes how arsenic can get mobilized in the groundwater. In this hypothesis arsenic is assumed to be present in certain minerals (pyrites) that are deposited within the aquifer sediments. Due to the lowering of the water table below the deposits, arsenopyrite which is oxidized in a zone of the aquifer called the Vadose zone releases arsenic as arsenic adsorbed on iron hydroxide. During the subsequent recharge period, iron hydroxide releases arsenic into ground-water. This theory is supported by two arguments. The first is the intensive irrigation development in West Bengal using deep tube wells and shallow tube wells. This method of extraction, which was exactly in the 20m to 100m below ground level ensured, increased contribution of groundwater to irrigation. The other argument that supports the pyrite oxidation theory is that prior to irrigation develop ment and drinking water supply schemes based on groundwater there were no reported cases of arsenic poisoning.

Arsenicosis or arsenic toxicity develops after two to five years of exposure to arsenic contaminated drinking water depending on the amount of water consumption and the arsenic concentration in water. Initially the skin begins to darken (called diffuse melanosis) which later leads to spotted melanosis when darkened sports begin to appear on the chest, back and limbs. At a later stage leucomelanosis sets in and the body begins to show black and white spots. In the middle stage of arsenicosis the skin in parts be-comes hard and fibrous. Rough, dry skin with nodules on hands or the soles of feet indicate severe toxicity. This can lead to the formation of gangrene and cancer. Arsenic poisoning brings with it other complications such as liver and spleen enlargement, cirrhosis of the liver, diabetes, goiter and skin cancers.

The state of India's rivers

India has always had a tradition of worshipping rivers. Most of the rivers in India are named after gods, goddesses or saints. However, a large majority of the Indian population including those who worship the rivers do not think twice be-fore polluting a river. Urbanization, industrialization, excess withdrawal of water, agricultural run-off, improper agricultural practices and various religious and social practices all contribute to river pollution in India. Every single river in India be it the Ganga, Yamuna, Cauvery or the Krishna have their own share of problems due to pollution. Waters from the Ganga and the Yamuna are drawn for irrigation through the network of canals as soon as these rivers reach the plains reducing the amount of water that flows downstream. What flows in the river is water from small nalas, and streams that carry with them sewage and industrial effluents. The residual freshwater, is unable to dilute the pol lutants and the rivers turn into stinking sewers. In spite of data from scientifically competent studies conducted by the Central Pollution Control Board (CPCB), the Government has not been able to tackle this issue. Sewage and municipal effluents and non-point pollution sources.

In 1985, India launched the Ganga Action plan (GAP) the largest ever river clean-up operation in the country. The plan has been criticized for, overspending and slow progress. The GAP Phase

Il in 1991 included cleaning operations for the tributaries of the Ganga, ie; the Yamuna, Gomti and the Damodar. Thus the Yamuna Action Plan (YAP), Gomti Action Plan and the Damodar Ac-ion plan were added.

In 1995 the National River Conservation plan was launched. Under this all the rivers in India were taken up for clean-up operations. In most of these plans, attempts have been made to tap drains, divert sewage to sewage treatment plants before letting out the sewage into the rivers. The biggest drawback of these river cleaning programs was that they failed to pin responsibilities as to who would pay for running the treatment facilities in the long run. With the power supply being erratic and these plants being heavily dependent on power, most of these facilities lie underutilized. Moreover, the problem of river pollution due to agricultural run-off has not been addressed in these programs. NRCP is scheduled to be completed by March 2005. The approved cost for the plan is Rs. 772.08 crores covering 18 rivers in 10 states including 46 towns. The cost is borne entirely by the Central Government and the Ministry of Environment and Forests is the nodal agency that coordinates and monitors the plan. Under this plan the major activities include treating the pollution load from sewer systems of towns and cities, setting up of Sewage treatment plants, electric crematoria, low cost sanitation facilities, riverfront development, afforestation and solid waste management.

Control measures for preventing water pollution

While the foremost necessity is prevention, set-ting up effluent treatment plants and treating waste through these can reduce the pollution load in the recipient water. The treated effluent can be

reused for either gardening or cooling purposes wherever possible. A few years ago a new technology called the Root Zone Process has been developed by Thermax. This system involves running contaminated water through the root zones of specially designed reed beds. The reeds, which are essentially wetland plants have the capacity to absorb oxygen from the surrounding air through their stomatal openings. The oxygen is pushed through the porous stem of the reeds into the hollow roots where it enters the root zone and creates conditions suit-able for the growth of numerous bacteria and fungi. These micro-organisms oxidize impurities in the wastewaters, so that the water which finally comes out is clean.

RESULT ANALYSIS

Darbhanga College of Engineering, Darbhanga 8th Sem. (2016-20), Mechanical Engineering Dept.

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48.	16102111048	NITESH KUMAR
49.	16102111049	KRISHNA KUMAR
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