

Paper Mill Pollutants, Their Monitoring and Measurement Techniques

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The pulp and paper industry utilizes various raw materials, such as forest based and non-forest based (agricultural residues, grasses etc.) species. Some of the non-forest based are renewable in nature. Such species include bagasse, rice straw, wheat straw, jute, hemp etc. For integrated mill the weight of major inputs, outputs and wastes per tonne of paper can be given below:

Raw materials (Bamboo/ wood etc.) 2.75-3.0 t/t, coal 1.5-2.0 t/t; chlorine 150-200 kg/t; lime 500-600 kg/t; sodium sulphate 125-150 kg/t; talcum powder/chemicals 150-200 kg/t; other chemicals (alum/ Rosin etc.) 75-200 kg/t- total 5.250-6.250 t/t.

To produce pulp and paper out of these raw materials various chemicals are employed. Some materials/ chemicals are also being discharged as by product or as refuse in form of gases, liquids or solids are mostly potential pollutants.

SOURCES OF POLLUTION

From material balance of wood for manufacture of paper by kraft process it is observed that about 41.8% of wood is recovered as bleached pulp of the remaining wood, roughly 4.2% ends up as solid waste, 5.25% goes into waste waters as dissolved organic matter and 2.3% goes as suspended solids in waste water.

The potential pollutants from a pulp and paper mill fall into four principal categories as under:

(i) Solid Wastes:

- Sludges from primary and secondary treatment and causticizing in kraft mill recovery section.
- Solids such as grit bark and other mill wastes.
- Ash from coal fired boilers.

The gaseous emissions are released from digesters, chemical recovery

furnace, steam boiler, H_2S , SO_2 , SO_3 malodorous gases (like mercaptans Dimethyl sulphide, Dimethyl Disulphide). The order problem in kraft mills is essentially due to reduced Sulphur compounds.

(ii) Water Effluents:

- Suspended solids including bark particles, fibre, pigments, dirt and the like.
- Dissolved colloidal organics like hemicelluloses, sugars, lignin, compounds, alcohols, turpentine, sizing agents, adhesives like starch and synthetics which create BOD load.
- Colour bodies, primarily lignin compounds and dyes.
- Dissolved inorganic such as $NaOH$, Na_2SO_4 , bleach chemicals etc.
- Bleach plant effluents ($TOCl$, AOX , $TCDD$, BOD , COD etc.)
- Thermal loads.
- Microorganisms such as coliform group.
- Toxic chemicals if present.

(iii) Particulates:

- Fly ash from coal fired power boilers
- Chemical particles primarily Na and Ca based
- Char from bark burners

(iv) Gases:

- Idourous Sulphur gases such as mercaptans and H_2S released from various stages in Kraft pulping and recovery processes.
- Oxides of Sulphur from power plants, Kraft recovery furnace and lime kiln.
- Bleach plant emissions, Cl_2 , ClO_2 , O_3 , Chloroform etc.
- Steam since it can be hazardous when visibility is impaired/ lime kilns containing particulate matters.
- Other NCG (CO , CO_2 , Hydrocarbon, H_2S , HCl , HF etc)

Emission rates, kg/tonne of pulp from a chemical pulp bleaching are as under: Cl_2 :0.1-3, ClO_2 : 0.1-1 and SO_2 : 0.1-1

The statics of the pollution loads, norms and gravity standard instrumental techniques are given in Tables 1-19.

Parameter	Indian mills	Attainable	Integrated mill
Fibrous raw materials, Debarked wood/ Bamboo	2.2-3.0	1.4-1.7	2.75-3.0
Bagasse(50% moisture), t/t _{paper}	5.8-6.2	-	
Salt cake, kg/t	30-50	15-35	125-150
Caustic soda, kg/t	40-150	30-70	
Chlorine, kg/t	80-200	50-120	150-200
Alum, kg/t	50-150	20-80	
Lime, kg/t	350-500	250-400	500-600
Steam, kg/t	11-16.9	6.5-9.0	
Electrical power, kWh/t	1288-1985	1100-1300	
Coal, t/t	0.77-4.2		1.5-2.0
Water, m ³ /t	200-400	20-140	
Chemical recovery, %	80-88	95-98	
Man power, Nos /1000 annual t	50-120	10-15	

Table-2. Characteristics of combined Waste Waters from Pulp and Paper Mills.

Parameter	Large Paper Mills Range (Av)	Small Paper Mills	
		Agroresiduals based Range (av)	Waste Paper based Range (av)
Flow, m ³ /t paper	197-281 (220)	187-383 (252)	72-159 (107)
PH	6.6-10	6-8.5	7.1-7.7
S.S mg/l	620-1120 (764)	600-1115 (615)	350-885 (542)
BOD ₅ , 20°C, mg/l	240-380 (295)	220-1067 (698)	100-273 (187)
COD mg/l	840-1660 (1118)	2120-4763 (2940)	472-876 (654)
COD/BOD	2.95-4.37 (3.8)	2.49-5.40 (4.2)	2.7-5.7 (2.4)
Colour Pt-CO unit	300-655	15000-24000	-
Lignin mg/l	-	320-700 (563)	-
SAR	2.0-6.3 (3.5)	4.7-7.6 (6.4)	-
Pollution Load kg/t Paper:			
SS	168	155	58
BOD	65	176	20
COD	246	741	70

Table-3. Solid Waste Generation in Paper Mills

Waste Source	Kg Dry Solid tonne paper	
	Large Paper Mills	Small Paper Mills
Raw material handling Preparation	45	210 for Straws (550 for Bagasse)
Hypochlorite preparation grit	20	-
Recausticizing lime mud	593	-
Power plant/Boiler ash	656	1300
Waste water treatment plant:		
Primary sludge	159	116
Secondary sludge	34	105
Total	1507	1731 (2071)
% organic solids	16	25 (35)
% Inorganic solids	84	275 (65)

Table 4. Heavy Polluting Industries Stack Emissions (Permissible concentrations)

Parameter	Industrial area	Residential/Rural area	Sensitive
SPM mg/m ³	500	200	100
Dustment mg/m ³ (Fe, Zn, Cu, etc)	50	30	15
SO ₃ , H ₂ SO ₄ mist mg/m ³	100	50	20
SO ₂ PPM	500	200	100
CO PPM	100	50	30
HC PPM	50	30	15
NH ₃ PPM	100	50	20
F PPM	50	30	15
Mercaptan	10	10	10

Table-5. Moderate Polluting Industries Stack Emission (Permissible Concentration)

Parameter	Industrial Area	Residential/ Rural Area	Sensitive Area
SPM, mg/m ³	2000	1000	500
Iron Dust mg/m ³	1000	500	250
SO ₂ PPM	5000	2000	1000

Table- 6. Emissions from Large Pulp and Paper Mills

Particulate matter	250 mg/Nm ³ *
H ₂ S	10 mg/Nm ³
*To be reduced to 150 mg/NH ₃ after October 1992.	

Table -7. Emissions from Lime Kilns

Capacity of Kiln	Parameter	Standard
Upto 5 T/day	Particulate matter	A hood should be provided with a Stack of 30m height from ground level (including Kiln height)
5-40T/day	Particulate matter	500 mg/Nm ³
Over 40T/day	Particulate matter	150 mg/Nm ³

Table-8. Guide Lines for Maximum Stack Height

For All Plants Except Thermal. Power Plants	Stack Height min 30 m
1. For plants where SO ₂ emission is estimated as Q (kg/hr), stack height H in m is given by $H = 14 (Q)^{0.3}$ 2. For plants where particulate emission is estimated as Q (Tonnes/Hr) the stack height H in m is given by $H = 74 (Q)^{0.27}$ Maximum of the calculated value with a minimum of 30 m stack height should be used.	

Table-9. Quantum of Odourous Compounds from Paper Mill

	A ₀ g lb S/ton pulp	SO ₂	H ₂ S	RSHa	RSRa	RSSRa
Digester vent	2	1-785	16-18,800	0-4,370	3,850-65,000	0-65,000
Blow gases	4	10-1,050	0-782	0-9,840	522-46,900	0-10
Pulp washer	0.4	0.1-0.2	0-12	0-79	0	0.1-0.4
Evaporator						
Noncondensables	0.4	5-2,890	907-32,600	455-36,700	0-27,600	0-1,278
Recovery furnace	21	4-789	14-1,140	0-498	0-260	0-17
Smelt dissolving tank	0.6	0.5-70	10-44	0-212	0-91	0-4
Lime kiln	2.3	0-169	0-254	0-128	0-60	0-18
Tall oil cooking	1.0	2-822	5,400-101,000	0-4,660	0	103-769

Compound	Boiling point °C	Heat of combustion K. Cal/mole	Explosive concentration range in air %	Dissociation constant of ag. Solution at 100
H ₂ S	- 61.8	124	4.3 45.5	$K_1 = 2.1 \times 10^{-7}$ $K_2 < 10^{-14}$
CH ₃ SH	+ 58	299	2.2 9.2	$K = 4.3 \times 10^{-11}$
CH ₃ S CH ₃	+ 338	457	3.9 21.8	Not dissociated
CH ₃ S. SCH ₃	+ 118	530	Not determined	Not dissociated.

Table-11. Air quality standards for primary pollutants

Pollutant	Tolerance ppm	Levels µg/m ³	Relative toxicity
CO	9.0 (Not to be exceeded more than once/year for 8-hour period)	10,000	1,00
	35.0 (Not to be exceeded more than once/year for 1-hour period)	40,000	
Hydrocarbons		19,300	2.07
SO _x	0.50	1,430	28.00
NO _x	0.25	514	77.8
Particulates	-	375	106.7

Table-12. Threshold values of some common air pollutants

Pollutant	Values, ppm
CO	50
F	1
HCL	5
HF	3
H ₂ S	10
Hydrocarbon	500
NO _x	5
O ₃	0.05
SO ₂	5

Table-13. Maximum Permissible Concentrations of certain impurities in Air as per Air Pollution Act.

Substances	Maximum concentration (mg/m ³)	
	Av. Over 24 h	At any instant
Dust (20% silica)	0.15	0.50
SO ₂	0.15	0.50
CO	2.00	6.00
NO _x	0.13	0.40
H ₂ SO ₄	0.10	0.30
Cl ₂	0.02	0.06
H ₂ S	0.005	0.015
Pb	0.0007	0.002
NH ₃	0.10	0.30
Hg	0.0003	0.001
HCl	0.02	0.06
Soot	0.05	0.15
F	0.01	0.03
Phenols	0.10	0.30

Table-14. Stack Emission Factors for Pulp and Paper Mills

Source	Unit	Control Equip.	Particulate Matter	SO ₂	SO ₃	H ₂ S	Mercapt
Digester:							
-Relief	Kg/t pulp	-	-	-	-	0.80	0.02
-Blow down	Kg/t pulp	-	-	-	-	1.97	0.04
Rec. Furnace	Kg/t BL	ESP	13.4-26.5 (0.93-8.53)	0.28 -0.63	0.09-0.17	0.06-7.8	0.08-0.1
Smelt dissolving tank vent	Kg/t BL	-	0.17	Negible	0.02-0.09	Negible	-
Limekiln	Kg/t Lime	Scrubbev	2.7-10.36	0.04-0.38	0.06-0.16	0.017	-
Power house boiler	Kg/t coal	Multi Cyclone	47.7-49.45 (3.82-20.76)	1.16-10.8	0.04-9.83	-	-

Table-15. Effect of Exposure to various levels of NO₂ on human health

Level of NO ₂ , ppm	Duration of exposure	Effects on human health
50-100	Up to 1 hour	Inflammation of lung tissue for 6-8 weeks
150-200	-	Bronchiolitis fibrosa obliterations-fatal result within 3-5 weeks of exposure
500 or more	2-10 days	Death

Table-16. Effect of continuous exposure to various levels of carbon monoxide

CO level, ppm	% Conversion of O ₂ Hb to COHb	Effect on humans
10	2	Impairment of judgement and visual perception
100	15	Headache, dizziness, weariness
250	32	Loss of consciousness
750	60	Death after several hours
1000	66	Rapid death

Table-17. National ambient air quality standards

Pollutant	Averaging time	Primary standard
Carbon monoxide	8 h 1 h	10,000 µg/m ³ (9ppm) 40,000 µg/m ³ (35ppm)
Hydrocarbons ^a	3 h	160 µg/m ³ (0.24ppm)
Lead	Monthly avg.	1.5 µg/m ³
Nitrogen dioxide	Annual avg. 1 h	100 µg/m ³ (0.25ppm) 500 µg/m ³ (0.25ppm)
Photochemical oxidants ^b	1 h	240 µg/m ³ (0.12ppm)
Sulfur dioxide	Annual avg. 24 h	80 µg/m ³ (0.3ppm) 365 µg/m ³ (0.14ppm)
Total suspended particulate	Annual geometric mean 24 h	75365 µg/m ³ 260365 µg/m ³

^aCorrected for CH₄.^bCorrected for SO₂ and NO₂.

Table 18. Instrumental techniques are given in Tables 1 - 19.

Pollutants	Instrumentals techniques
CO	IR spectrophotometry (non-dispersive), Gas chromatography
SO ₂	Spectrophotometry, Conductivity, Amperometry
NO _x	Chemiluminescence, IR spectrophotometry, spectrophotometry
Hydrocarbon	Gas spectrophotometry (GS-MS), IR spectrophotometry
NH ₃	Spectrophotometry, potentiometry
Polycyclic aromatic hydrocarbon	Gas chromatography (GC-MS)
Volatile compounds (e.r)	Gas chromatography (GC-MS)
H ₂ S	Uv molecular absorption
Particulate Matter	
Pollutants	Instrumentals techniques
Silicates	Chromatography
Polycyclic aromatic hydrocarbon	Chromatography
Fluorides	Potentiometry
Sulphates	Electron spectroscopy

Table-19. Element (Air/ Particular Matter)

Pollutants	Instrumental techniques
As	AAS, NAA, S, XRF
Be	AAS, S, ES
Cd	AAS, XRF, S, ES
Cr	AAS, NAA, XRF, ES
Cu	AAS, NAA, XRF, ES
Fe	AAS, NAA, XRF, ES
Mn	AS, NAA, XRF, SES
Pb	AAS, XRF, S, ES
Hy	AAS, (Flameless), NAA, ES
Zn	AAS, XRF, ES
Se	NAA, XRF, S
F	P

AAS-Atomic Absorption photometry
 NAA-Neutron Activation Analysis
 XRF- X-Ray fluorescence
 S- Spectrophotometry
 ES- Emission Spectroscopy

Fumes: more than 5% of the initial mass of black liquor solids, partially burnt liquid droplets, sodium and potassium volatile vapours forming Na₂SO₄, Na₂CO₃, NaCl, K₂SO₄, K₂CO₃, KCl etc.

HAZARDOUS GASES

Chlorine

Health Hazard

3.5 ppm gas	Odor detection limit
5-8 ppm gas	Severe irritation to eyes, nose and respiratory tract
30-50 ppm gas	Lethal in 1 h Local corrosive effects

Concentration of 50 ppm is dangerous even for a short period whereas 1000-ppm is fatal.

Chlorine di-oxide

Health Hazard

0.1 ppm	Permissible limit for 8 h exposure.
High concentration	Local corrosive effects

Ozone:

It is a powerful toxic substance. O₃ causes irritation of the eyes and respiratory tracts of human beings. It attacks mucous membrane and causes headache. Exposure to 50 ppm of ozone for several hours will lead to mortality due to pulmonary edema, i.e. accumulation of fluid in the lungs. At lower levels, ozone brings about nonlethal accumulation of fluid in the lungs and damage to the lung capillaries. Young animals and humans are more susceptible to

those toxic effects than older subjects.

Hydrogen sulphide: Highly poisonous- the presence of 1 part of the gas in 1000 parts of air causes death. Antidote of H₂S poisoning is dilute chlorine.

Nitrogen Oxides: NO_x

The effect of exposure to various levels of NO₂ is shown in Table.

Sulphur di-Oxide

Effect on Plants

SO₂ causes acid rains, which also damage plants, besides aquatic lives in rivers and lakes.

Carbon- Monoxide:

The characteristics of combined wastewaters from large and small paper mills are given in respective table. Bleach plant effluents constitute nearly 65% of total BOD and 90% of total colour load of combined effluents in large mills.

The high pollution load of small paper mills is due to non-recovery of chemicals from black liquor. Thus each tonne of paper produced in small paper mills (without chemical recovery using pulping) generates 2.60 times the pollution load discharged from a large paper mill with chemical recovery.

Lignin and its derivatives, responsible for the brown colour of wastewater, are not readily biodegradable and thus constitute recalcitrant pollutants. A number of toxic pollutants have been identified in wastewaters from pulp washing and bleaching operation. These include resin acids, chlorinated lignins, chlorofatty acids and chloroforms. Although these compounds exert toxicity to fish, they are readily biodegradable in the concentrations they are present in combined wastewater in aerobic biological treatment systems. Other toxic pollutants come from include tri and pentachlorophenols from slimicides and biocides. These compounds are now being replaced by other, non-toxic products. The waste water from chlorination stage produces significant mutagenicity (Ames test positive), which decreases linearly with increasing substitution of ClO_2 for equivalent chlorine in bleaching. Much of the mutagenicity is lost when wastewater pH is raised to 7-8. Since bleaching effluents are neutralized before treatment or discharge to receiving media, water mutagenicity is destroyed before entering the environment.

Solid wastes constitute a complex problem in the industry due to the varying nature and enormity of the wastes generated. Table shows the quantity of solid waste generated per tonne paper.

The environmental management in pulp and paper industry is to run the mill optimally to minimize the generation of wastes and maximize recycle/reuse of residues/products through good housing and improved

operational practices. The country has set up discharge standards and the environmental authorities are responsible for ensuring that these standards are met. Mills are required to adopt strategies to meet the standards. These are developed based on mill audit of the discharges.

GAS EMISSIONS

The monitoring of gas emissions can be at source (stack) or in the vicinity of recipient for pollutant concentration. The major steps involved are collection of a representative sample and accurate analysis. Sampling is done by a sampling train and analysis is done by various chemical/ instrumental methods.

After assembling the collection equipment (train) at place of measurement, a known volume of the gas is drawn through sampling train. After pretreatment, the flow is measured. The sampling probe can be single or two tube probes made of either glass or SS or Teflon or titanium with 90° bend. The collection equipment has absorption of gas in liquids or solid surfaces or follow freezing or collection in grab collection bottles. The flow measurement is done after filtering and drying gas through a meter (orifice/rotameter or dry gas meter). The prime movers are usually a source to cause vacuum leading to gas flow.

Particulates measurement is more difficult -and one uses isokinetic samplers. For finding ground level concentration values one must get meteorological data relating to wind speed and wind direction besides emission data.

Gas discharge characterization is more difficult.

The environmental audit requires fair skills at sample collections flow measurements and analysis. Reliability and accuracy are of concern. The skill required to correlate environmental parameters to process parameters takes time to develop. These audits are necessary

to keep a mill in good health..

POLLUTION CONTROL

The air pollution control needs are split between process and combustion sources. The process sources consist of NCG controls, pulp mill wastewater treatment, and bleach plant vent scrubbing (bleached pulp mill only). The combustion sources consist of HCl scrubbing of recovery boiler flue gases, and black liquor oxidation controls (BLOX if it at all exists)

Steps to consider for Control:

- Step 1: Identify each source of Emissions
- Step 2: Determine actual and potential emissions
- Step 3: Determine applicable emission limits
- Step 4: Determine whether emissions comply with all applicable limitations
- Step 5: If necessary, propose a compliance schedule
- Step 6: Propose measurement, record keeping and reporting methods
- Step 7: Select an appropriate equipment and operation to meet the target

Control of Pollutants:

SOx : There are four possible approaches to the removal and control of SOx emissions:

- Removal of SOx from flue gases, example chemical scrubbers with CaCO_3 or Citrate ions
- Removal of sulphur from fuel before burning
- Use of low sulphur fuels
- Substitution of other energy sources for fuel combustion

Monitoring Techniques:

The selection of a monitoring techniques for a component and its integration into a multicomponent monitoring system can have a significant effect on the accuracy of the results. Factors to be considered when selecting a monitoring techniques include:

ACCURACY AND PRECISION

Reliability

Ease of operation and maintenance

Sample conditioning requirement

Cost

Some of the main species requiring monitoring are listed below:

Particulates:

1. Sulphur Dioxide (SO₂)
2. Nitrogen Oxides (NO_x)
3. Oxygen (O₂)
4. Carbon Monoxide (CO)
5. Hydrogen Chloride (HCL)
6. Hydrogen Fluoride (HF)
7. Organic Compounds
8. Heavy Metals (e.g Lead, Cadmium, Copper, etc)
9. Dioxins, Furans

Traces species:

Standard wet chemical techniques are used to measure such species as HCL and HF. This involves bubbling a measured volume of gas through solution which absorb HCL and HF and then determining their concentration by ion chromatography analysis. Fuel gases are sampled iso-kinetically and heavy metals are removed in a cyclone and filter or by bubbling through a solution of nitric acid. The total heavy metals concentration (i.e. solid and vapors phase) is obtained by analysis of the collected solids and solution. To sample for dioxins and furans, toluene is used instead of nitric acid.

Particulates:

Optical density instrument, undergo periodic calibration using this as a reference method. A modified version of this equipment is used for high temperature particulates sampling which is sometimes required for incineration plant. Most continuous gas analysis equipment is complicated and fragile and not suited to handling contaminated gases or to operating in often-hostile environment of process plant. Continuous gas analysis equipment within a mobile laboratory has now

been in use now a day. All filters and samples lines are heated to prevent consideration of moisture or hydrocarbons which can have a significant effect on.

TECHNIQUES FOR THE ABATEMENT OF NO_x EMISSION:

The requirement for control of emission of NO_x are determined by the uncontrolled emission and the applicable legislative limit. Several oxides of nitrogen are formed during combustion, although normally only two, nitric oxide (NO) and nitrogen dioxide (NO₂), are present in significant quantities. In general more than 90% of NO_x is present as NO. The formation of NO_x during combustion is dependent primarily on the fuel and firing method, and in particular combustion temperature and oxygen concentration. It is generally accepted that, during combustion, three processes are responsible for the formation of oxides of nitrogen: those produced by the oxidation of nitrogen bounded in the fuel are known as fuel NO_x; those from oxidation of nitrogen present in the combustion air are termed 'thermal NO_x'; and those produced by the reaction of atmospheric nitrogen and hydrocarbon radicals from the burning fuel are called 'prompt NO_x'. Fuel NO_x is the major source of NO_x from coal combustion.

Control of NO_x emission:

Since the formation of NO_x in combustion system is largely dependent on the firing method rather than the nitrogen content of the fuel, fuel switching from a higher to a lower nitrogen, could at best play only a minor role in reducing emissions. These are not viable options. In practice there are two options available for controlling NO_x emission, (a) Modification to the combustion system, and (b) Treatment of the flue gases. Normally the best approach is to concentrate first on combustion system because this is generally recognized as the lower cost approach. If further

reductions are necessary, the flue gases may need to be treated. However, this is relatively expensive in terms of both capital and operating cost.

NCG CONTROLS

NCGs take two forms: HVLC (e.g., liquor tank and wash hood vents) and LVHC (e.g., evaporator and digester vents). The cluster Rule proposed treatment requirements for NCGs are as follows:

1. Reduce total HAP emissions by at least 98% by weight, or, if an incinerator is used, reduce total HAP emissions by at least 98% by weight, or, meet an outlier concentration of 20 ppm by volume of total HAP
2. Route all emission point gas streams to an incinerator designed and operated at a minimum residence time of 0.75 seconds and at a temperature above 1600°F
3. Route all emission point gas streams to a boiler, lime kiln, or recovery furnace, which introduces all emission point gas streams with the primary fuel or into the flame zone.

The major concerns with the NCG system are installing properly sized condensers, brown stock washer hood selection, and selection of incineration source ideal LVHC: lime kiln/ideal HVLC: bark boiler.

The HVLC system cost is driven by duct size and length. By properly sizing the condenser(s), the minimum economical duct size can be determined for the gas streams collected.

The total volume of the HVLC system is driven by the brown stock washer filtrate tank and hood emissions, the NCG; volumes from the brown stock washers and their filtrate tanks vary as follows:

- Vacuum drum washers: 1500-4000 ft/min per washer
- Pressure washer: 600-1000 ft/min per washer
- Belt washer: 4000-6000 ft/min per system

MONITORING OF LIQUID EFFLUENTS

1. Colour

- Visual Comparison Method- Pt-Co method of measuring colour is the standard method
- Spectro-photometric method
- Tristimulus Filter method

2. Turbidity

- Nephelometric Method
- Visual Method- Jackson Method

3. Temperature

4. Toxicity

5. Taste

- Taste Threshold Test
- Taste Rating Test

6. Odour

7. Inorganic analysis

- Acidity
 - Alkalinity
 - pH
 - Dissolved solid
- a) Argentometric method.
 - b) Mercuric Nitrate Method
 - c) Potentio metric method
 - d) Automated Ferriccyanide method
- Nitrogen- Ammonia
 - Sulfides
 - Heavy Metals

8. Organic Analysis

- BOD
- COD
- Total Organic Carbon (TOC)

9. Characterization of solid fraction

- General sludge

characteristics

- a) Sludge settling characteristics
 - b) Sludge volume index
- 1) MLSS
 - 2) MLVSS
 - 3) Sludge specific resistance
 - 4) Compressibility coefficient
- Chemical composition of sludges
 - Biological characteristics of sludges

10. Sampling of effluent

INSTRUMENTAL TECHNIQUES FOR AIR POLLUTANTS

Gaseous Air Pollutants

Analysis of particulate method:

The standard method for particulates in the high volume method uses a high volume sampler. Samples analyses are detailed in standard method of analysis.