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# DEVELOPMENT OF STANDARDS FOR RUBBER PRODUCTS MANUFACTURING INDUSTRY



**CENTRAL POLLUTION CONTROL BOARD  
MINISTRY OF ENVIRONMENT & FORESTS**

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April 2007

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**Central Pollution Control Board**

(A Govt. of India Organisation)

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## FOREWORD

The Central Pollution Control Board (CPCB) brings out publications entitled "Comprehensive Industry Document series (COINDS)" based on the industry-wise studies. These reports are intended to cover various aspects of different types of industrial units in the country with respect to their number, locations, capacities, types of product, usage of raw materials, process adopted, waste minimisation, pollution prevention and control measures. The Minimal National Standards (MINAS) have been evolved as a result of the COINDS, which could be achieved by the industry techno-economically. The present report entitled "The Comprehensive Industry Document for Rubber Products Manufacturing Industries" is latest one being published by the CPCB.

The study for the report was conducted on behalf of the CPCB by M/s Consulting Engineering Services (CES), New Delhi. The help and assistance extended by the State Pollution Control Boards, rubber products manufacturing units and All India Rubber Industries Association during the conduct of this study are gratefully acknowledged. Shri Ajay Aggarwal, EE and Ms. Pavithra L.J. AEE, coordinated the activities to develop the standards. Shri T Venugopal, Director, Shri R. C. Saxena, SEE and Ms. Pavithra L.J., have put efforts in preparing this volume under the guidance of Dr. B. Sengupta, Member Secretary.

It is hoped that this report would be useful to the rubber industry, regulatory agencies, consultants and others interested in pollution control.

J. M. Mauskar  
Chairman

April, 2007

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## CHAPTER- 1

### RUBBER PRODUCTS MANUFACTURING INDUSTRY: AN OVERVIEW

#### 1.1 INTRODUCTION

Since the establishment of the first rubber products manufacturing unit in 1921, the Indian rubber products manufacturing industry has undergone remarkable growth and expansion, particularly during the post-independence era. It has achieved overall development by increasing its size, spatial distribution, technological sophistication and more prominently the wide range of products manufactured. Besides its self-sufficiency by catering to the entire domestic demand, the industry has broken new barriers on the export front as well. This chapter gives an overview on rubber and rubber products, their production, classification, distribution and consumption pattern, their imports and exports.

#### 1.2 INDUSTRY STRUCTURE

The rubber product manufacturing industry in India is basically divided into two major sectors: tyre and non-tyre. The tyre sector produces all types of automotive and non-automotive tyres whereas the non-tyre sector produces high technology and sophisticated products and comprises the medium scale, small scale and tiny units. Barring industries engaged in raw rubber production, there are approx. 4800 rubber based product manufacturing units comprising 30 large scale, 300 medium scale and around 4470 SSI and tiny sector units, employing four lakh people, including around 22000 technically qualified support personnel, with a turnover of 200 billion rupees and contributing 40 billion rupees to the National Exchequer through taxes, duties and other levies. Rubber products industry thus plays a core sector role in the Indian national economy (AIRIA, 2003).

#### 1.3 RUBBER PRODUCTS INDUSTRIES IN INDIA

##### 1.3.1 Industry Scenario

Indian Rubber industry is well established and self sufficient in all respect i.e. Natural Rubber, all ingredients, Machinery, Technical manpower etc. Only deficiency is in the area of Synthetic Rubber, majority of which is imported to meet the requirement. Rubber industry of the country has developed to a modern state in case of organized sector companies like tyre and some of the non-tyre units but the conditions with majority of small scale units are far from satisfactory level.

During last three decades industry has been adopting modern technology and upgrading the machinery and process as well as employing qualified persons. Some of the educational institution like IIT, Kharagpur & Delhi, MIT, Chennai, MG University, Kottayam and some of the Polytechnic & Organizations are imparting education in the field of Rubber Chemistry & Technology, which is useful to the industry.



There are many automotive tyre manufacturing units in the country of which major groups are MRF Tyre (Chennai based), Apollo Tyre (Delhi based), J.K. Tyre (Delhi based) & Goodyear (Delhi based) are the main tyre companies having multiple units at different places of the country. For example MRF has eight units spread over in Tamilnadu, Kerala, Andhra Pradesh & Goa. Similarly Apollo has units in Kerala, Baroda, and Pune whereas J.K. Group has Plants in Rajasthan & Madhya Pradesh.

### 1.3.2 Distribution of Industries

#### 1.3.2.1 Geographical Distribution

There are more than 4800 rubber products manufacturers in the country. Northern India (Delhi, Haryana & Punjab) accounts for major rubber consumption (approx. 40% of National Consumption) and have maximum number of rubber products manufacturing units, primarily in small & medium scale. Other major States in this sector are Kerala, Tamilnadu, Andhra Pradesh, Gujarat & Karnataka.

A state wise distribution of manufacturers for the period 1999-2005 is given in Table 1.1.

**Table 1.1 Production Units - By State-wise (Nos.)**

State/Union Territory	99-00	00-01	01-02	02-03	03-04	04-05
Kerala	974	891	906	854	851	896
Maharashtra	623	612	624	578	563	542
Punjab	552	554	539	522	478	472
Tamil Nadu	506	502	503	486	483	483
Uttar Pradesh	450	438	439	439	430	435
West Bengal	484	447	437	435	409	403
Gujarat	395	378	377	381	368	374
Haryana	311	289	307	324	324	332
Delhi	297	276	242	220	206	195
Karnataka	249	229	219	203	194	199
Andhra Pradesh	140	139	155	160	160	160
Rajasthan	92	87	99	111	109	111
Madhya Pradesh	91	88	86	82	77	74
Goa	28	25	31	33	33	26
Jharkhand (Bihar)	33	34	28	27	27	25
Orissa	16	14	13	13	12	10
Others	62	59	61	63	37	34
<b>Total</b>	<b>5303</b>	<b>5062</b>	<b>5066</b>	<b>4931</b>	<b>4791</b>	<b>4800</b>

Source: Rubber Board

From the above Table it can be seen that Kerala has the highest number of production units. It is also observed that total number of production units in the country has decreased every year from 1999 to 2004, except in the year 2004-2005, where a slight increase in the production units has been observed over previous year.

### 1.3.2.2 Size-Wise Distribution

A size-wise distribution of units is shown in Table 1.2 as below

**Table 1.2 : Classification and Number of Industries**

S.N	Industries	Consumption Groups.	Natural Rubber Consumption (Tonnes/Year)	No.
1	Tiny	A	Up to and including 10 tonnes	1868
2	Small	B and C	Above 10 tonnes and up to and including 100 tonnes	2443
3	Medium	D and E	Above 100 tonnes and up to and including 1000 tonnes	427
4	Large	F	Above 1000 tonnes	62
<b>Total</b>				<b>4800</b>

Source: Rubber Board

### 1.3.2.3 Product-Wise Distribution

A wide variety of rubber products are produced all over the country. Footwear production units are highest in number and Modified Form of Rubber production units are the least.

Rubber industry is scattered all over country, practically in all states, including J & K. Over last two decades, growth of rubber industry had been primarily in north & south of the country and decline in eastern part. Also from main centres like Calcutta & Mumbai due to closures and shifting of major units (e.g. Dunlop, MRF etc. in Calcutta & Firestone / Modistone in Mumbai) these centres have lost their earlier importance. New tyre units have grown in size and volume in north (e.g. JK & a number of medium size tyre units like Superking, Malhotra, Radhu, Speedways, Asian, Ralson etc.) and south (Vikrant, Falcon, MRF units, Excel, Rado etc.) and west (Baroda, Pune).

Kerala, the main centre of Natural Rubber (NR) production in the country, has developed much over the years as manufacturer of rubber products – Auto & Cycle tyre and Tube, Tread Rubber, Shoe & Hawaii and Latex products.

## 1.4 Production Statistics

### 1.4.1 Rubber Consumption

#### a) State-wise Rubber Consumption

Statistics on State wise Rubber Consumption of Natural, Synthetic and Reclaimed Rubber for the year 2004-05 is given in **Tablet 3**

**Table 1.3: State-Wise Consumption of Rubber (2004-05)**

(In Metric Tonnes)

State/Union Territory	Type of Rubber					
	Natural	Share (%)	Synthetic	Reclaimed	Total	Total (%)
Kerala	124554	16.5	49746	7895	182195	17.3
Maharashtra	97076	12.9	40528	11533	149137	14.2
Punjab	81573	10.8	9228	17406	108207	10.3
Uttar Pradesh	33200	4.4	7231	4118	44549	4.2
West Bengal	34765	4.6	10511	3970	49246	4.7
Tamilnadu	37596	5.0	14999	5194	57789	5.5
Haryana	47665	6.3	8919	1550	58134	5.5
Rajasthan	47035	6.2	9990	1511	58536	5.6
Gujarat	46839	6.2	10935	1977	59751	5.7
Karnataka	49192	6.5	16242	6671	72105	6.8
Andhra Pradesh	36533	4.8	11489	4898	52920	5.0
Madhya Pradesh	31308	4.1	16826	3556	51690	4.9
Goa & Daman	36625	4.8	7860	1021	59751	5.7
Orissa	28212	3.7	5875	258	34345	3.3
Delhi	16580	2.2	2036	1150	19766	1.9
Pondichery	2904	0.4	1769	138	4811	0.5
Jharkhand	1112	0.1	299	163	1574	0.1
Others	2636	0.3	167	51	2854	0.3
<b>Total</b>	<b>755405</b>	<b>100</b>	<b>224650</b>	<b>73060</b>	<b>1053115</b>	<b>100</b>

Source: Rubber Board

Kerala is the highest consumer of natural, synthetic and reclaim rubber closely followed by Maharashtra similar as in the case of production units.

**b) Product wise Rubber Consumption**

Table 1.4 and 1.5 show the statistics on rubber consumption with respect to end product.

**Table 1.4: Rubber Consumption According to End Product (Tonnes)**

Product	98-99	99-00	00-01	01-02	04-05
Auto Tyres & Tubes	357017 (44.5)	393933(45.8)*	389551 (45)	385242 (44)	519024 (49.29)
Cycle Tyres & Tubes	117802 (14.7)	116504 (13.5)	116120 (13.4)	119577 (13.6)	127095 (12.07)
Camel Back	48558 (6)	50004 (5.8)	50843 (5.8)	51565 (5.8)	56201(5.34)

Product	98-99	99-00	00-01	01-02	04-05
Footwear	99884 (12.5)	106530 (12.4)	109934 (12.7)	113485 (12.9)	120079 (11.40)
Belts & Hoses	48024 (5.9)	49306 (5.7)	50076 (5.8)	52667 (6)	56683 (5.38)
Latex Foam	31352 (3.9)	31762 (3.7)	31620 (3.6)	32536 (3.7)	32973 (3.13)
Cables & Wires	4113 (0.5)	4159 (0.5)	4227 (0.5)	4243 (0.5)	4548 (0.43)
Battery Boxes	14541 (1.8)	14452 (1.7)	14231 (1.6)	14266 (1.6)	14764 (1.40)
Dipped Goods	28103 (3.5)	29898 (3.5)	32081 (3.7)	32381 (3.6)	33898 (3.22)
Others	61641 (6.7)	62232 (7.4)	65722 (7.9)	70653 (8.3)	87694 (8.33)
<b>Total</b>	<b>811035</b>	<b>858780</b>	<b>864405</b>	<b>876615</b>	<b>1052960</b>

Source: Rubber Board

\* Value in parenthesis gives % of rubber consumption.

**Table 1.5: Consumption of All Types of Rubber According to End Product in 2004-(MT)**

S. N.	Product	2004-2005			
		NR	SR	RR	Total
1.	Auto Tyres & Tubes	379260(50.21)	124146(55.26)	15618 (21.42)	519024(49.29)
2.	Cycle Tyres & Tubes	68627(11.76)	17341(7.72)	20927(28.70)	127095(12.07)
3.	Camel Back	40739(5.39)	11138(4.96)	4324(5.93)	56201(5.34)
4.	Footwear	74736(9.89)	38042(16.93)	7301(10.01)	120079(11.40)
5.	Belts & Hoses	41443(5.49)	10497(4.67)	4743 (6.51)	56683(5.38)
6.	Latex Foam	32973(4.36)	0	0	32973(3.13)
7.	Cables & Wires	1830(0.24)	1842(0.82)	876(1.2)	4548(0.43)
8.	Battery Boxes	1828(0.24)	2738(1.22)	10198(13.99)	14764(1.40)
9.	Dipped Goods	33899(4.49)	0	0	33899(3.22)
10.	Others	59870(7.93)	18906(8.42)	8918(12.23)	87694(8.33)
	<b>Total</b>	<b>755405(71.7)</b>	<b>224650(21.3)</b>	<b>72905(6)</b>	<b>1062960 (100%)</b>

Source: Rubber Board

Value in parenthesis gives % of rubber consumption

Auto Tyres and Tubes are the major products registering highest rubber consumption. Total rubber consumption was continuously increasing during the period 1999-2005. Going by share of rubber consumption, automotive tyre sector is the single largest sector accounting for about 50% consumption of all kinds of rubber, followed by bicycles tyres and tubes 12%, footwear 11%, belts and hoses 5%, camel back and latex products 8%. All other remaining rubber products put together account for 14%.

c) **Sector wise Rubber Consumption**

Sector wise (in terms of Tyre Sector and Non-Tyre Sector) consumption of Natural, Synthetic, Reclaimed and total rubber is shown at Table 1.4. Consumption in Tyre Sector is higher than that of Non-Tyre Sector in case of Synthetic and Reclaimed Rubber, whereas in case of Natural rubber, consumption is higher in Non-Tyre sector than that of Tyre Sector. Overall consumption of rubber is increasing with an average growth rate 4.4 % per year during period 2000-05.

**Table-1.6: Sector-wise Rubber Consumption (Metric Ton)**

Rubber/Sector	2000-01	2001-02	2002-03	2003-04	2004-05
<b>NATURAL RUBBER</b>					
Tyre Sector	305718	304425	353032	378070	406226
Non-Tyre Sector	325757	333785	342393	341530	349179
<b>SYNTHETIC RUBBER</b>					
Tyre Sector	98362	95277	107483	119431	131267
Non-Tyre Sector	72308	79253	87367	90759	93383
<b>TOTAL (NR + SR)</b>					
Tyre Sector	404080	399702	460515	497501	537493
Non-Tyre Sector	398065	413038	429670	432289	442562
<b>RECLAIM RUBBER</b>					
Tyre Sector	13256	12925	16138	18284	19908
Non-Tyre Sector	49004	50950	51182	52176	52997
<b>TOTAL (NR + SR + RR)</b>					
Tyre Sector	417336	412627	476653	515785	557401
Non-Tyre Sector	447069	463988	480942	484465	495559
<b>GRAND TOTAL</b>	<b>864405</b>	<b>876615</b>	<b>876615</b>	<b>1000250</b>	<b>1052960</b>

Source: International Rubber Study Group (IRSG)

The Percent Ratio of Synthetic Rubber consumption to Natural Rubber consumption in major consuming countries is shown in Table 2.9, where it is seen that Synthetic Rubber consumption is lowest in India with respect to Natural Rubber during the period 1999-2002.

**Table-1.7: The Percent Ratio: SR to NR Consumption – Major Consuming Countries**

S. N.	Country	1996 (%)	1997 (%)	1998 (%)	1999 (%)	2000 (%)	2001 (%)	2002 (%)
1	Russian Federation	96.5	98.0	98.4	96.7	93.8	94.1	96.7
2	Germany	72.0	70.4	70.2	71.4	71.7	71.4	71.2
3	France	70.5	68.4	66.8	63.2	60.9	62.2	67.0
4	USA	68.6	69.0	67.0	66.5	64.7	65.4	63.2
5	Japan	61.1	62.0	61.2	60.7	60.2	59.8	59.6
6	China	51.8	52.2	54.4	60.1	57.4	56.5	57.2
7	Brazil	64.3	65.8	61.8	62.7	58.5	59.9	56.8
8	Rep of Korea	59.5	57.3	49.4	54.2	53.5	52.9	54.1
9	Malaysia	16.4	20.4	19.1	22.3	21.6	22.5	25.9
10	India	20.2	21.7	21.1	21.0	21.2	21.4	22.0

Source: International Rubber Study Group (IRSG)

India is the third largest producer, fourth largest consumer of natural rubber and fifth largest consumer of natural and synthetic rubber together in the world. Besides, India is the world's largest manufacturer of reclaim rubber.

In spite of being the third largest producer of rubber, per capita consumption is lowest in India among the major rubber consuming countries. Table 1.6 shows the per capita consumption of rubber in major consuming countries. This envisages tremendous growth pockets of the industry in the years to come as India is far from attaining any saturation level, so far as consumption of rubber products is concerned.

**Table-1.8: Per Capita Consumption: Major Consuming Countries (Kg)**

S. N.	Country	1996	1997	1998	1999	2000	2002	2004
1	Japan	14.62	14.93	14.42	14.76	14.89	14.48	15.32
2	France	10.59	10.39	11.46	11.62	13.42	11.76	10.84
3	Canada	12.05	12.88	12.74	11.87	12.46	12.24	11.65
4	USA	11.86	12.61	12.74	11.83	11.84	10.46	10.37
5	Germany (FR)	8.19	6.72	9.47	10.11	10.84	10.42	10.29
6	Italy	6.81	7.08	7.37	7.34	7.39	6.80	6.96
7	UK	5.82	6.12	5.46	5.43	5.45	4.75	4.97
8	Australia	5.8	5.5	5.47	5.17	4.91	3.50	3.68
9	Brazil	2.82	2.94	2.94	2.9	3.34	3.32	3.76
10	China	1.36	1.56	1.46	1.69	1.99	2.39	3.12
11	India	0.7	0.76	0.76	0.79	0.81	0.83	0.91

Source: Rubber Board

Production of major Rubber Goods in Organised (Non-SSI) Sector is shown in Table-1.7, where it is seen that tyre production is maximum among other major rubber products and it was continuously increasing during the period of 1999-2005. In non-tyre sector, production of conveyor belting has gone up by 20.89% during the year 2004-05 while production of contraceptives has gone down by 5.78%.

**Table1.9: Production of Major Rubber Goods in Organised (Non-SSI) Sector**

Product	Unit	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Auto Tyres	Mil Nos.	35.72	35.78	36.14	36.86	35.02	37.13
Giant Tyres	Mil Nos.	11.87	11.87	10.72	12.67	12.75	12.40
Car Tyres	Mil Nos.	6.05	6.81	7.48	8.51	9.95	11.86
Auto Tubes	Mil Nos.	30.90	N.A.	N.A.	N.A.	NA	NA
Giant Tubes	Mil Nos.	6.60	6.57	6.23	7.24	7.54	7.81
Car Tubes	Mil Nos.	3.90	N.A.	N.A.	N.A.	N.A.	N.A.

Product	Unit	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Cycle Tyres	Mil Nos.	12.89	12.74	23.57	33.56	50.09	71.85
Cycle Tubes	Mil Nos.	15.65	13.67	13.77	32.79	48.15	69.05
Footwear	Mil Pairs	23.80	16.49	18.90	20.22	20.51	27.45
Conveyor Belting	M.T.	12669	3791	16955	14500	19425	23483
Hoses (Other Types)	Mil Mtrs.	3.15	0.98	1.27	2.06	2.28	3.19
Contraceptives	Mil Nos.	1243.20	1470.40	2703.70	2381.40	2061.87	1942.50

**Note:** As advised by Govt., the figures may undergo changes based on factual reporting  
(Source: ATMA, Rubber Board, Ministry of Industry)

Mil Nos: Million Numbers

## CHAPTER 2

### PRODUCT MANUFACTURING PROCESSES

#### 2.1 INTRODUCTION

This chapter describes the main industrial processes employed within the rubber products manufacturing industry. It specifically contains a description of commonly used production processes, associated raw materials and possible sources of effluent and emission. Schematic process flow diagrams are suitably depicted to make the descriptions more illustrative.

#### 2.2 BASIC PROCESSES

Rubber product manufacturing is as diverse as the number of rubber products produced. Even with this diversity, several basic common processes are identifiable. These common processes are:

- Mixing
- Milling
- Extruding
- Calendaring
- Building (Fabrication)
- Vulcanizing
- Finishing

The rubber product manufacturing process begins with the production of a rubber mix from raw and / or synthetic rubber, carbon black (the primary filler used in making a rubber mixture), oils and miscellaneous chemicals. Rubber mixture differs depending upon the desired characteristics of the products being manufactured. Production of the rubber mixture involves weighing and loading of appropriate ingredients into an external / open mixer known as a "Banbury" mixer which is used to combine these ingredients. The area where the chemicals are weighed and added to the machine is called the compounding area. The ingredients are often introduced into the mixer hopper manually. The mixer creates a homogeneous mass of rubber using two rotors, which shear materials against the wall of the machine's body. This mechanical action also adds considerable heat to the rubber.

The mixed rubber mass is discharged to a mill (rubber sheeting mill) or other pieces of equipment which forms it into a long strip or sheet. The hot, tacky rubber thus passes through water based "anti-tack" solution, dry power, which prevents the rubber sheets from sticking together as they cool to ambient temperature. The rubber sheets are cooled through the application of cool air or by contact with cooling water. The process of rubber mixture includes all these steps – Banbury mixing, Milling (or other means of sheeting), Cooling and Anti-tack coating.



After cooling, the sheets of rubber are passed through another mill. These mills are used to "Warm-up" the rubber for further processing on extruders and calendars. Some extruders can be "Cold fed" rubber sheets, making this milling step unnecessary.

Extruders transform the rubber into various shapes or profiles by forcing it through dies via a rotating screw. Extruding heats the rubber and the rubber remains hot until it enters a water bath or spray conveyor where cooling takes place. Calendars receive hot strips of rubber from mills and squeeze them into reinforcing fibers or cloth-like fiber materials, thus forming thin sheets of rubber coated materials. Calendars are also used to produce non-reinforced, thickness-controlled sheets of rubber.

Extruded and calendared rubber components are combined (layer, built-up) with wire, polyester and other reinforcing materials to produce various rubber products. Adhesives, called cements, are sometimes used to enhance the bonding of the various product layers. This fabrication, reinforcing, pre-curing and bonding process is referred to as building.

All rubber products undergo vulcanization (curing). Vulcanization is accomplished in heated compression moulds, steam heated pressure vessels (autoclaves), hot air and microwave ovens or various molten and fluidized bed units. During the curing process, the polymer chains in the rubber matrix cross-link to form a final product of durable elastic, thermo set rubber. Increasing the numbers of cross-links in the rubber matrix gives rubber its elastic quality.

Finishing operations may include grinding, printing, washing, wiping and buffing.

**Fig-2.1** illustrates the basic processes sequentially in the manufacture of the various rubber products. Inventory of unit process operations in rubber product manufacturing is given in **Annexure 1.1**.

As indicated, due to the diversity of products and facilities all the processes shown in **Fig-1.1** are not necessary for every product. The major product specific processes and its associated possible sources of contaminants are discussed in the following sections. In order to have a clear understanding of process and its associated pollution aspects, it is imperative to have insight of raw materials and its recipe generally used in rubber processing industries. This issue has been taken up before describing the detailed product specific processes.

## **2.3 RAW MATERIALS**

The basic ingredients used in rubber processing industry are elastomer in the form of natural, synthetic and reclaimed rubber, carbon black and crumb rubber as filler, oils and miscellaneous chemicals. Natural rubber originates from the sap of the rubber tree, which is extracted and solidified by acidification. Synthetic rubber is manufactured from a product of petroleum cracking. The miscellaneous chemicals include processing acids, vulcanizing agents, activators, accelerators, age resisters, fillers, softeners and specialty materials. The following is a list of these miscellaneous chemicals and the functions they perform:

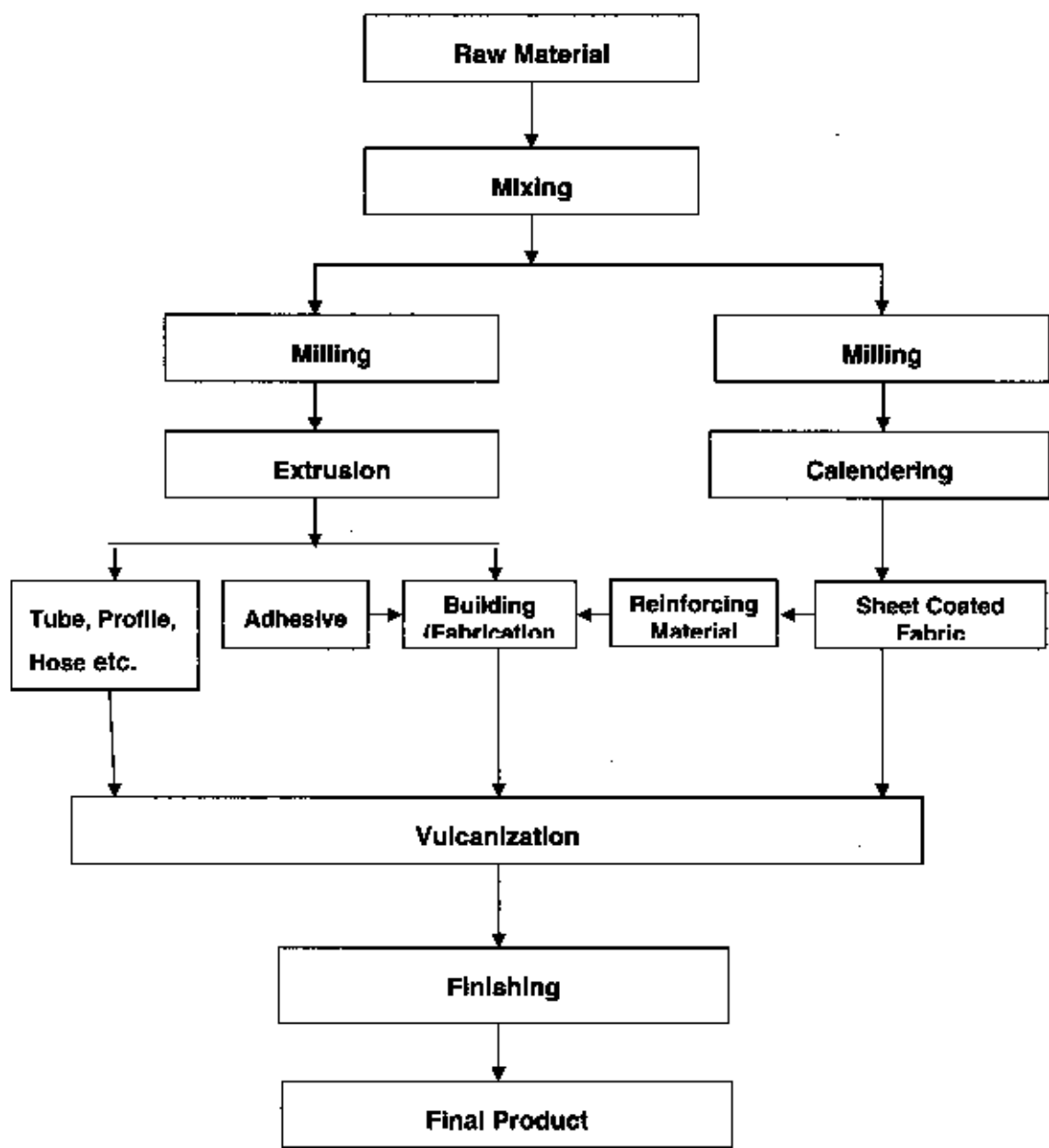


Fig. 2.1 General Process Flow Diagram for Manufacturing of Rubber Products

**Processing aids** such as – zinc compounds modify the rubber during the mixing or processing steps or aid in a specific manner during the extrusions, calendaring or moulding operations.

- **Vulcanizing agents** most commonly used as sulfur creates cross-link between polymer chains changing the thermoplastic to the elastic condition.
- **Activators**, in combination with vulcanizing agents, reduce the curing time by increasing the rate of vulcanization. Some of the common activators used are nickel compounds, hydroquinone, phenol, alphanaphthylamine and P-phenylenediamine.
- **Accelerators**, such as zinc compounds, ethylene, thiourea and diethanolamine form chemical complexes with activators and thus aid in obtaining the maximum benefits from the acceleration system by increasing vulcanization rates and improving the final product's properties.
- **Age resistors** such as selenium compounds, zinc compounds and lead compounds slow down the deterioration of the rubber products that occurs through reactions with materials that may cause rubber failure (i.e., oxygen, ozone, light, heat radiation etc.).
- **Fillers** such as carbon black, reinforce or modify the physical properties of the rubber, impart certain processing properties and reduce cost by decreasing the quantity of more expensive materials needed for the rubber matrix.
- **Softeners** aid in mixing, promote greater elasticity, produce tack or extend (replace) a portion of the rubber hydrocarbon (without a loss in physical properties).
- **Specialty materials** include retarders, colorants, blowing agents, dusting agents, adorents etc. Specialty materials are used for specific purposes and are not required in the majority of rubber compounds.

The compounding of rubber is necessary to develop required properties of the end product according to the customer need. Compounding of rubber means adding necessary ingredients to rubber to improve its basic qualities. The basic raw material list with typical proportion of raw material for a typical compound for each category is given in **Table-2.1**.

**Table-2.1 Raw Materials Types & Typical Consumption Pattern (Wt%)**

Category	A	B, C & D			E <sup>W</sup>		F
		Good <sup>o</sup>	Medium <sup>s</sup>	Low <sup>s</sup>	Wet	Dry	
Rubber (NR, SR, RR)	55 (NR+SR)	50-55	45-50 NR+SR+R+RR	30-40 (NR+RR)	167 (NR Latex 60%)	100 (NR Latex 60%)	88-90 (Crumb)
Filler (CB + Silica)	30-40	30	25-30	10			2
Non-Black	-	-	20-30	≥ 40-100			
Process Oils	5	8	10	10-20			5-8

Category	A	B, C & D			E**		F
		Good*	Medium*	Low*	Wet	Dry	
	(Good Quality)			(Spindle Oil)			
Activators	5	5	3-5	~3	8-10	4-5	1-2
Accelerators	1	1.0-1.5	1.0-1.5	1.5-2.5	2	1	
Anti-oxidants	2-4	1.5-2.5	1-2	<1.0	2	1	
Curing/Vulc. Agents	1-2.0	2.0-2.5	2.5	2.5-3.0	3.6	1.8	
Other Ingredients	1-1.5		0.5-1.0	0.5			
KOH (10%)					2	0.2	
ZnO**					8	4	

NR: Natural Rubber; SR: Synthetic Rubber; RR: Reclaimed Rubber

\* Standard/Good quality Auto tyres; \*\* As 50% Aqueous Dispersion; # Belts, Hoses, Cyclostyles

\$\$ For Foam Manufacturing, sodium silico-fluoride & potassium oleate are used additionally

## 2.4 PRODUCT SPECIFIC PROCESS

### 2.4.1 Tyre Manufacturing Process (Category A)

The typical tyre manufacturing process consists of the following:

1. Preparation or compounding of the raw materials
2. Transforming of these compounded materials into the five basic tyre components i.e., the tread, the sidewall, the cord, the bead and the inner liner
3. The building, moulding and curing of the final product.

The sequential steps involved in the process are described below:

- Mixing involves weighing and combining various ingredients (natural and synthetic rubbers, oil, carbon black, zinc oxide, sulphur and other chemicals) to create a homogeneous rubber compound that is discharged to a drop mill.
- Milling creates warm malleable sheets that are cooled and coated with an antitack solution. These sheets are then fed into an extruder
- Extruding the rubber mixture between pairs of large rollers to prepare it for the feed mill, where it is slit into strips to take the shape of the tread and side wall material.
- Processing fabrics and coating them with rubber are in calendaring operation.
- Processing bead-wires and coating them with rubber is an extruding process
- The various tyre components go through cooling and cure prior to tyre building. Belts that lower their temperatures through the application of cool air or cool water from the milling and extruding operations, the rubber sheets are placed onto long conveyor.

- Cementing and marking process are used at various stages throughout tyre building process. Cements (adhesive or solvent) are added to improve the adhesion of different components to each other throughout the process. Cement usage can vary significantly among facilities depending on the type of tyre being manufactured and the process being used. Marking inks are used to aid in identifying the components being managed. Typically they are applied to extruded tread stocks to aid in identifying and handling cured tyres. Marking practices can also vary significantly among facilities.
- Assembling all of the components (bead-wires, coated fabrics, treads etc.) on a tyre building collapsible cylinder, shaped like a wide drum.
- First the inner liner is applied to the drum. Then layers of chord are applied, one layer tying the beads together in one direction and another layer in the other direction. The heads are attached to the tyre by folding over the ends of the cord fabric. Next the built fabric is laid onto the cord. Finally the tyre tread is placed over the chords and fabric and wrapped around the beads. The cylinder is removed. These green tyres (uncured tyres) are now ready for final processing.
- Lubricating the green tyre (green tyre spraying) involves preparing the uncured (green) tyre for curing. The green tyre may be coated with a lubricant (green tyre spray). The function of the green tyre spray is to ensure that the cured tyre does not stick to the curing mould during extraction of the tyre after curing.
- Vulcanizing and moulding the tyre with heat and pressure – Vulcanizing (curing) involves collapsing drum and loading the green tyre into an automatic tyre press to be cured at high temperature and pressure. The vulcanization process converts the rubber and also bounds the various parts of the tyre into a singular unit. In curing process, an inflatable rubber bladder bag is inflated inside the tyre causing the tyre to take its characteristic shape. The mould is simultaneously closed over the shaped tyre. Heat is applied by steam via the mould and the bladder bag. Excess rubber and trapped air escape through weep holes. After a timed, temperature-controlled cure, the press is cooled, the bladder is deflated via a vacuum and the tyre is removed. The tyre is again inflated with air and left to cool in the atmosphere.
- Finishing the product involves trimming, buffing, balancing and quality control inspection.

After moulding and curing operations, the tyre proceeds to the grinding operations where the excess rubber, which escaped through the weep holes is ground off. Most tyres receive further grinding of the tread in order to balance the tyre.

After the grinding operations, the tyre receives a protective coat of paint. The paint is generally water based. After inspection and possibly some final repairs, the tyre is ready to be dispatched.

A flow diagram for the typical plant process is shown in Fig-2.2.

## 2.4.2 Tube manufacturing process (Category A)

The process by which the tube is formed is similar to the extrusion of the tread in the tyre industry. The different steps involved are:

1. Preparation or compounding of the raw materials.
2. The extrusion of these compounded materials to form a tube.
3. The building, moulding and curing to form the final product.

Fig. 2.3 illustrates the typical process in a tube production facility

## 2.4.3 Molded Product Manufacturing (Category B)

### 2.4.3.1 Process Details

Rubber moulding process typically consists of the following steps:

#### (1) Compounding

Plants use special rubber compound recipes; compound rubber stock from basic ingredients such as rubber, Carbon black, pigments, extruder oils, antioxidants and accelerators. Compounding is generally carried out in Bunbury mixer/roller mill/kneader depending upon scale of operation. These equipments require cooling water. Leakage of lubricating oil and grease are common.

#### (2) Formed Rubber Preparation

After compounding, the rubber stock is worked on a warm-up mill and formed to approximately the required shape ready for molding by either a calendar or extruder.

#### (3) Cooling and Antitacking of Rubber Form

The formed rubber is cooled and generally dipped in an antitack agent. In many cases, the formed rubber is cooled in an open tank, which produces a cooling water overflow.

#### (4) Preparation of Blank / Preform

The Preforms are prepared from the calendared or extruded stock rubber by cutting, slicing or stamping out. Cutting can be accomplished by a machine or hand. Slicing is generally carried out on a slicing machine or guillotine.

#### (5) Moulding

Rubber articles are produced by moulding, a process in which uncured rubber, sometimes with an insert of textile, plastic or metal is cured under pressure in a mould. There are three general molding techniques as described below.

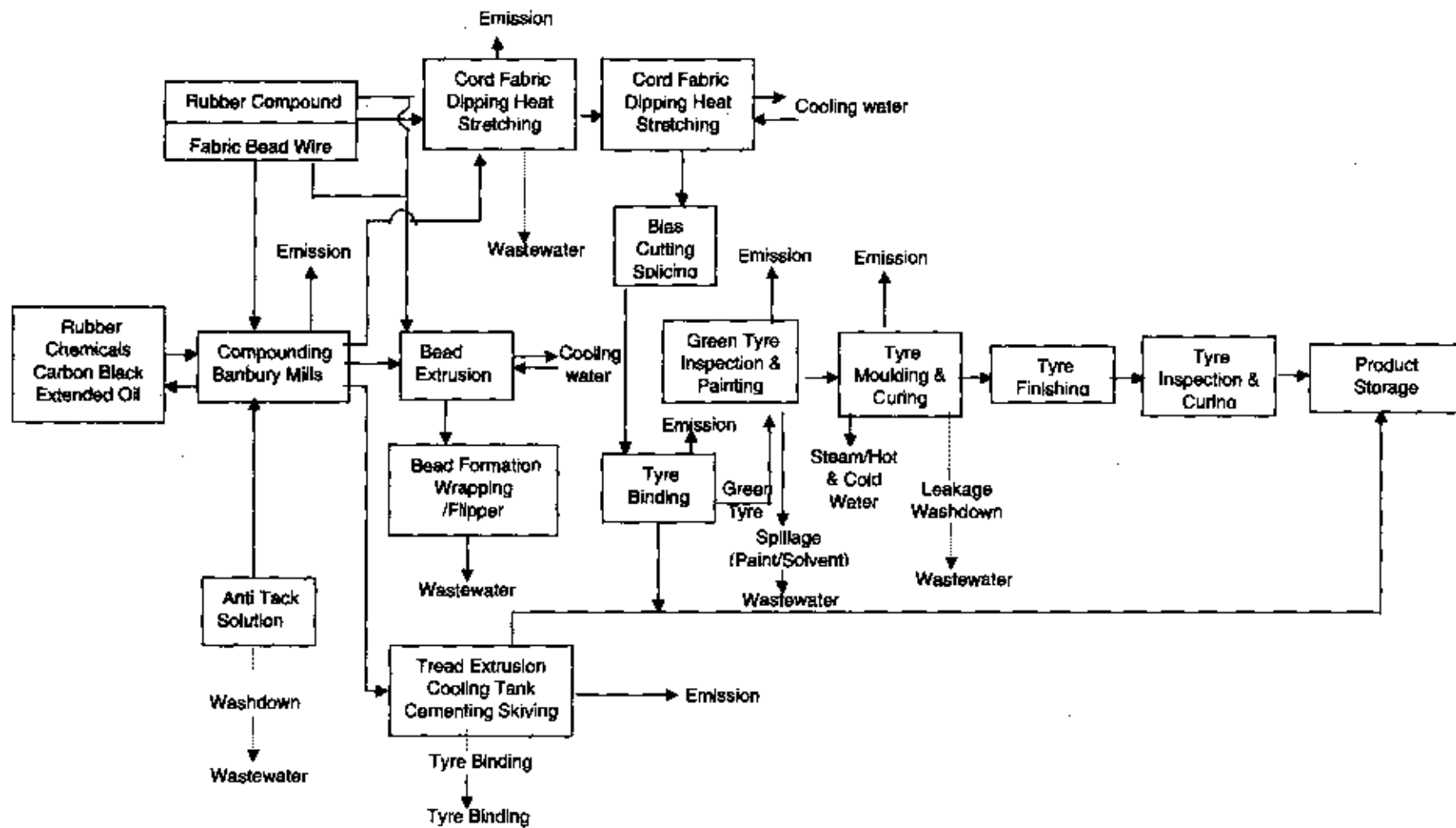


Fig-2.2 Process Flow Diagram for Tyre and Camel Back Production Facility

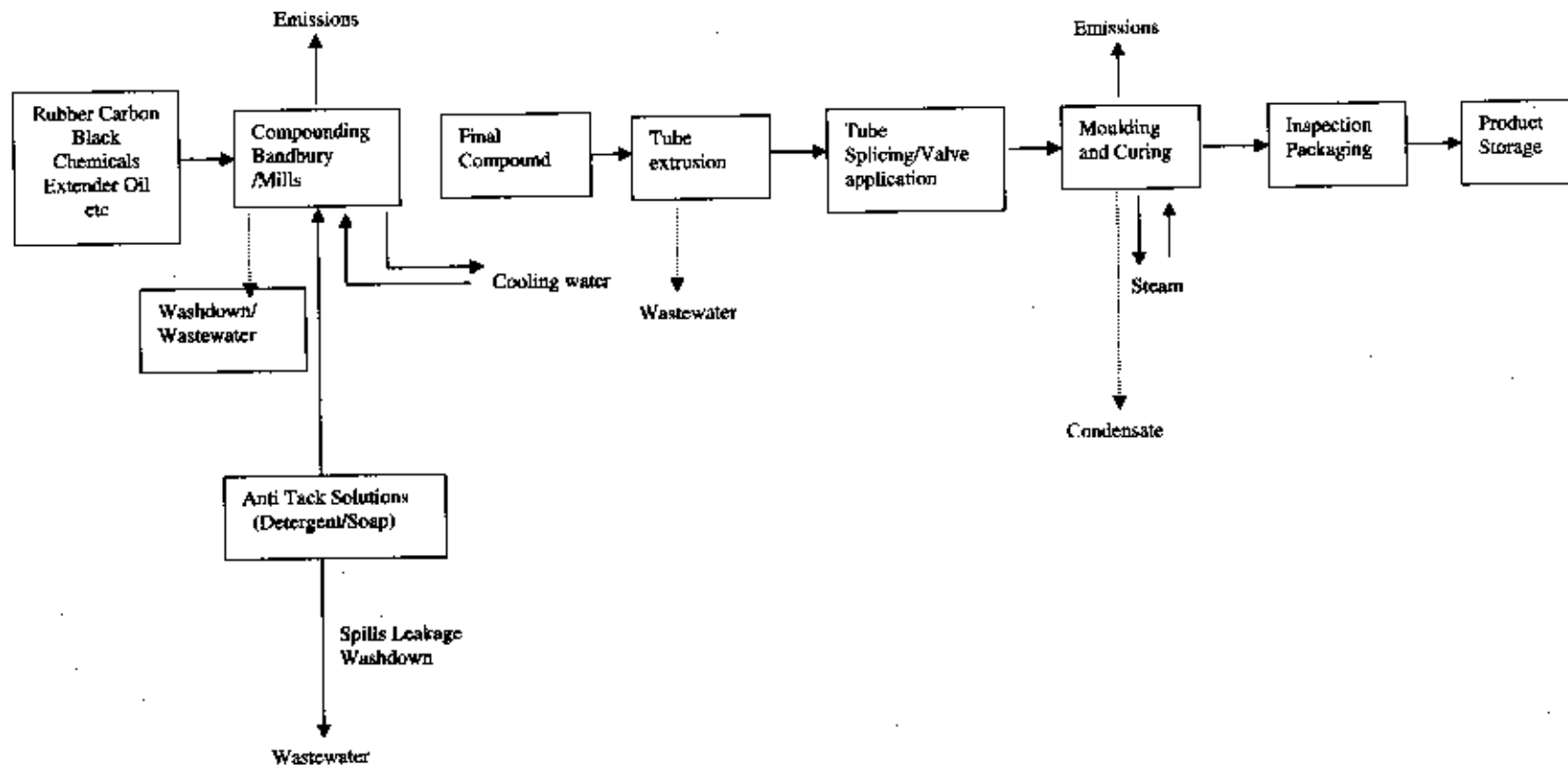


Fig-2.3 Process Flow Diagram for Typical Tube Production Facility



(a) *Compression Molding*

Compression molding is the oldest method of making mold parts. In compression molding, preformed piece is placed in the pretreated by release agent. For small mold items, each mold generally has multiple mold receptacles, which enable several items to be molded simultaneously. The mold is closed and held together, normally by hydraulic oil pressure, during the curing cycle. Heat is provided by electrically, hot fluid or steam. Oil leakage frequently occurs from the hydraulic mold closing systems and the hydraulic pump itself. At the end of the molding cycle, the items are removed from the mold and sent to the deflashing operation.

(b) *Transfer Molding*

Transfer molding involves the transfer of the uncured rubber from the transfer pot to the mold under force through a narrow flow channel, called sprue or a runner system by a ram piston. Preparation of preform is not required in this technique. The force of the press when applied to the ram plus the heat from the mold causes the stock to be softened and flow through runners into previously empty molding cavities, where the stock is cured in the desired form. The mold has to be hot enough to ensure curing of the rubber, but the transfer pot has to be at a lower temperature.

The rubber for transfer molding is compounded in the same way as that for compression molding. Transfer molds are normally heated by steam and are operated by hydraulic oil systems similar to the compression mold hydraulic systems. Oil leaks and spillages are frequent.

(c) *Injection molding*

Injection molding is the same as the transfer molding with exception that the stock is injected into the cavities. There are three different types of injection molding machines. One machine uses a ram to force the stock through runner into the cavities; another uses a screw and third is a combination of the first and two and is a reciprocating screw. There is little difference between three machines from the point of view of water use. All require cooling water.

Advantages of injection molding comprise reduced labour costs, shorter cure times, better dimensional control and more consistent mechanical properties of the product. Both compression molding and transfer molding are still widely used in the industry worldwide, even though injection molding has a number of advantages. This is often because the fabricator has an existing press in good working order. The main economic factor is that the capital cost of the machines and molds increases in order compression molding, through transfer molding, to injection molding.

(6) **Deflashing**

As a result of molding operation, the rubber overflow or flash must be removed from the part before it is dispatched. Deflashing usually is carried out by hand, grinding wheel or press operated dies. In some cases, deflashing involves chilling with dry ice and then tumbling or shot blasting.

Fig. 2.4 illustrates the typical Moulded Product

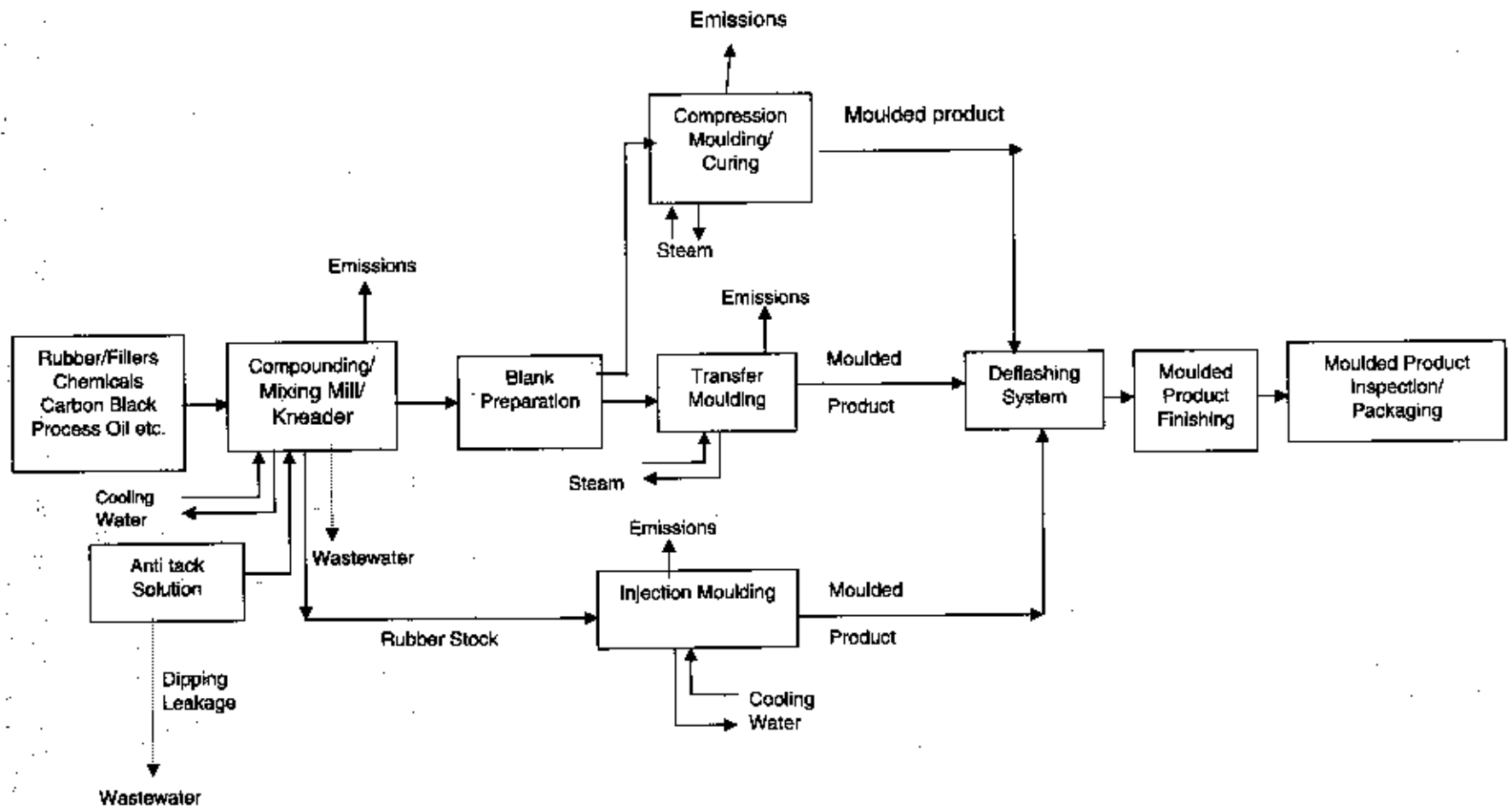


Fig-2.4 Process Flow Diagram for Typical Moulded Item

#### **2.4.3.2 Rubber-to-Metal Bonded Items**

Metal-bonded items, which consist of a molded rubber component bonded to the metal part, are manufactured in a manner similar to that for other rubber molded products. Additional activities involved in such plants are.

The metal parts entering the molding plant are generally contaminated by grease. The metal part is first degreased using a suitable degreasing solvent, frequently trichloroethylene.

In a few cases, the metal part is pickled to prepare the surface for bonding with rubber.

In some molding plants, poor quality molded items are recycled to reclaim the metal component for re-use. To reclaim the metal, the reject rubber is ground and buffed from the metal. The metal item is then sand-blasted clean.

The metal surface to which the rubber is to be molded is normally prepared to provide good adhesion between the metal and the rubber. The mating surface of the metal part is first sand blasted to roughen it and then coated with rubber cement either by hand for small items or sprayed for larger metal surfaces.

The prepared metal part and its mating component are placed in this mold cavity and molded in a similar way as described earlier.

#### **2.4.4 Extruded/Calendared Product Manufacturing Process (Category C)**

As described above, rubber extrusion is used to prepare the performs and blanks in compression and transfer molding process. The extrusion operation is a minor element of the overall production process for molded items. Rubber Extrusion/calendaring, however, plays more significant role in the manufacture of such items as rubber belting and sheeting. The basic steps involved are:

- a. Compounding of basic ingredients similar to molding items
- b. Sheeting of rubber on a sheeting mill
- c. Contact cooling and antitacking of rubber sheet
- d. Extruding the rubber sheet as final desired sheet. In cases where the dimensions of the extruded rubber sheet are critical, the extruded rubber is calendared to the desired thickness.
- e. Contact cooling and antitacking of extruded/calendared sheets for further storage/processing
- f. Belting is manufactured by extruding the rubber onto the wire reinforcement in the extruder or calendaring the rubber sheeting onto reinforcement fabric. Extruders and calendars require cooling water. Oil and grease can leak from the machinery.
- g. Curing of belting or extruded and calendared sheeting press curling technique.

The press curing technique consists of two heated belts, which hold the rubber belting or sheeting between them under pressure to facilitate the curing process. The

heated belts turn and drag the sheeting or belting through the press. Cured belting or sheeting is inspected, cut to length and stored for dispatch. Fig-2.5 & Fig-2.6 show the manufacturing process of typical Extruded and Calendered products respectively.

#### **2.4.5 Fabricated Product Manufacturing Process (Category D)**

The types of products and processes covered by this industry sector are varied. Rubber hoses, rubber footwear, rubber coated materials and cables are the important sub-sectors of the general fabricated product groups. Processes employed in this industry sector are compounding, milling, fabrication, molding and vulcanization. Examples of some product specific rubber building or fabricated manufacturing processes are described in the following section.

#### **2.4.6 Latex Based Products Manufacturing Process**

To manufacture rubber goods from latex component, it is necessary to convert the compounds into solids of the desired form. The latex producer generally stabilizes latex compounds before transporting to the rubber goods manufacturing facility. Here, the stabilized latex goods are transformed into the final rubber goods. Prior to forming the rubber goods, the latex is compounded (mixed) with various ingredients, such as anti-oxidants, in accordance with a specific recipe. Several types of rubber goods are fabricated from latex mixtures. The major classes of latex based goods are dipped goods such as surgical gloves, condom and foam-backing materials as discussed in the following sections.

##### **2.4.6.1 Latex Based Dipped Goods Manufacturing Process**

There are two principal techniques used in the manufacture of dipped rubber goods. One is the straight-dip method employed in the production of very thin-walled dipped goods such as condom from which water can readily and quickly be removed by evaporation.

The second technique is coagulation dipping where the rubber goods are produced by coating with coagulants followed by a film of rubber from latex dipping operation onto shaped forms. Coagulation dipping makes thicker-walled items such as gloves.

The various steps involved are discussed below.

##### **(1) Coagulant Dip**

The forms are first dried in oven prior to dipping in the coagulant solution. The coagulant solution used is usually a mixture of organic water based solvents and coagulants. Typical coagulants are calcium nitrate, calcium chloride, and zinc nitrate. Combination of ethanol and acetone are generally used as organic solvent. A surfactant is sometimes added to the mixture to ensure good wetting of forms and release agents are added in case where the form has a complicated shape and removal of the dipped goods from the forms is difficult.

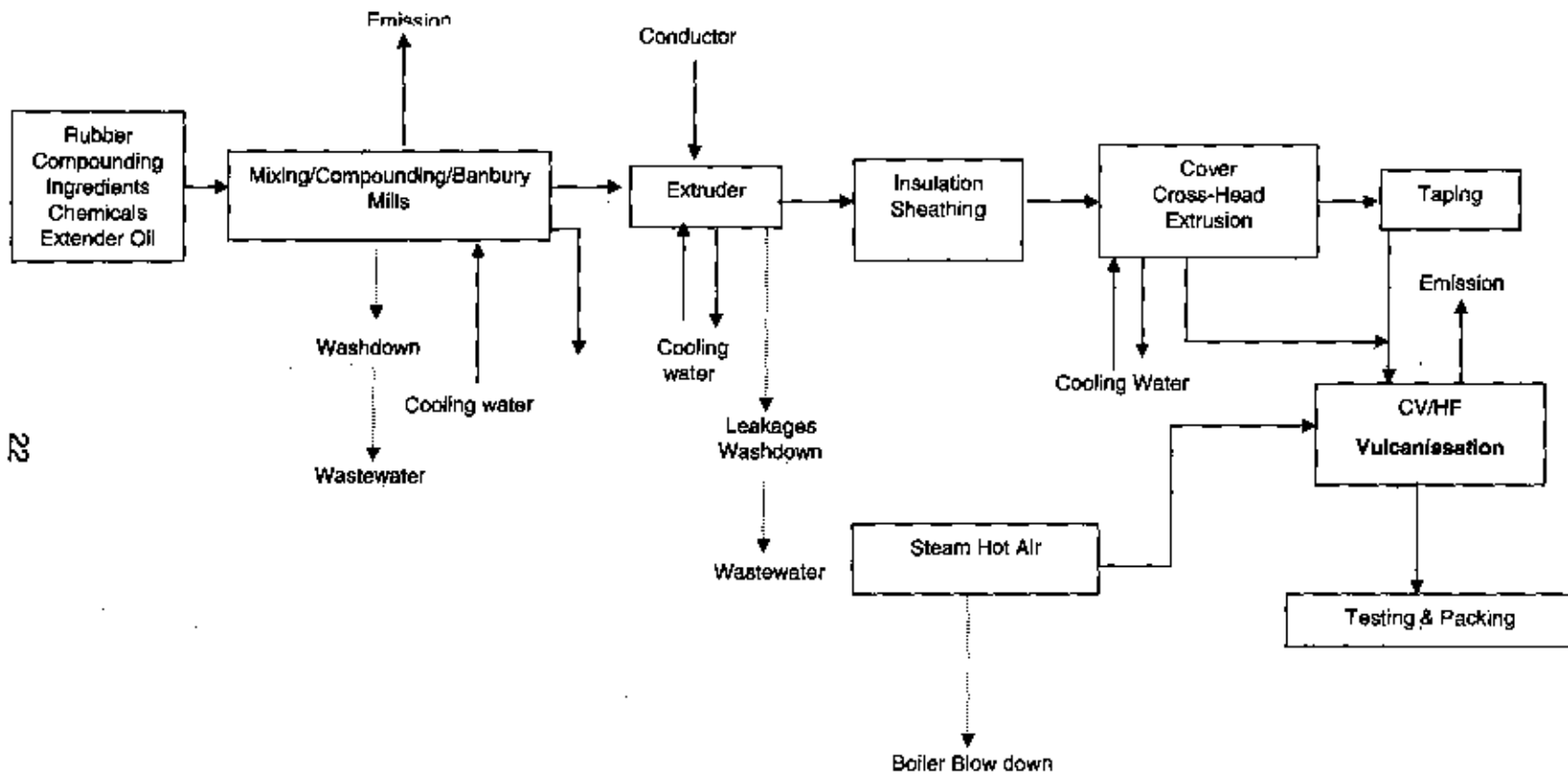


Fig-2.5 Process Flow Diagram for the Production of Typical Extruded Item (Cable)

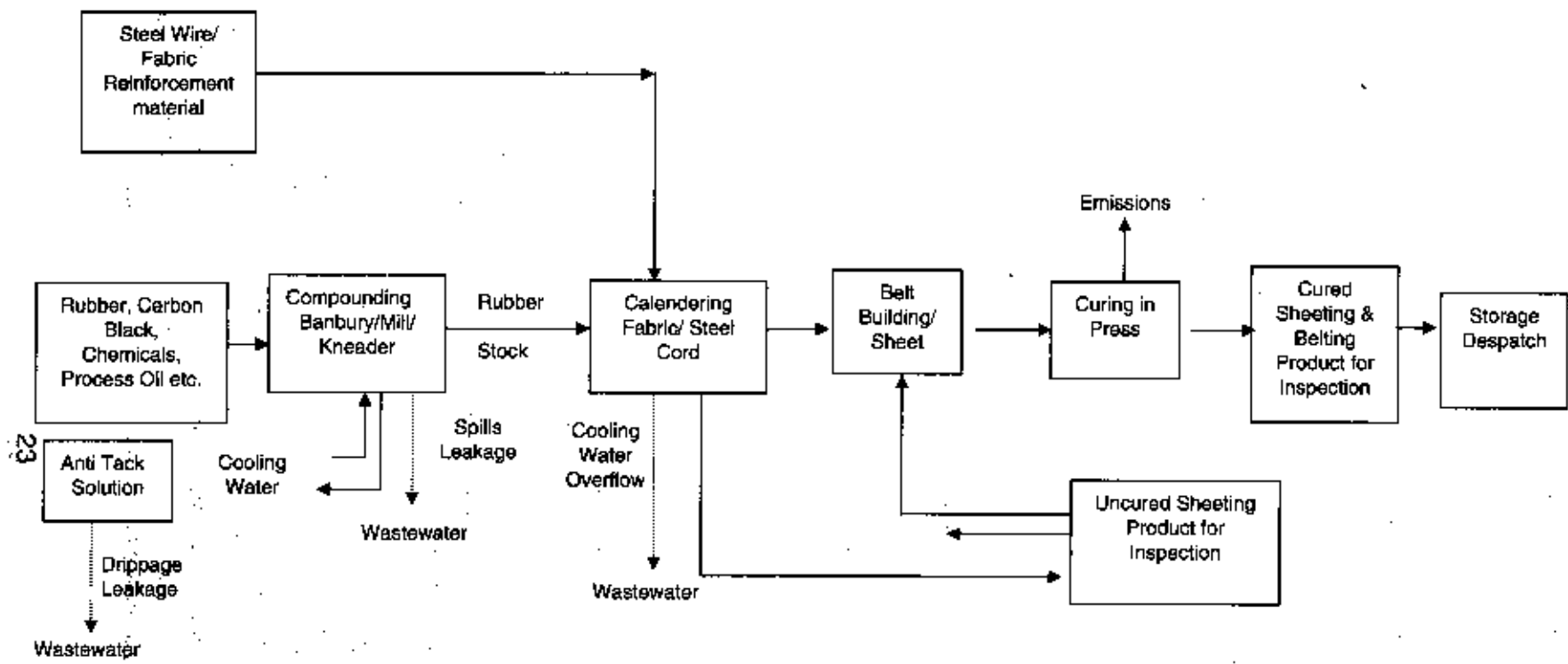


Fig-2.6 Process Flow Diagram for the Production of Calendered Items such as Belting and Sheetting

- (2) **Latex Dip**  
After coating with coagulants, the form is dipped in the rubber latex. The rubber latex and ingredients are compounded prior to the dipping operation. In some cases, the latex storage and compounding tanks are cooled degradations of the latex.
- (3) **Preliminary Drying**  
The coated forms are passed through a preliminary drying oven to dry the film sufficiently so that it does not disintegrate and wash away in the subsequent washing step.
- (4) **Washing and Drying**  
The latex dipped forms are washed generally in hot water tank. The coated forms are again sent through a drying oven to dry the goods. Dried forms are sent for curing.
- (5) **Curing**  
The rubber goods are cured in an oven at approx. 200° F.
- (6) **Cooling and Form Stripping**  
After curing, the items are cooled in a water-cooling tank (contact cooling) and mechanically stripped from the forms usually with the aid of a lubricating detergent. The detergent is subsequently washed from the goods in a rinse tank.
- (7) **Packaging**  
The final manufacturing operation consists of drying the goods, dusting them inside and outside with talc to prevent sticking and packaging.
- (8) **Sterilization**  
In cases where sterilized products are required such as surgical rubber gloves, the goods are immersed in a chlorine dip tank (free chlorine concentration typically 1000 mg/L) to provide disinfection and improve the surface finish of the glove. After disinfection the goods are dipped in a hot water tank to remove the residual chlorine from the rubber product. In many cases, the gloves are sterilized by dipping in a hot water bath.
- (9) **Form Washing**  
Periodically, it is necessary to clean the form upon which the goods are deposited. The porcelain forms are passed through a bath containing a cleaning agent (chromic acid). The cleaned forms are rinsed of residual chromic acid in a subsequent rinse tank. The tank is equipped with a fresh water make up and overflows to blow down the accumulation of cleaning agent. The cleaning frequency is generally in the order of once a week. Other methods of cleaning involve simply scrubbing the forms with clearing agents followed by rinsing.

The straight-dip method involves all steps excluding first one as described above. The forms are dipped directly into the latex and slowly removed. A multiple-dipping process can make thicker articles with drying between dips. Fig-2.7 shows the process involved in the production of latex dipped products.

#### **2.4.6.2 Cement based Dipped Goods Manufacturing Process**

It is pertinent to discuss the manufacture of dipped goods from rubber cement because the production process has similarities to the manufacture of latex based dipped product as described earlier. Various products are made via cement dipping process. The rubber cement is prepared in blend tanks using fixed quantities of compounded rubber stocks and solvent. The compounded stock is cut in small pieces to facilitate dissolution in the solvent. The solvent used is generally aliphatic in nature, for example hexane. Cement dipping results in a product which has good electrical resistance since no water or ionic species are trapped in the cement, as would be the case with latex dipped gloves.

#### **2.4.6.3 Latex Moulded Product Manufacturing Process**

Plaster of Paris or unglazed porcelain mold with pore sizes smaller than the smallest rubber articles are used in the industry. The latex compound is poured through a funnel shaped opening into the mould. The latex compound is allowed to dwell in the mold until a deposit of the desired thickness has developed on the mold wall. This technique is used for a number of latex moulded products such as dolls and squeeze toys, etc.

#### **2.4.6.4 Latex Adhesive Manufacturing Process**

Latex obtained from rubber manufacturer is mixed with water and starch to prepare latex based adhesive. The process is described below.

**(1) Boiling**

Water is allowed to boil and starch is added gradually with continuous stirring for ten minutes.

**(2) Screening**

The prepared solution is screened with the help of a marking cloth. The solution, which passes through the screen, is taken into the process and the portion retained is considered as waste and disposed off.

**(3) Cooling and Mixing**

Screen solution is cooled and afterwards mixed with the latex. The adhesive is now ready for packing.

#### **2.4.6.5 Latex Thread**

The manufacture of extruded thread consumes a relatively small volume of latex but is of techno-commercial interest. The process is carried out by flowing latex under constant hydrostatic head into a bath of dilute asetic acid and carrying the continuously formed thread by means of constant speed rolls through the acid bath and



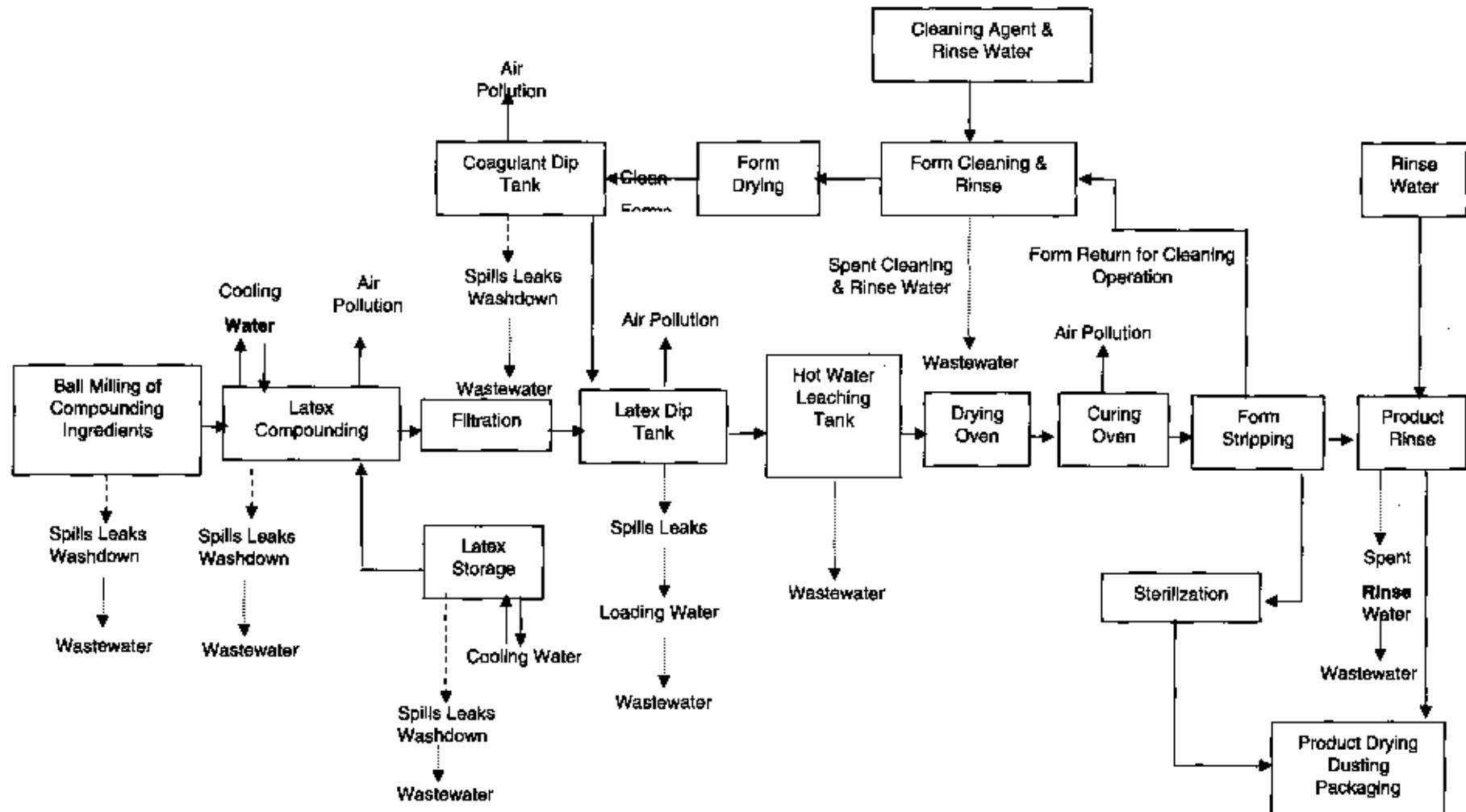


Fig-2.7 Process Flow Diagram for the Production of Typical Latex Based Dipped Items

a wash tank and then to a belt operating in a tunnel drier followed by curing of thread in hot air.

#### **2.4.6.6 Latex Foam Manufacturing Process**

Many different processes are patented for preparing this type of product, but there are two processes of prime commercial interest for manufacturing such articles as molded-foam cushioning stock. These are the Dunlop and Talalay processes. Some products have developed variations, which in effect are a combination of the two processes. However, today mainly the Dunlop process is followed. Fig-2.8 shows the typical manufacturing process of Latex Foam.

##### **(1) Dunlop Process**

The basic features of the Dunlop Process are:

- Mechanically whipping the latex to a froth
- Setting the frothed mass with a coagulant or gelling agent (The gelling system usually consists of sodium silico-fluoride in conjunction with zinc oxide).
- Vulcanizing the rubber so that the foam is permanent. When the curing cycle is completed, the product is removed from the mold and washed with water to remove those ingredients of the latex recipe which are not held permanently in the foam matrix and finally dried.

##### **(2) Talay Process**

In the Talalay process the froth is produced by chemicals rather than mechanical means. Latex foam and synthetic foam are manufactured by the same process mentioned above.

In some industries under this group, hydrogen peroxide and enzymatic catalysts are mixed into latex and the mixture is placed in the mold. Decomposition of the peroxide by the added enzyme results in the liberation of oxygen, which causes the latex mix to foam up and fill the mold. The foam is rapidly chilled and carbon dioxide is then introduced to gel the latex. The gelled foam is then handled in a manner similar to that used in the Dunlop process.

#### **2.4.6.7 Foam Backing**

For foam backing on various fabrics such as carpets, scatter mats, etc., a different type of gelling agent is employed in place of generally used gelling agents for latex foam production. The gelling system usually consists of either ammonium acetate or ammonium sulfate in combination with zinc oxide.

The latex froth is prepared with an Oakes machine, the gelling agent is added to the machine and the foam is applied to the fabric by spreading directly on the fabric or spreading on a belt and transferring the wet gel to the fabric via the belt.

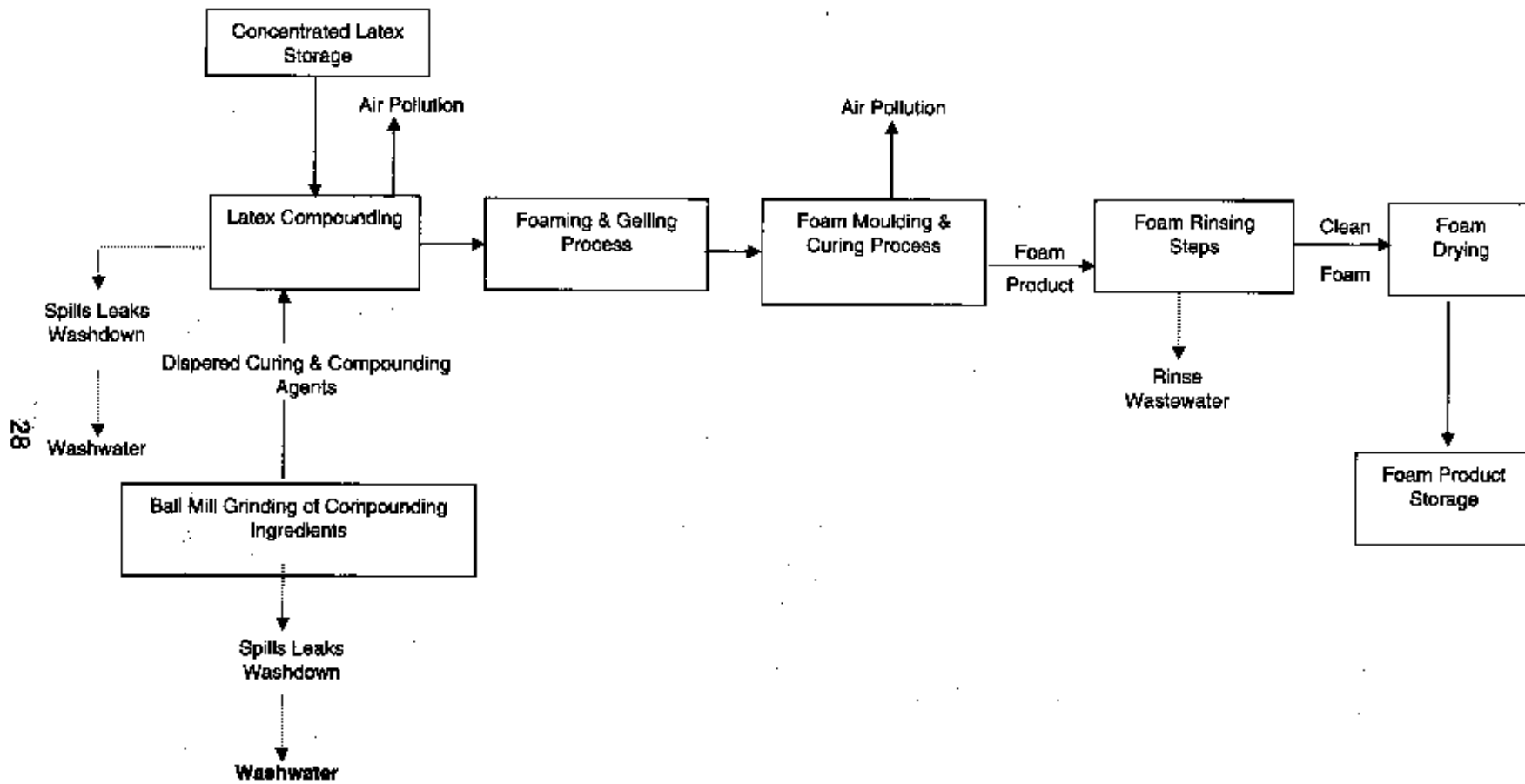


Fig-2.8 Process Flow Diagram for the Production of Typical Latex Based Foam Items

## 2.4.7 Reclaimed Rubber Manufacturing Process

Reclaimed rubber is the product resulting from the treatment of ground scrap tyres, tubes and miscellaneous waste rubber articles with heat and chemical agents where the rubber compound is converted to its plastic state by devulcanisation (depolymerisation) process. It is then compounded and vulcanized like regular natural and synthetic rubber and in most cases is blended with new rubber to achieve balance in processing and physical properties. Reclaimed rubber manufacturing process involves the following main steps, which are shown in Fig-2.9

- **Debeading**

Beads in scrap tyres are removed manually for its further processing. In most of the existing plants, debeaded tyres are being received.

- **Size Reduction**

Debeaded scrap tyre is reduced by mechanical chopping or cracking on a very heavy cracker mill to a suitable size for the devulcanization step being used. The cracked ground stock is conveyed to a vibrating screen of a given mesh size. The oversized material is returned to the crackers for further grinding. The stock, which passes through the screen, is conveyed for the storage to use in the depolymerization process.

Some reclaiming plants use a series of screens, air separators and sizing equipment to remove/ reduce fiber content from ground rubber scrap.

- **Depolymerization (Devulcanization)**

Rubber scrap separation and size reduction is followed by appropriate depolymerisation process. Three basic techniques are used to produce reclaimed rubber are used to produce reclaimed rubber as discussed below.

- a. **Wet Digester Process**

The digester process consists of placing the ground scrap, water and reclaimed agents into a steam-jacketed agitator-equipped autoclave (digester). The batch is then cooked for 5-24 hours at 370-405° F. Reclaiming agents are used include petroleum and coal tar-based oils and resins as well as various chemical softeners such as phenol alkyl sulfides and disulfides, thiols (mercaptans) and amino compounds. The reclaiming agents generally function by catalyzing the oxidative breakdown of the polymer chain and oxidative disruption of sulfur crosslinks. Sometimes, defibering agents such as caustic soda or chlorides of zinc and calcium and plasticizing oils are added to the digester to complete the charge. At the end of the digestion period, the contents of the digester are screened, frequently washed, dewatered and dried in a hot-oven prior to further processing.

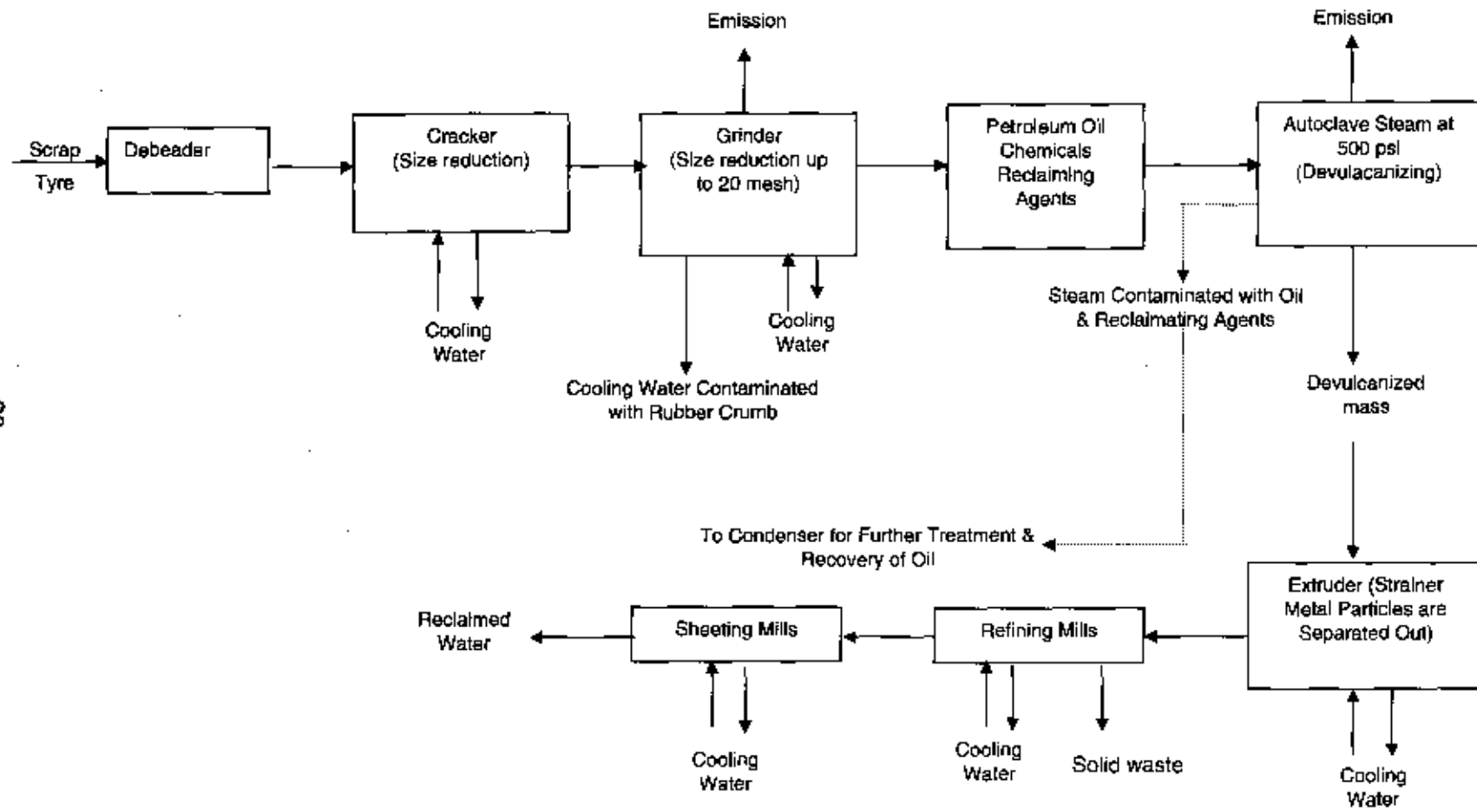


Fig-2.9 Process Flow Diagram for the Production of Reclaimed Rubber

Chemical defibering and the subsequent washing process create an effluent problem. Hence, this process is not opted by reclaim industries these days.

***b. Pan (Heater) Process***

The finely ground scrap which is usually free from fiber is blended with the correct amount of reclaiming agents and placed in a single shell pressure vessel (autoclave) into which live steam is passed. Depolymerisation is carried out at about 365° F for 2-18 hours. After this treatment, the heater is vented, the pressure vessel discharged and the crumb of rubber sent on further processing. Since the condensate from this operation is highly contaminated with oils, resins etc, it cannot be returned to the boilers and therefore, must be treated as a waste. This process is relatively inexpensive because the equipment is simple and the washing and drying steps are eliminated. This process is mainly used in India with some variation, known as dry digester process.

***c. Mechanical Reclaiming Process***

The mechanical reclaiming process, unlike the other two preceding processes, is continuous. The fine ground, fabric free rubber scrap is fed continuously into a high-temperature, high shear machine. The discharged reclaimed rubber needs no drying and is ready for further processing. This process is not common in India.

• ***Final Processing***

The final stage of the reclaiming operations involves straining to remove foreign matter before going to refining and sheeting mill. The strainer is an extruder, which contains a wire mesh screen held between two strong perforated steel plates in the head of the machine. The reclaim is then given a preliminary refining on a short two-roll mill having a high-friction ratio between the roll surfaces. The reclaim is then sheeted for the final thickness on a sheeting mill. Sheeted reclaim is cooled, dusted with talc to prevent sticking with each other, tested, packed and finally dispatched to the customer.

## **2.5 SUMMARY**

Based on the products and processes comprising the industry segment as described above, it is possible to make some general conclusions about the waste water characteristics of the industry segment and which product areas should be grouped for further discussion in succeeding chapters.

Since tyre and tube industry by itself is the largest segment of the industry, it will continue to be individual category for further discussion.

Although the types of products manufactured by molding techniques are diverse, the manufacturing processes are very similar. In addition, it is believed that the characteristics of the wastewater generated by the three principal molding techniques (compression, transfer and injection) are comparable.

Extrusion / calendaring is another fundamental rubber processing technology by which several types of products are made. The wastewater types throughout the industry appear to be similar and independent of the type of extruded product.

The final stage in the manufacture of many rubber products involves fabrication using molded or extruded components. In general, fabrication operations are dry and the necessary wastewater control and treatment requirements appear to be simple.

Based on the apparent nature and origin of the wastewaters, it can be concluded that molded, extruded/calendared and fabricated rubber products can be grouped together for further discussion. The processing method used generates wastewaters limited to spills, leaks and housekeeping operations.

Latex based and Rubber reclaim segment of industries will continue to be under separate group for discussion due to its different nature of processes and wastewater generation.

In summary, following categories of industries are further grouped together for detailed study in the succeeding chapters.

- Tyre and Tube Industry – Category A
- Moulded, Extruded/calendared and Fabricated group of industries – Category B, C, and D
- Latex Based Industry – Category E
- Rubber Reclaiming Industry – Category F

## CHAPTER 3

### WATER CONSUMPTION, WASTE WATER GENERATION AND CHARACTERIZATION

#### 3.1 INTRODUCTION

Data pertaining to water consumption, Waste Water generation and its characterization was obtained from plant visits, industrial records and questionnaire survey. The industry sizes vary from as low as 1 tonne to as high as of a few thousand tonnes of licensed annual capacity. As has been earlier discussed, the variety of products is also very large. Adequate number of sample industries of small, medium and large groups from all six categories has been selected from all over India for in-depth study. As most of such industries maintained no record of relevant information and have no process specific drainage system, it was not possible to collect requisite data and representative sample for analysis. In order to avoid misleading information, extensive literature survey and wide consultation to experienced plant personnel were made to confirm and supplement the plant visit data. The present chapter summarizes the findings of each category in the following sections.

#### 3.2 TYRE AND TUBE INDUSTRY (Category-A)

##### 3.2.1 Water Consumption

Tyre and tube industry is basically dry process and water is mainly required for cooling of machinery used for rubber processing at different stages of final product. There is considerable heat generated by compounding, extruding, calendaring and moulding processes of solid raw materials involved in the manufacturing of tyre and tube and it must be dissipated and controlled to ensure the quality of final product. The other main area for water consumption is boiler for steam generation used in curing/vulcanization process. The water uses in all possible areas of tyre and tube industry are listed as below:

- Steam Generation (Boiler)
- Non-contact cooling water of machinery
- Contact cooling of tread tyre
- Make-up water for antitack solutions and water based spray of green tyres
- Washing of floor and machinery
- Domestic use in Toilets, Canteen and gardening etc.

The industrial water consumption varies widely mainly due to different cooling water systems adopted by tyre and tube industry. The consumption variations are mainly due to the use of once-through cooling water in certain plants as compared to re-circulation cooling in others. Some plants use partly Once-through and partly re-circulating system. The tyre and tube industries with re-circulation cooling water facilities show no significant variations in water consumption ranging from 6 to 16 liters per Kg of raw material consumption. As compared to these plants, industries with once-through



cooling water system show this figure ranging from 48 to 123 litres per Kg of raw material consumption.

### 3.2.2 Wastewater Generation Sources

The wastewater from the process areas includes water and steam leakages, overflows, runoff from oil-storage areas, soapstone solution spillages and wash down and runoff from process or storage areas.

Water leakages occur at various water-cooled machinery units including mills, Banburies, extruders and tread cooling tanks. In addition, water can escape from the hydraulic water system used in Banbury and Press areas. Water and steam leakages occur in the process area due to broken seals, failing bladder bags and overflows from the collection pumps. Oil and solid matter, which have collected on the floor area, scavenged by these various water streams and are carried, untreated to the drainage system. Oil on the floor spaces is lubricating oil, which is dripped or leaked from oil seals of mills, pumps and like equipment, from open gears, from gearboxes and from the hydraulic water system.

In mixing and compounding area, soapstone solution is used for coating rubber sheets to prevent them from sticking together during storage. Spills in the soapstone area are common and may create a wastewater problem.

Wastewater problem in the tread processing area arise from the spillage of the solvent base cements, from oil and water leakages from the various mills and from accidental overflows from the cooling water system. The cooling water overflow would not normally be a problem since the rubber tread is relatively inert and therefore does not contaminate the water. However, it does serve as a wash-down agent for an area contaminated with the cements and oils.

Waste water problems in tyre cords and belts arise due to the latex dipping operation in addition to problems with oil and water leaks and spillages, which are similar to those of the tread process.

In the final operation of grinding and painting involved in tyre manufacturing process, relatively small grinding particles and runoff due to over spraying of the paint may find their way to local drainage system creating waste water problem.

In general wastewater problems arising from compounding, extrusion, molding and curing operations in tube manufacturing are very similar to that of the tyre manufacturing.

Another component of wastewater arises in tyre and tube industry from utility services such as

- Once through cooling waters
- Boiler Blowdown
- Cooling tower/pond blowdown in case of recirculating system
- Water Treatment Waste water

The third component of wastewater is generated from toilet and canteen as domestic wastewater stream.

### **3.2.3 Volume of Industrial Wastewater**

Volume of wastewater generation from tyre and tube industry depends upon production capacity, plant age, cooling water management and house keeping practices adopted by industry. Nature of wastewater generation is intermittent type except once through cooling water. Volume of wastewater generated from wash down, machine cleaning, spills and leakages is usually small relative to wastewater generated from utility services. Plant details of Indian scenario with re-circulated cooling water facilities show volume of industrial waste water generation ranging from 2 to 5 litre per Kg of raw material consumed from tyre and tube industry. As per USEPA documents, this figure varies from 3.2 to 5.4 litres per Kg of raw material consumption. Use of Wet air pollution control devices such as wet scrubber in developed country is found to be additional source of wastewater generation when compared to Indian scenario. Manufacturing steps for all tyre production are similar. Although there are variations due to equipment manufacturer and automations, these differences do not lead to significant variations in the volume or constituents of wastewater stream.

## **3.3 MOULDED, EXTRUDED/CALENDERED AND FABRICATED PRODUCTS (Category B, C and D)**

### **3.3.1 Water Consumption**

Similar to tyre and tube industry, manufacturing processes involved in moulded, extruded/calendered and fabricated products are basically dry and water is mainly required for cooling and heating (vulcanization/curing) purposes. The water uses in all possible areas of such industry are listed as below.

- Steam Generation (Boiler)
- Cooling water of machinery
- Contact cooling of Rubber sheets and products
- Product washings
- Washing of floor and machinery
- Washing of moulds
- Make-up water for preparation of antitack solution, latex adhesives and rubber cement solution
- Domestic use in toilets, Canteen and gardening etc.

Widely varying results of water consumption pattern were obtained from such categories of rubber product industries. Consumption of water mainly depends upon the extent of water consumed in cooling and product washing techniques. Water consumption data of such categories of industries indicate the range from 6 to 10 litre per Kg of raw material consumption with re-circulation cooling water facilities. Similar

plant details of other country show the variation ranging from 7 to 10.5 liter per kg of raw material consumption.

### 3.3.2 Wastewater Generation Sources

The primary source of wastewater from process associated activities within general moulded extruded/calendared and fabricated rubber categories are related to the use of heavy machinery and various antitack and adhesive solutions. Oil leakage frequently occurs from hydraulic mold closing systems and the hydraulic pump itself. Leakages of lubricating oil and grease are common in compounding mill and Banbury mixer. Leakage of bearing, gear and seal oil can readily pass into nearby drains and be carried into the wastewater effluents. Oil powered hydraulic systems provide additional potential for oil contamination of wastewaters. Antitack agents, which are allowed to spill on the floor, can, when not properly handled, contaminate plant effluents. Washdown of the dipping areas where antitack agents are in use may create an additional suspended solids loading. In addition, uncontrolled or untreated runoff from outdoor oil leakage areas will contribute to additional oil leakages in the effluent. In absence of capture units of air born particles in mixing, grinding and buffing areas, wet washings of floors scavenges settled particles to nearest drainage system and may contribute to higher suspended loadings.

Other waste waters of minor importance in process area include discharge of contact cooling water, Product testing waters, spillage of mould release solution, wasted stream condensate and spent degreasing solvent of metal parts in metal-bonded items. Wastewaters specific to particular products within these categories include vulcanizer condensate from the curing of both lead sheathed and cloth-wrapped hoses, vulcanizer condensate from the curing of cement dipped items and latex discharges from fabricated rubber production facilities.

In summary, the major wastewater generation sources from processing areas under these categories of industries are

- Spills, leakage and wash down from processing areas and runoff from outdoor storage areas
- Vulcanizer condensate from the curing of lead sheathed and cloth-wrapped hoses, cooling water from the lead sheathing press (or extruder) and waters from the cooling of cured lead-sheathed hose.
- Vulcanizer condensate from the curing of cement dipped items.
- Other streams from processing area are of negligible importance, their impact being minor or undetectable.
- Overall, wastewaters are of low flow rate and intermittent and have little impact on the total effluent flow rate.

Another component of wastewater under these categories of industries arises from utility services including once through cooling water, cooling tower/pond blow down, boiler blow down, water treatment wastes and domestic wastewater. The discharge of these wastewaters is also of intermittent nature except once through cooling water system.

### **3.3.3 Volume of Industrial Wastewater**

No firm co-relation could be established between water consumption and wastewater generation due to varied nature of products and different water management technologies adopted under such categories of industries. The largest portion of the total effluent flow is cooling water discharge and product wash water. Fluctuations in the flow rates generally reflect water management practices such as once through, re-circulated cooling, mixed nature of both techniques, different product washing and contact cooling techniques. The close examination of plant and process details under such categories of industry help to conclude on volume of wastewater generation in a way as mentioned below.

- Overall, volume of industrial wastewater generated from such categories of industries is low.
- The largest portion of the total effluent flow is cooling water discharge and product wash water.
- Industries with once through cooling system produce 70 to 80 % of water consumed as wastewater.
- Industries with re-circulating cooling water system produce 20 to 40 % of water consumed as Industrial wastewater.
- Major portion of industrial water consumption is consumed as make-up water in case of re-circulating cooling water system and steam generation in boilers.
- Variation is primarily due to requirement of contact cooling and washing of products and different vulcanization techniques as per the product specific process.

## **3.4 LATEX BASED INDUSTRIES (Category E)**

### **3.4.1 Water consumption**

Water is mainly required in the following areas:

- Washing of latex container
- Floor and Machinery washing
- Product Washing
- Form/Mold cleaning and rinse water
- Form stripping operations
- Product testing and sterilization operations
- Cooling water of Machinery
- Contact cooling of products
- Curing of products
- Domestic purpose

### **3.4.2 Wastewater Generation Sources**

The principal source of wastewaters within this category is latex container and product wash waters.

A second source of contamination results from spills, leaks, wash down and runoff from latex storage, compounding and transfer areas.

A third source of wastewater, relevant to latex dipping operations, is form-cleaning wastes.

### **3.4.3 Volume of Industrial Wastewater**

In the latex based Industries, cooling water contribution in wastewater generation is very low. In the latex-dipping and latex foam based industries, effluent generation is highly dependent on the washing water of product, latex container and form/mold. Flows are highly dependent on the size of the plants and washing technique employed. Higher flow rates are normally evolved from multiple washings. Plant details under Indian scenario show that volume of wastewater generated from such category of industry varies ranging from 15 litre to 40 litre per Kg of latex consumed. While in the case of developed countries, this figure is found to be in the range of 18 to 43 liter per Kg of latex consumed.

## **3.5 RUBBER RECLAIM INDUSTRY (Category F)**

### **3.5.1 Water Consumption**

Water requirement in rubber reclaim industry depends mainly on type of process employed. Wet digestion rubber reclaiming employs a wet process whereas Pan (Heater), Mechanical and dry digestion Rubber reclaiming utilize dry processes. All these processes employ similar rubber-scrap- separation and size-reduction methods. They differ in the depolymerisation and final processing steps. At present, dry digestion is common in India because the equipment is simple and the washing and drying steps are eliminated making it relatively inexpensive. It also reduces the wastewater problem inherent in the digester process. The present section covers water consumption, wastewater generation and characterization associated with only dry digestion process.

The water use areas in reclaimed rubber industry are:

- Steam generation for devulcanization (Boiler) process
- Cooling water for the machines (Cracker, Grinder and Refining Mills)
- Floor and Machinery washing
- Contact cooling of rubber sheets
- Make-up water for preparation of antitank solution
- Domestic Purposes

Water consumption in dry reclaim process is around 1 to 2 liter per Kg of finished product.

### **3.5.2 Wastewater Generation**

Steam, which is in contact with depolymerisation mass, is condensed to generate the primary source of wastewater. Second major sources of contaminant loading are spills, leaks and wash down from processing areas. In dry process, fiber content of scrap tyre is mechanically removed resulting generation of airborne particulate matter in bulk particularly in grinding and cracking section. In the absence of efficient capture unit of these airborne particulate matters, it settles down on floor of processing area and finds its way to nearest drainage along with floor washing water. The discharge of spills,

leaks and wash down from processing areas is qualitatively similar to the corresponding discharge of moulded, extruded/calendared and fabricated products. However, contaminant loadings on daily basis are substantially higher.

A third source of wastewater is from utility services such as boiler blow down, cooling tower/pond blow down, water treatment plant wastewater etc.

A fourth-minor source of contaminant loadings is air control equipment used to absorb uncondensed organic vapours leaving with steam. When absorbing materials such as activated carbon is regenerated with washing from water, this activity generates a wastewater stream with high organic content. Although this activity is twice or thrice in an year making wastewater discharge highly intermittent in nature.

### 3.5.3 Volume of Industrial Discharge

The nature of wastewater discharge is intermittent except steam condensate from devulcanization unit. Based on the plant visit data, about 30 to 40% steam is recovered as condensate from devulcanization section, which is around .10 to .20 liter/kg of finished product. Similar to moulded, extruded and fabricated category, about 20 to 40% of remaining water requirement is converted into wastewater. Plant details under Indian scenario show that the total volume of wastewater generated from such category of industries is about 0.2 to 0.4 liter per Kg of finished product. The corresponding figure for developed country is observed to be around 3.26 liter per kg of finished product as per USEPA document. It is to be noted that vapour condensate component of wastewater in both scenario is in the same range i.e. 0.12 to 0.16 liter/kg of finished product. The variation is mainly due to washing rate of spills & leaks, type of air pollution control devices and collection of run-off water from storage area.

## 3.6 SUMMARY

The possible sources of wastewater generation and major water pollutants for all categories of industries are summarized in Table- 3.1.

**Table-3.1: Wastewater Generation Sources and major Water Pollutants**

Type of Industries	Wastewater Sources	Contaminant
Tyre and Tube Industry	<ul style="list-style-type: none"> <li>• Cooling water bleed &amp; Boiler Blowdown</li> <li>• Floor wash down of different units (Batchwise)</li> <li>• Leakages &amp; Spills contaminating cooling water</li> <li>• Accidental overflow from Anti tack water tank</li> <li>Sanitary and other miscellaneous water</li> </ul>	Oil & Grease, Rubber Fines, Anti Tack agents etc.
Moulded, Extruded and Fabricated Products	<ul style="list-style-type: none"> <li>• Cooling water bleed &amp; Boiler Blowdown (Batchwise)</li> <li>• Rinse and Product Wash water (Batchwise)</li> <li>• Steam Condensate with organic leach (Batchwise)</li> <li>• Sanitary and other miscellaneous water</li> </ul>	Oil & Grease, Rubber Fines, Antitack Agents, Powder as fillers, etc.

Type of Industries	Wastewater Sources	Contaminant
Tyre and Tube Industry	<ul style="list-style-type: none"> <li>• Cooling water bleed &amp; Boiler Blowdown</li> <li>• Floor wash down of different units (Batchwise)</li> <li>• Leakages &amp; Spills contaminating cooling water</li> <li>• Accidental overflow from Anti tack water tank</li> <li>Sanitary and other miscellaneous water</li> </ul>	Oil & Grease, Rubber Fines, Anti Tack agents etc.
	<ul style="list-style-type: none"> <li>• Hydraulic Testing wastewater (Batchwise)Leakage &amp; Spills contaminating cooling water</li> <li>• Accidental overflow from Antitack/cooling water tank</li> <li>• Floor wash down of different units</li> <li>• Sanitary and other miscellaneous water</li> </ul>	
Latex Based Products	<ul style="list-style-type: none"> <li>• Cooling water bleed &amp; boiler blow down, Product wash water</li> <li>• Wash down from latex storage, compounding &amp; transfer areas</li> <li>• Form wash &amp; rinse waters</li> <li>• Accidental overflow water</li> <li>• Sanitary &amp; other miscellaneous water</li> <li>• Coagulation/Coagulating Agent Tank Wash/overflow</li> </ul>	<p>Latex spills, Surfactants, Coagulants etc.</p> <p>Ball milling &amp; washing containing chemicals including Zn Acid (Acetic/Formic) etc.</p>
Reclaimed Rubber	<ul style="list-style-type: none"> <li>• Cooling water bleed &amp; boiler blow down</li> <li>• Steam condensate from autoclave</li> <li>• Area wash down of all processing areas</li> <li>• Sanitary &amp; other</li> <li>• Miscellaneous water</li> </ul>	Oil & grease, soluble and insoluble organics, Rubber particles etc.

Based on the discussion in preceding sections, the water consumption and wastewater generation rate for all categories of Industries are summarized in **Table-3.2**.

**Table-3.2 Water Consumption and Wastewater Generation**

Sl. No.	Types of Industry	Water Consumption	Wastewater Generation
1.	Tyre & Tube Industry (Category)	9 to 15 liter/kg of raw material	2 to 5 liter/kg of raw material
2.	Molded, extruded/calendered and Fabricated Rubber Products	6 to 10 liter/kg of raw material	0.5 to 2 liter/kg of raw material
3.	Latex Based Industries	14 to 45 liter/kg of raw material	10 to 30 liter/kg of raw material
4.	Rubber Reclaiming Industry	1 to 2 liter/kg of product	0.2 to 0.4 liter/kg of product

## **3.7 WASTEWATER CHARACTERIZATION**

### **3.7.1 General**

In the preceding chapter and sections, detailed processes and its associated possible sources of wastewater generation and nature of contaminants have been presented.

Waste water samples from available sources in representative number of industries have been collected and analysed for parameters likely to be present based on processes and nature of contaminants. Further, available in-plant data and extensive literature survey have been made to substantiate the findings and to avoid the misleading results which could be due to non-availability of representative waste water characterizing samples in industries. Examination of In-plant and analytical data obtained during the site inspections of a number of production facilities indicates that some parameters are present only in insignificant amounts or are contributed by discharges unrelated to the primary production operations such as domestic wastewater and boiler blow down. Such discharges are the subject of other guideline studies and are covered by other CPCB documents. The present section describes the findings on characterizing parameters and data of wastewater in detail for each category.

### **3.7.2 Tyre and Tube Industry**

Ten plants producing passenger tyres, trucks tyres, cycle tyres, camel back and inner tubes were visited and studied to determine if the type of product affected the quality and quantity of wastewater streams and/or the control and treatment technology employed. Both single product and multi-product plants were included so the effect of combined lines on the plant wastewaters could be evaluated. Plants of various sizes were studied to determine the impact of production levels. The findings regarding wastewater characterization based on analysis of samples taken during plant visit are summarized below.

- Tyre and tube industry is basically dry process industry and waste water generation from process area and utility services as described in earlier section is of low volume and intermittent.
- As such there was no continuous stream from process specific section except cooling water for sampling to characterize process specific wastewater.
- In some plants, combined drain existed for both industrial wastewater comprising mainly once through cooling water and sanitary wastewater.
- Multi-product industries producing tyre and tube, as a major product has neither process associated nor plant product specific drains for sampling.
- Intermittent discharge of wastewater from process and storage areas and utility services find their way to re-circulating cooling pond and contribute in building up the levels of contaminant in re-circulating cooling water.
- Cooling water blow down rate of industrial waste water from cooling pond (Cooling water blow down) varies from industry to industry depending upon volume and



contaminant loading of waste water generated from other sources to join cooling water stream.

- In small medium plants, intermittent discharge is of low volume and pollution load that it becomes part of make-up water to cooling water leading to no discharge from cooling water pond. Cooling water pond is emptied twice or thrice in a year for its cleaning and industries claim to have zero discharge.
- In most of plants visited, sampling was done from cooling water blow down drain/re-circulating drain/pond, as there was no other stream of wastewater existing in the plant.
- As such, analysis results are highly dependent on cooling water management practice and house keeping measures and are not true indicative of contaminant loadings.
- However 14 no samples collected from different plants with proper re-circulating cooling water management practices and partially segregated drains from process areas show waste water characteristics in the range as mentioned below:

**Table 3.3: Wastewater Characterization from Tyre & Tube Industry**

Parameters	Range
PH	6 – 8.5
Suspended solids	43 – 314 mg/L
Total Dissolved solids	1520 – 2735 mg/L
BOD	15.4 – 184.6 mg/L
COD	21.3 – 270.4 mg/L
Oil and Grease	5.5 – 37.9 mg/L
Zinc as Zn	BDL – 1.0 mg/L
Phenolic Compounded	BDL
Sulphide as S	BDL to 0.35 mg/L

Levels of other physico-chemical parameters are found either BDL or significantly low.

The above results are the characteristic of combined industrial wastewater after suitable in-plant control measures. The wide variation in result is due to extent of in-plant control and house keeping measures adopted by different industries. The low range of BOD, suspended solids and total dissolved solids in some samples are due to municipal water utilized for most of industries.

- Based on aforementioned discussion and close examination of process details as discussed in preceding chapter, it can be concluded that the following constituents are present in measurable quantities in waste water effluents from tyre and tube production facilities.
  - BOD
  - COD
  - Suspended Solids
  - Total Dissolved Solids
  - Oil and Grease
  - pH
  - Temperature
  - Chromium

Examination of in-plant and analytical data obtained during the site inspections indicates that certain parameters are present only in insignificant amounts or are contributed by mainly domestic waste water discharges unrelated to the process facilities.

### 3.7.3 Moulded, Extruded/Calendered and Fabricated Products

Five plants under moulded products, seven plants under extruded/calendered products and six plants under fabricated products representing tiny, small, medium and large industries have been visited to study waste water characterization from such categories of industries under Indian scenario. Salient points regarding wastewater sampling and characterization observed during plant visits have been summarized as below.

- As the process involved in such industries is mostly dry and waste water generated from all possible sources is generally of low volume and highly intermittent, sampling could not be done from process specific wastewater stream.
- Only cooling water drains were available for wastewater sampling. In some plants, waste water generated stream due to contact cooling/ washing of product could be found for sampling.
- Periodical discharges of wastewater from spills, leakages, wash own and run-off from processing and storage areas and from boiler blow down and water treatment plant discharge find their way in cooling water open drain and contribute in bundling up the levels of contaminants in re-circulating cooling water pond. Here, analysis results are found with high range depending upon cooling water management practices and housekeeping measures adopted by such industries.
- Such periodical discharges from process areas and utility services when find their way to mix with once through cooling water drain, is diluted to such an extent showing very minimal or no pollution load to waste water stream.
- The analysis results of collected samples from seventeen plants are summarized below:

**Table 3.4: Wastewater Characterization From Moulded, Extruded/Calendered and Fabricated Products.**

Parameter	Range of Value
pH	6.6 – 9.9
Total Suspended Solids	36 – 140 mg/L
Total Dissolved Solids	1520 – 2830 mg/L
BOD	9 – 60 mg/L
COD	20 – 182 mg/L
Oil and Grease	2.4 – 19.5 mg/L
Zinc	BDL – 0.15 mg/L
Phenolic Compounds	BDL
Sulphide (as S)	BDL
Lead	BDL
Chromium	BDL

Source: Plant visit and Sample Analysis.

The levels of other physico-chemical parameters are found to be either significantly low or below detection limit (BDL).

The above data pertain to raw combined effluent of moulded, extruded/calendered and fabricated product industries with suitable in-plant control and good house keeping measures. The low BOD and suspended solids found in the range 1-5 mg/l in some samples are due to use of good quality ground water for industrial use. This shows that effluent quality can be kept almost same as of influent quality with suitable in-plant control and good house keeping measures.

From the study of detailed process associated with such categories of industries and from examination of waste water sample analysis data and literature review, it appears that the following pollutants are present in measurable quantities in the waste water effluents from categories B, C and D production facilities.

- pH
- BOD
- COD
- Suspended Solids
- Total Dissolved Solids
- Oil and grease
- Temperature (Heat)
- Lead
- Chromium

#### **3.7.4 Latex Based Industries**

Wastewater characterization data for latex based production facilities were obtained from plant visits and EPA documents. Plant visits were made at four latex based products, one latex adhesive product and two latex foam products.

Waste water characteristics of different latex based products, i.e. latex dipped, coagulant dipped, foam product, latex thread and latex adhesive are comparable and the principal difference lie in loadings of parameters and volume of waste water generation.

As per the process details and wastewater generation sources described in the preceding sections, three main sources of wastewater as mentioned below may be generated from each category of industry.

- Product wash water
- Washdown and runoff from latex storage and compounding area
- Form/mould wash water specific to latex dipped and moulded products.

Product wash water is characterized by COD, BOD, dissolved solids and suspended solids loading. The loadings of these wastewaters are highly dependent on the washing techniques employed by the company. Some plants use detergents in the washing operations whereas some use only high temperature water. The use of detergents adds to COD and BOD loadings in the raw effluents. In addition to the other loadings, discharges of product wash water from latex foam facilities can contain high concentration of zinc. Zinc oxide is used as gelling/curing agent during foam

manufacture. The wash waters remove zinc components, which are not held or fixed in the foam matters.

The second source from spills, leaks, wash-down and runoff from latex storage, compounding and transfer areas will contain latex and is characterized by COD, BOD, suspended solids, dissolved solids, oil and surfactant loadings. COD, BOD and suspended solids are present due to the latex in the wastewater. Oil and surfactants are contributed by coagulation agents, extractable organics and emulsifier aids. Form/mould cleaning waste is characterized by loadings by COD, BOD and suspended solids. Literature and EPA documents indicate that certain latex dipped operations use chromic acid solutions to clean forms. The resulting wastewater can appear in the process effluent.

In view of findings from literature survey and process details, effluent from such category of plants were analysed for COD, BOD, suspended solids, dissolved solids, oil, surfactants, zinc, phenols, and sulphide. The analysis results for each plant visited are given in Individual plant profile. The results are summarized below.

**Table 3.6: Wastewater Characterization From Latex Based Industries**

Parameters	Range of value
pH	5.5 – 8.8
Total Suspended Solids	25 – 225 mg/L
Total Dissolved Solids	1830 – 3350 mg/L
BOD	40 – 160 mg/L
COD	55 – 350 mg/L
Oil and grease	8 – 18 mg/L
Zinc as Zn	BDL – 10 mg/L
Phenolic Compound	BDL
Sulphide as S	BDL
Surfactants	BDL

**Source: Sample Analysis from Plant Visits.**

The range of wastewater loadings in terms of suspended solids, BOD, COD are high due to different wash water techniques employed. Since plants had no separate streams for different process, it is not possible to characterize process-associated wastewater.

Ranges of pollution loadings are substantially higher because one plant uses detergents in the washing operations. The use of detergents adds to COD, BOD and surfactant loadings.

### 3.7.5 Rubber Reclaim Industry

Data for characterizing rubber reclaim industry wastewater is obtained primarily from two reclaim industries. One of these two plants has been visited thrice to get wastewater samples during different period of depolymerisation process cycle and discharge of stream condensate. The plants visited are having dry depolymerisation process and the only wastewater stream was available of condensed steam from air

pollution control device (condenser followed by adsorbing unit). In one plant, this wastewater stream is led to mix with re-circulating water in cooling pond after decanting oil partially. Cooling pond appears to be sink of wastewater generated from other sources periodically. No visible drain going of the cooling pond was available for wastewater sampling generated due to blow down. On enquiry from plant personnel regarding this, it was revealed that blow down is done very occasionally perhaps once or twice in a month through the underground pipe. Similar system exists for another plant also with the only difference that waste water condensate steam was discharged without any treatment and mixing with cooling water. Samples from raw condensate stream and re-circulating cooling water pond were taken to characterize wastewater and analysis results are summarized below.

**Table 3.6 Wastewater Characterization of Raw Condensate Stream (Rubber Reclaim)**

Parameter	Range of Value
pH	7.86 – 8.75
TSS	360 – 520 mg/L
TDS	2225 – 2400 mg/L
BOD	748 – 900 mg/L
COD	3780 – 5620 mg/L
Oil and grease (Free and Emulsified)	820 – 1235 mg/L
Zn	BDL – 0.56
Phenolic compound	BDL – 0.65
Sulphide	BDL – 0.80 mg/L

Source: Plant visits

**Table 3.7: Wastewater Characterization of Recycling Cooling Water (Rubber Reclaim)**

Parameter	Range of Value
pH	8.20 – 8.40
TSS	65 – 89 mg/L
TDS	4550 – 5115 mg/L
BOD	118 – 180 mg/L
COD	614 – 736 mg/L
Oil and grease	40 – 42 mg/L
Zn	BDL
Phenolic compound	BDL
Sulphide	BDL

Source: Plant visits

As per the forgoing discussion, it is clear that wastewater characterization of re-cycling cooling water can not be true representative one for blow down from cooling pond. However it shows appropriate range of concentration level of contaminants at the time of blow down and nature of characterizing parameters generally found in re-circulating cooling water.

Both plants data with similar process under Indian scenario and literature survey can not be compared due to different cooling water management practices adopted by them but characterizing parameters of waste water are confirmed. USEPA document shows pollution load of two-wastewater stream generated from this category as below.

**Table 3.8 Wastewater Characterization from Rubber Reclaim Industry**

Parameter	Spills, Leaks, Washdown and Runoff	Vapour Condensate from air Pollution control Devices
Flow	3.1 liter per kg of product	0.16 liter per kg of product
COD	110 mg/L	340 mg/L
BOD	27 mg/L	160 mg/L
TSS	287 mg/L	8 mg/L
Oil	154 mg/L	65 mg/L

Source: USEPA Document

Oil is measured after oil separation from this stream for recycling of process oils as in-plant control measure.

It is clear from this table when compared to Indian scenario data that condensate stream is mainly characterized by oil content as pollution load in terms of all other parameters is drastically reduced by reducing the content of oil from this stream.

Review of published literature, EPA documents, industry documents, industry records of process details and the findings of the plant visit indicate that the following attributes are pollutants likely to be found in measurable quantities from rubber reclaim waste water effluents.

- BOD
- COD
- Suspended Solids
- Total Dissolved Solids
- Oil and Grease
- pH
- Temperature
- Zinc

## CHAPTER 4

### CONTROL AND TREATMENT TECHNOLOGY

#### 4.1 INTRODUCTION

In order to review and fully evaluate the wastewater control and treatment technologies in the rubber processing industry in Indian scenario, plants were visited to conduct operation analysis; review water and wastewater management programmes and evaluate wastewater treatment facilities. Moreover, exemplary or/and advanced plants and their wastewater control and treatment technologies in developed nations have been studied through literature survey. The present chapter discusses the summarised findings on present status of wastewater treatment generally adopted for rubber product industries. Based on such findings, best practical, economical and technological viable control and treatment technology has been suggested for each category of rubber product industry.

#### 4.2 TYRE AND TUBE INDUSTRY

##### 4.2.1 Existing Status of Control & Treatment Technology

Four scenarios generally exist for the control and treatment of wastewater generating from different sizes of tyre and tube production plants as mentioned below.

- The first approach adopted by some plants is to combine domestic and industrial wastewater and to treat the entire plant effluent. Generally, the reasons supporting this approach are as follows.
  - In-plant drains for domestic and industrial wastewaters are usually combined, thus making combined treatment more attractive.
  - Industrial flows in case of re-circulated cooling water management particularly for low production line of industries is highly intermittent and of low volume as compared to continuous domestic waste water generation.
- The second approach generally adopted by the plants of lower production lines is to use re-circulating cooling water pond as a sink and diluting pond of intermittent and low volume industrial waste water generated from process areas and utility services. Such industries claim to have zero industrial discharge and no treatment to industrial wastewater is given.
- Once through cooling water as used by some plants is mixed with low volume and intermittent wastewater generated from other sources. Pollution load is diluted to such an extent requiring no further treatment as claimed by some of the industries.
- The fourth approach adopted by very few plants particularly of high production lines is to control and treatment of a segregated and undiluted wastewater. This

approach has been followed in plants having partially or wholly segregated industrial drains. This would, of course, include any plant using re-circulated cooling water. Treatment units adopted by such plant generally include oil segregation followed by settling tank.

#### **4.2.2 Control and Treatment Technology by Exemplary Plants**

Review of control and treatment technology adopted by exemplary plants under literature survey shows existing trend of in-plant control measures followed by end-of-pipe technology. In-plant control technology covers segregation and measures for handling, reuse, modification of processing and disposal of various types of waste waters including spills and leakage, wash downs, control of runoff and house keeping practices. End-of-pipe treatment technology covers the primary treatment given at end of pipe after combining wastewater generated from different sources. The following sections summaries control measures generally adopted by exemplary tyre and tube industry as a model guidelines to be followed by industries.

#### **4.2.3 In-Plant Control Measures**

##### **a) Handling of Anti-Tack Solution**

Soapstone generally used as anti-tack is slurry normally consisting of clay, an emulsifying agent and water. Soapstone, if continuously discharged, will contribute a high solids and BOD loading to the industrial wastewater. The standard method of eliminating a continuous discharge of large quantities of soapstone is the use of closed-loop recirculation system. Such a system needs periodic cleaning, usually on a weekly basis. This cleaning operation can, but does not necessarily, lead to discharge. Prior to cleaning, the soapstone solution in the system is generally transferred to storage tanks. Soapstone waste wash water is a potential discharge, which is commonly sent to end-of-pipe treatment. Some plants under literature survey store this wash water and use it as makeup for the soapstone solutions for future operations. Alternative methods for controlling discharges from weekly wash down adopted by some plants include the use of substitute solutions which require the system to be cleaned on a less frequent basis.

Control of minor discharges of soapstone, such as spills and leakage, is achieved by the use of curbing and by blocking of drains in the dripping area. In addition, drip pans are provided for stock during the air drying operation. Soapstone that is spilled into the curbed area is periodically containerised and sent to a landfill site. Instead of curbing, steel grates are placed on the floor in some plants. These can be removed when cleaning the area.

##### **b) Latex Dip**

The most common practice of the larger manufacturers is to eliminate this operation from tyre facility. Fabric is dipped by a centrally located facility and then sent to the tyre plant. However, in plants that still dip fabric, the accepted procedure is to seal off drains in the immediate area, provide the area with curbing and drum the waste



solutions for disposal at landfill sites. The alternative is to dump the waste solution into drain, which is destined for end-of-pipe treatment systems. Containerisation of the solution is therefore preferred, since treatment of this stream once diluted with other streams is difficult.

**c) Air Pollution Control Residues**

It is not common for manufacturers to use large quantities of wet particulate collection systems. In the compounding, in particular, bag-houses, rather than wet scrubber are used. Wet system are more common in the tyre finishing area, where they collect the grindings from the white side wall grinding machines, balancing machines and their tyre repair area.

Discharges from wet scrubber contain high loading of settleable solids. The solids collected from tyre finishing area can be settled out in a small sump. The particulates are large, and with a properly designed separator, the clarified water is frequently reused.

Additional air pollution control equipment is found in the tyre painting areas. The industry is currently attempting to substitute water based paints and sprays for solvent-based materials.

**d) Spills and Leakages**

To control oily wastewaters resulting from spills and leakage, the common practice is to provide curbing and oil sumps and to seal drains. Curbing is used to keep normal area wash down and periodic leakages and spills from entering the industrial wastewater stream. Updated seal designs prevent this leakage of oil. In many cases, potentially contaminating areas have no drains, thus eliminating the possibility of oil in industrial wastewater.

**e) Washdowns and Machine Cleanings**

Common practice for prevention of process-area wash downs from contaminating wastewaters is the use of dry sweeping requirement. These include automatic sweepers, brooms and shovels. Only spills are cleaned using solvents and rags, the resulting contaminated material being drummed and sent to a landfill. Practices employed in non-process areas (such as the boiler house and storage areas) are similar.

Machines and machinery parts are normally cleaned with solvents or steam. Spent solvents are drummed and sent to a landfill. The use of steam requires a special area supplied with curbing and an API separator to remove separable oil and solids. Discharges of untreated oil and solid contaminated steam condensate occur and constitute a significant source of industrial wastewater. Although steam cleaning has the disadvantage of having a discharge that must be treated, it eliminates the possibility of a careless operator discharging large quantities of organic solvents into an untreated industrial wastewater stream.

#### f) **Run-off**

Run-off from oil storage areas occurs due to oil spills, storm water and various blow downs, which occur in the storage area. Handling practices vary within the industry. Minimum control involves the diking of all oil-storage areas to prevent contamination of wastewater by large oil spillages, which can occur during unloading or due to leaking tanks. These dikes are generally provided with drainage parts to prevent normal storm from filling the diked areas. This allows minor oil spills attributable to operator negligence to contaminate stream run-off. A better system involves the diking of the storage areas, the roofing of storage area to prevent storm run-off contamination and use of an oil sump to collect minor spills and leakages. Collected oil is drummed and sent to a landfill site or sold to other end users. To prevent oil from unloading areas from contaminating the wastewaters, drains are diked and covered with stream filters.

Solvent storage and maintenance areas are normally confined to buildings. To decrease the possibility of contamination due to operator or maintenance negligence, these areas are not provided with drains

#### **4.2.4 End-of-Pipe Treatment**

End-of-pipe treatment in this segment of the industry generally involves the treatment of combined wastewater in a primary sedimentation basin or lagoon. Once through, non-contact cooling water usually is not treated even though the possibility exists for oil contamination.

The most effective system though not generally applicable because of land requirements, is the use of judicious use of water management techniques to minimize wastewater discharges and of holding lagoons to contain all wastes including storm run-off. Residence time varies from twelve to twenty four hours with surface loadings as high as 12000 litres per minute per square metre. Auxiliary equipment observed include oil skimmers and sludge handling equipment. From the standpoint of treating wastewaters, these systems suffer heavily from dilution, particularly in the treatment of grease or oily wastes. Dilution by heavy storm run-off was an additional problem at many locations.

#### **4.2.5 Summary of Findings**

Based on the foregoing discussion, the existing treatment status on wastewater from tyre and tube industries can be summarised as below:

- Large-scale tyre and tube companies have satisfactory pollution treatment system even in Indian scenario. The treatment technology generally adopted by such plants includes in-plant control measures and end-of-pipe treatment comprising oil separator for segregated or partially segregated wastewater stream from process area followed by settling tanks.
- Some medium scale industries under this group provide combined end-of-pipe treatment for industrial and domestic waste comprising primary units such as equalization/holding tank, clariflocculator and sludge drying bed.

- Most of medium/small scale industries do not have any end-of-pipe treatment as liquid effluent from industrial process is of small quantity and highly intermittent.

### **4.3 MOULDED, EXTRUDED/CALENDERED AND FABRICATED PRODUCTS.**

#### **4.3.1 Existing Status of Control & Treatment Technology**

The treatability status of wastewater under these categories of industries in India is observed to be similar of tyre and tube industry as discussed in earlier section. Of the sub categories of B, C and D plants visited, only one had primary treatment system and none use secondary system. Most of these categories use re-circulating cooling pond as a sink of wastewater generated intermittently from other sources and claim to have zero discharge of industrial wastewater. Analysis results of samples collected from re-circulated water tanks from most of industries in low line of production under such categories show very low pollutant loads despite the building up concentration of contaminants due to low blow down rate. These facts indicate that the magnitude of wastewater pollution is not appreciable or the problem can be effectively controlled by sound house keeping and in-plant control measures. Volume and pollution load of wastewater generation particularly for lower production line of Industries is of small and intermittent due to less number and size of machineries involved as compared to tyre and tube industry. As such no treatability data exists except some of large industries which has oil separator/interceptor followed by holding/sedimentation tank.

#### **4.3.2 Control and Treatment Technology by Exemplary Plants**

Control and treatment technology generally adopted by similar plants in other developed countries has also been reviewed under literature survey and documented in following section as a model guideline to be followed by similar type of industries.

#### **4.3.3 In-plant Control**

In-plant control measures and practices generally adopted under such categories of industries include proper handling and isolating general spills and leaks of potential contaminants, soapstone and other anti-tack agents, latex compounds, solvents and rubber cements, metal preparing wastes and wet air pollution control equipment

##### **a) General Spills and Leaks**

Most moulding, extruding/calendaring and fabricated rubber manufacturing plants such as hose or foot wear manufacturing facilities; can generate waste water containing machinery oils and greases as well as suspended solids. If uncontrolled, this wastewater can enter floor drains, thereby polluting the plant effluents.

The exemplary subcategories B, C and D plants studied under literature survey share the following common methods to reduce the type of oil contamination discussed above:

- Blocking of existing floor drains
- Removing oil leaks promptly with dry absorbent granules.

- In some cases, curbing the problem area to contain oil and grease leaks.

Plants which have water and oil leakages occurring at some pieces of equipment, often use oil-water sumps inside the oil retention areas to collect the highly contaminated water in order that it can be adequately containerized or treated. For cases with relatively voluminous leakages, these collection sumps are equipped with pumps, which empty the sumps by pumping the oily water to a location where it can be treated or held or disposed.

#### **b) Run-off**

Outside storage areas where fuel, maintenance and process oils are kept, are frequent causes of oil pollution in a plants effluent. The situation is aggravated at these facilities by high run-off rates during storms. The most effective way to prevent contamination of large quantities of storm water is to retain the oil, preventing its entry in clean storm water and at the same time, roofing the oil contaminated regions to keep the clean storm water from picking up the oil.

#### **c) Lead-Sheathed Hose Production**

In the manufacture of hose via lead-sheathed process, lead-laden wastewater results. The source of lead are the lead press and cure hose cooling water and vulcanizer condensate. In order to treat it properly for lead, these streams should be segregated prior to treatment.

#### **d) Soapstone and anti-Tack Dip Solutions**

The spillage of soapstone and other anti-tack solutions is controlled in exemplary plants in a manner similar to the containment methods used for oils and greases. Floor drains have been blocked to prevent the slurries from entering plant drains. Spills and dripage are mopped up or are simply allowed to evaporate.

#### **e) Latex compound**

Several types of fabricated product require the use of latex during the manufacture. Latex spills can occur at the storage loading areas, facilities where bulk latex is transferred to drums and processing areas. Where such spills occur, it is common to wash the latex down with water, producing a latex-laden wastewater. In addition drums are frequently rinsed to clean with water. This latex wastewater is segregated, chemically coagulated and clarified, usually in a batch wise treatment system.

A more effective way to handle latex is the use of plastic liners in latex drums. When the drum is reused, the old liner is discarded. In this manner, wastewater from drum cleaning is not generated. Latex spills around storage and transfer facilities are coagulated with alum in situ and scraped from the ground. In the processing areas where latex is used, floor drains are blocked.

#### **f) Solvents and Rubber Cements**

Many plants use rubber cements as adhesives. In addition, the cement dipping industry handles large quantities of cements and solvents. In most of the cases observed, these organic liquids are mixed and stored in areas without floor drains. This is by far the

most positive method to control solvents or cement spills and leaks. Solvents should be kept out of plant drains for the reason of safety as well as quality, since they have high flammability and explosiveness.

#### **g) Metal Preparation**

The methods used to prepare and recycle metal components for rubber bonded moulded products are essentially dry. Degreasing liquids are used in closed systems and discarded when saturated with grease.

#### **h) Air Pollution Control equipment**

Wet scrubbing devices are used to trap rubber-buffing and metal sand blasting fines. The wastewater from wet scrubbing devices are settled and filtered before discharge.

### **4.3.4 End-of-Pipe Treatment**

In general, only minor end-of-pipe treatment is used by the industries covered under these categories. This is due largely to the fact that wastewater contamination is limited to essentially two parameters: Oil & grease and suspended solids. In addition, good effluent quality can be achieved most economically by employing good house keeping practices with well designed in-plant control measures.

Of the subcategories B, C and D plants studied, only two have primary treatment system and none used secondary treatment. Furthermore, only one of these plants used the local municipal sewage treatment system to provide the equivalent secondary treatment. One plant uses gravity separation to remove oil from the combined plant effluent. This combined effluent includes industrial wastewater and storm water. In-plant control measures are employed as the primary method of oil reduction and the oil separators are designed as a backup system. In addition, the plant's boiler blow down, autoclave condensate and compressor condensate pass through a holding pond to separate solids and oils from these wastewater types before its discharge. The holding pond also allows these wastewaters to cool before they are discharged. The other plant manufacturing footwear, which does employ primary treatment uses appreciable quantities of latex adhesives. The handling of these materials produces latex-laden wastewaters, which are chemically coagulated and allowed to separate in a batch wise manner. This plant utilizes oil collection-separation sumps to trap oil leaks produced at the mills and other heavy machinery.

The quality of the effluent from one plant discharges to a municipal treatment system is satisfactory without primary treatment or pre-treatment. This quality of effluent is achieved when correct in-plant control and house keeping practices are followed.

### **4.3.5 Summary of Findings**

Based on the foregoing discussion, the existing treatment status on wastewater from moulded, extruded/calendered and fabricated products can be summarised as below:

- Normally no end-of-pipe treatment adopted as liquid effluent from process area is of small quantity and highly intermittent.
- Volume and pollution load of wastewater generation is of small and intermittent as compared to tyre and tube industry of similar line of production due to less number and size of machineries involved.
- As such, no treatability data exists except some of large/medium industries having oil separator/interceptor followed by holding/sedimentation tank.
- Exemplary and advanced plants in other countries keep containment of pollutants most economically by employing good housekeeping practices with well-designed in-plant control measures.

#### 4.4 LATEX BASED INDUSTRIES

Wastewater treatment status in latex based industries currently practised in India and other countries are obtained from plant visits and EPA documents. In-plant control measures and end-of-pipe treatment status based on review of findings given under individual industry profile are summarised below as a model guideline to be followed by similar type of other industries.

##### 4.4.1 In-Plant Control Measures

###### a) General Latex Spills And Leaks

In-plant control measures employed by this type of industry are designed primarily to control, handle and treat latex-laden wastewaters. It should be noted that the latex-laden wastes could be reduced and potentially eliminated by careful house keeping and good latex handling practices. Excessive wash down and cleaning waters should be avoided when dealing with latex spills. Latex spills can often be coagulated in situ with alum or other coagulants and removed as a solid mass by shovelling and scrapping.

The major spillages and wash downs occur at the storage, unloading area and in the latex compounding building. In addition, the transfer drums require cleaning between latex mixes and this produces a latex-laden wastewater. Plastic drum liners can be used to eliminate pollutants from entering the wastewaters during drum cleanings. In the latex foam plant, the latex-laden wastewaters are generated at storage and curing press areas. The areas where the latex spills and leakages occur are designed to restrict the spread and further contamination by this latex wastes.

###### b) Form/Mould Cleaning Wastes Reduction

In most latex dipping and moulded product facilities, the dip forms/mould require cleaning. In some cases, this is necessary on each dip cycle prior to the first dip tank whereas, in other plants only periodic cleaning is required.

Frequent cleaning operations can be performed in a tank of water containing detergent or other type of cleaning liquid. The form/mould can be dipped simply into the cleaning water and gently scrubbed in the tank with mechanical scrubbing equipment. After the cleaning step, the forms are rinsed before the latex dipping operation. The rinsed water is allowed to overflow from rinse tank and contains detergent or cleaning agents and exhibits a BOD load. Plants limit the volume and loading of rinse water overflow more by reliance on mechanical scrubbing than on the activity of the detergent agent. In addition, counter current rinsing is sometimes employed in which the final rinse water overflows to the first rinse tank where a higher concentration of detergent can be tolerated. The volume rinse water discharged is thereby reduced.

c) **Segregation of Waste Water Stream**

In tiny /small plants, no segregation of wastewater is done as the flow is of small volume and loading. In large plants, wastewater of small volume and high pollution load is segregated for giving local treatment before they mix with the total plant effluent. One plant under Indian scenario treats the product wash water and wastewater generated from spills, leak and floor washing separately. In one latex foam plant under literature survey, the latex laden wastewaters are generated at the latex concentration, intermediate storage and curing press areas. The wastewater from these operations are collected in a separate drain system and treated by chemical coagulation and clarification.

After curing, latex foam requires rinsing to remove excess compounding and curing agents entrained in foam matrix. The resulting foam waters pick up soluble zinc compounds and the zinc concentration in these wastes is high. A significant reduction in the volume of this rinse water was achieved in one plant under literature survey by employing a counter current rinsing process. The zinc laden rinse water is then treated for zinc removal in a continuous chemical precipitation and clarification system. The clarified effluent (zinc concentration about 10 mg/L) is then discharged to combine with total effluent. In some latex dipping plants, the forms are cleaned only periodically, usually when they become fouled with rubber. One method to clean this type of stubborn rubber deposit as encountered in one plant under literature survey is to dissolve it in chromic acid and rinse the acid from the form. The form rinse water generated is characterised by low pH and hexavalent chromium. A satisfactory method of treating this segregated wastewater, as employed by this industry, is the batch precipitation of the chromium after reducing it to the trivalent state using ferrous sulphate. The trivalent chromium is then precipitated with lime at a pH of approximately 9 and allowed to settle. The settled lime sludge is then dried on a sludge drying bed.

#### **4.4.2 End-of-Pipe Treatment (Indian Scenario)**

Study of the production facilities included in this group reveals the broad size distribution in this segment of industry. Wastewater generated from this type of industries varies from few litres to thousand litres per day depending upon size of industries. No end-of-pipe treatment is given by most of tiny/small industries and small volume of wastewater is discharged into drain by them. One tiny plant collects the intermittent discharge in small holding tank and leaves it for settling and evaporation.

The volume of wastewater from another tiny plant is 15 to 20 litres per day. This type of wastewater is treated taking the waste into a chamber and diluting to 50 litres for being fed to septic tank. Twin chamber septic tank with a total volume of 500 litres is provided for the treatment. Effluent from the septic tank is taken into a reaction chamber with aeration arrangement for 30 minutes aeration. The effluent is then disposed for land irrigation.

One large plant producing male condom employed chemical coagulation and settling for sinking latex solids and foam floater for skimming floating latex solids followed by mixed media filter for waste water treatment. The wastewater generated in the plant is separated into three separate streams according to their quality as mentioned below:

- Latex stream from compounding section
- Slurry stream from vulcanising section
- Wash water stream from floor washing, form cleaning, cooling water flow etc.

These three streams are treated separately in the effluent treatment plant. The plant consists of three equalization tanks where effluent from three streams are taken separately and mixed to obtain uniform quality of effluent. The latex stream carries fine coagulated rubber particles from compounding, moulding and vulcanizing process. These rubber particles are removed in the following three stages.

- Coagulation
- Foam separation
- Filtration

Ferric alum is used as coagulant. The coagulation is conducted through on-line ventures where the latex stream is mixed for one minute with 1 percent solution of ferric alum at a rate of 5 ml per litre. After coagulation, the natural latex particles are removed by a foam separation technique using 1 percent solution of surfactant. The surfactant is also added at a rate of 1 ml per litre to the latex stream before it reaches foam separation chamber. In this foam separation chamber, finely distributed air bubble stabilizes foam due to presence of surface active agents. The foam thus selectively removes 90 percent of these natural rubber particles. However, the treated latex stream remains mildly turbid due to presence of very small fraction of fine rubber particles, which escapes the foam separation treatment. This stream is taken to multimedia filter consisting of charcoal, sand and limonite for further removal of remaining particles. Treated water is taken to a storage tank.

The slurry stream effluent is taken to a slurry holding pond of capacity 25 m<sup>3</sup>. The inorganic suspended impurities such as particulate, silica, calcium, carbonate etc. present in slurry are removed in clarifier after adding alum and electrolyte. One percent alum solution is added at a rate of 10 ml per litre and polyelectrolyte solution (1%) is added at a rate of 3 ml per litre. The settle sludge is taken to a sludge-drying pit. The overflow from the clarifier is taken to the treated water storage tank.

The effluent of wastewater stream with low pollution load is taken to an equalization tank from where it is transferred to treated storage tank. The lay out plan of the effluent treatment plant is shown in Fig. 4.1.



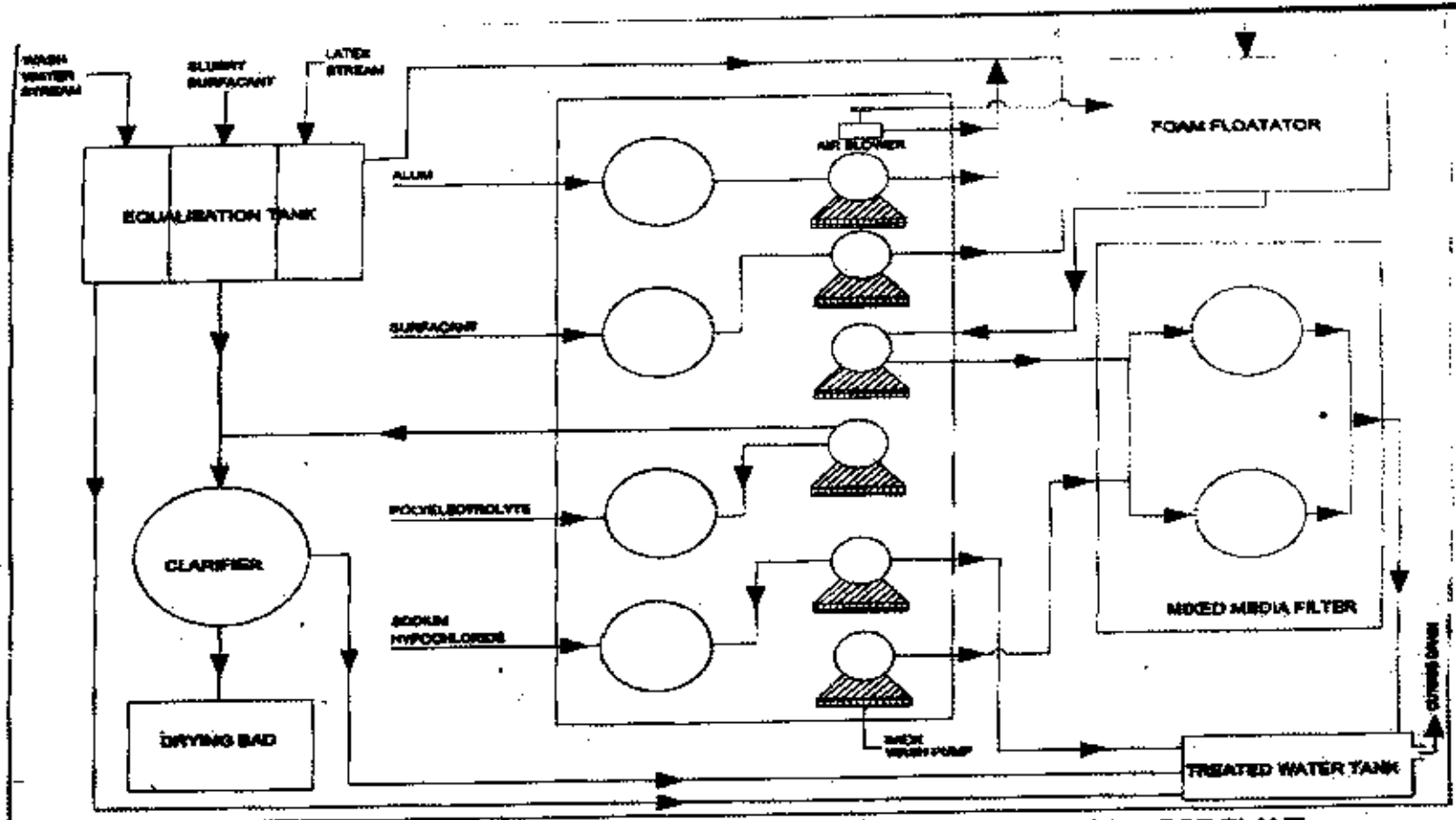


Fig. 4.1 FLOW DIAGRAM OF EXISTING EPT FOR CATEGORY E ( LATEX DIPPED ) LARGE PLANT

The other medium sized plant producing latex dipped item employed the treatment plant for combined industrial waste utilising same basic principle as discussed earlier. Wastewater is bubbled with air in two small aeration tanks to skim out the floatable latex solids. Skimmed out effluent is mixed with caustic potash to adjust its pH around 10 to 10.5 to facilitate coagulation. The coagulation chemicals, alum and polyelectrolyte are added to tank. The tank contents are vigorously mixed to bring together the coagulated chemicals and latex solids. Wastewater then flows to a flocculation tank where the coagulation process is completed with mild mixing in order to create a separate solids floc. The mixture of flocculated solids and wastewater passes to the clarifier where coagulated solids settle from the wastewater. The clarified wastewater from settling tank overflows to multimedia filter unit of charcoal and stone filter bed. Filtered water is used for irrigation purpose. Settled solids from settling tank are periodically removed to sludge drying bed from where it is disposed to a landfill site. The complete treatment plant area is approximately 30 m by 20 m containing smaller units for small volume of flow. The layout plan of the effluent treatment plant is shown in Fig. 4.2.

The treatment facilities of one latex foam plant include some batch type of coagulation, flocculation followed by settling.

#### **4.4.3 Treatment Plants Under literature Review**

Many latex dipping plants use the local municipal treatment plant to treat the primary effluent after chemical coagulation and clarification of the latex solids. This type of treatment is very suitable and is possibly the most attractive economically for most plants that are adjacent to a municipality.

One latex dipped goods plant passes its waste water through a two pond settling lagoon system prior to final discharge to a receiving stream.

Some latex dipping plants use aerated lagoon and settling pond treatment systems to treat the wastewaters. These systems perform well. Few plants use activated sludge treatment. It is considered that the wastewater loadings, particularly BOD, are too low to produce an adequate biomass to support activated sludge treatment. Therefore, aerated lagoon and settling pond systems are more applicable as per EPA document.

In one latex foam plant, wastewaters are collected in a pit and transferred batch wise to a treatment tank where pH is adjusted and coagulation chemicals (alum and polyelectrolyte) are added. Latex solids float to the surface and are removed with the tank overflow. The clarified underflow wastewaters are discharged to the river. The skimmed latex solids in the overflow are screened and containerized for disposal. Wastewater from the product washing is treated by chemical precipitation to remove zinc hydroxide as precipitate.

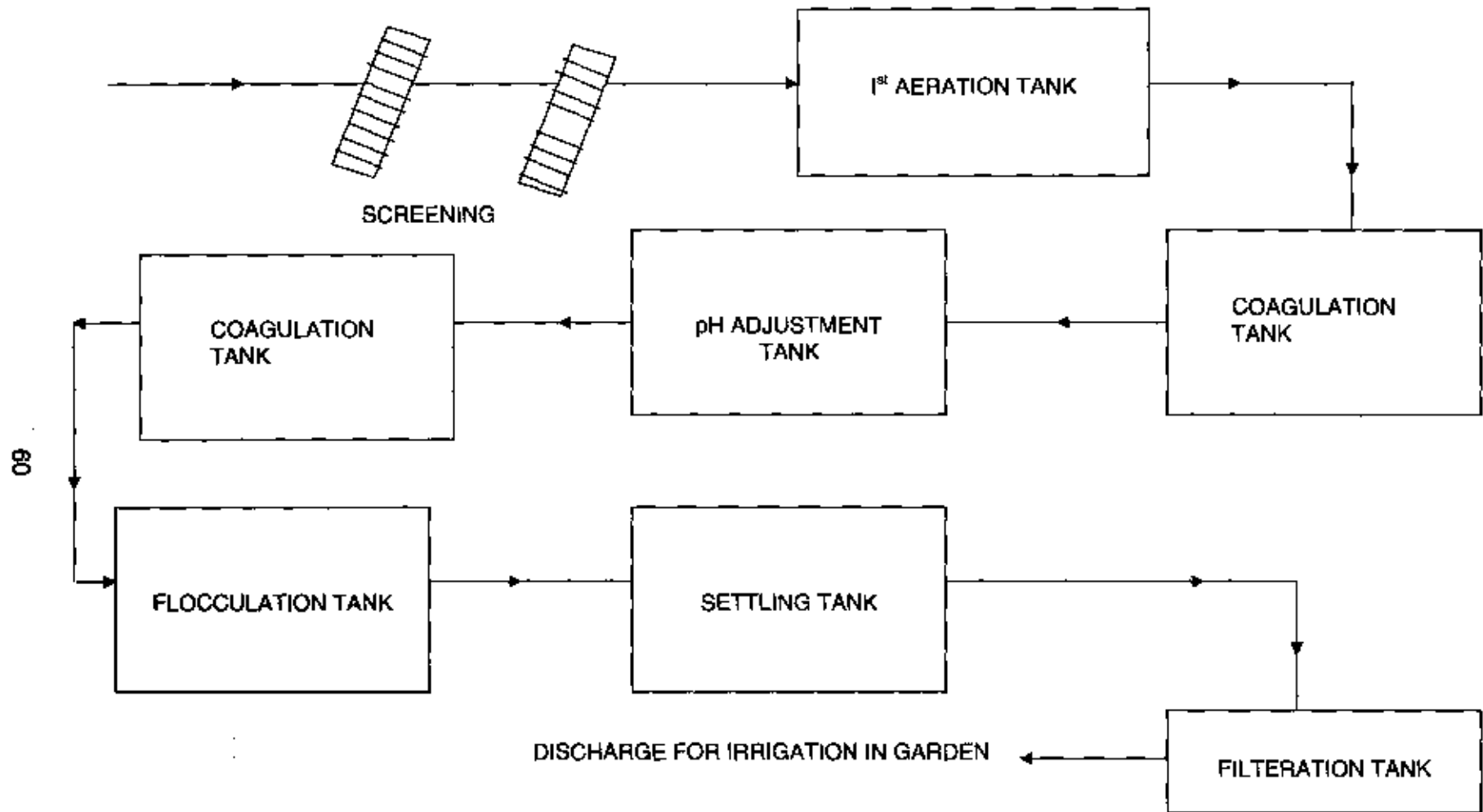


Fig. 4.2 Flow Diagram of Existing ETP for Category E (Latex dipped) Medium Plant

#### **4.4.4 Summary of Findings**

Based on the foregoing discussion, the existing treatment status on wastewater from latex based industries can be summarised as below:

- Most of the tiny/small scale group of industries discharge their waste to the drain with out any treatment.
- Some tiny/small scale plants use holding tank to collect small volume of wastewater for soaking and evaporation.
- One small plant uses septic tank followed by aeration to treat small volume of latex laden wastewater.
- Some large/medium scale plants provide primary treatment consisting of coagulation with alum to form latex solid rubber, aeration/foam separation technique to skim floating latex solids and sinker such as clay, polyelectrolyte to separate settleable solids followed by a dual media filter to remove remaining fine particles.
- No biological treatment is given for large/medium plants as observed in Indian scenario.
- Exemplary and advanced plants emphasize careful housekeeping and good latex handling practices to reduce latex laden wastes. Excess wash down and cleaning waters are avoided when dealing with latex containers and spills. The benefits, in treatment cost and effluent quality, created by these and other techniques as explained under in-plant control measures are appreciable.
- Primary treatment principle as adopted by the plants under literature survey is similar to Indian Scenario.
- Due to stringent regulation on wastewater, some plants under literature survey provide primary treatment followed by biological treatment as mentioned above.
- Biological treatment units generally include aerated lagoons and settling tank for latex dipped products and activated sludge process for latex foam product.

#### **4.5 RUBBER RECLAIM INDUSTRY**

##### **4.5.1 Existing Status of Control & Treatment Technology**

Two plants under Indian scenario and one plant under literature survey have been studied for in-depth analysis of treatability status of wastewater generated from such types of industries. Most of the dry reclaiming plants do not generally have end-of-pipe treatment for their wastewaters.

Under Indian scenario, the steam condensate as primary wastewater stream is given partial treatment for oil removal by gravity oil separator. The treatment given is not effective in reducing oil content particularly emulsified oil content. The effluent is either discharged on land or mixed with re-circulating cooling water for cooling the machinery. The wastewater due to other sources as identified in earlier section finds their way to re-circulating cooling pond. No treatability data for such contaminated cooling water is available as reclaim industries claim to have zero discharge with such system.

Steam condensate from plant under literature survey is decanted effectively by API separator. The resulting effluent contains oil in the order of 10 mg/L. The in-plant control and end-of-pipe treatment generally adopted by such industries under literature survey is summarised below as a model guideline to be followed by other industries.

#### **4.5.2 In-Plant Control**

The wet digestion reclaiming process is obsolete and industry involving such process is not expected in India. If any industry is encountered, the conversion of a wet digestion reclaiming plant to any of the three dry reclaiming processes (Pan, Mechanical or dry digestion), in order to improve the quality of the plant's effluent, would constitute considerably more than an in-plant control measure. The wet digester process can more readily be converted to the dry digester process than to either the Pan (heater) or mechanical process. In comparison to the wet digester process, the wastewaters from dry reclaim process have lower flow and are less contaminated. This is primarily due to the absence of the dewatering liquor. The scope for in-plant wastewater controls is thereby reduced and is limited to this containment of spills and leaks and the effective condensation and decanting of vaporised process oils and organics.

The flows, characteristics and applicable control methods of the spills and leak in the dry reclaiming industry are similar to those found in moulded, extruded/calendered and fabricated product industries.

The spills originate at heavy equipment, material handling and storage areas. The contaminants are characterised by oil and suspended solids and are prevalent in the scrap cracking, scrap grinding, product milling and storage areas.

Successful control techniques include good house keeping, curbing and drain blockage to contain the spills and isolation modifications, which restrict the spread of the polluting material and prevent contact with uncontaminated waters.

#### **4.5.3 End-of-Pipe Treatment**

As per USEPA documents, no treatability data exists for the biological treatment of pan, mechanical or dry digester processes because the BOD is so low (20 mg/L typically) that biological treatment is inappropriate.

#### **4.5.4 Summary of Findings**

Based on the foregoing discussions, the existing treatment status on wastewater from rubber reclaim industries can be summarised as below:

- Most of the dry reclaiming plants do not generally have end-of-pipe treatment for their wastewaters and as such no treatability data available for end-of-pipe treatment.

- The steam condensate from depolymerisation process as segregated wastewater stream is given partial treatment for oil removal by gravity oil separator. The treatment given is not effective in reducing emulsified oil content.
- The wastewater flow and treatment status from other process areas are similar to those found in moulded, extruded/calendared and fabricated product industries.
- No treatability data exists for biological treatment both under Indian and developed country scenario.

## **4.6 SUGGESTED TREATMENT METHOD**

### **4.6.1 General**

Based on the review of wastewater characterizing data and control and treatment technologies currently available, the following section will describe the best practicable technology currently available, which can be economically adopted by Indian Rubber Product Industries. As clear from the discussion in preceding section, most of rubber product industries suffer heavily from dilution of contaminants and mis-management of cooling water systems from the standpoint of treating industrial wastewaters. Dilution by heavy storm runoff was an additional problem at many locations. In order to streamline the treatment method, certain measures are required as a pre-requisite as summarised below.

- Complete segregation of drains for industrial wastewater, domestic waste water and storm runoff with some modification of in-plant drainage system.
- Only re-circulating cooling water management practice should be allowed to promote water conservation and to avoid dilution of contaminants.
- Re-circulating cooling water should be in closed circuit with cover drain to avoid it getting contaminated with wastewater generated from other sources.
- Wastewater drains leading to cooling water pond/drain should be completely blocked.
- Storm water should not be allowed to enter into cooling water pond. If possible cooling pond should be dyked and roofed.
- The cooling water should be managed as per the guidelines prescribed by CPCB. Blowdown rate should be optimised.

Industry specific treatment method has been suggested as below presuming that all above measures are strictly implemented before introducing the treatment system.

#### **4.6.2 Tyres and Tube Industry**

Industrial wastewater from all sources will be led to centralized holding cum equalisation tank. Equalisation tank is required to prevent shock loads of oil, suspended solids on batch dumps of dipping solutions, boiler/cooling tower blow down and washing operations.

Wastewater collected in centralised holding cum equalisation tank will be periodically pumped to an API-type gravity separator, where the separable oils and solids fraction is removed. A typical diagram of API-type gravity separator is given in Fig.4.3. Settleable solids collected in the separator will be periodically removed and also sent to a landfill. Concentrated oil-water mixtures will be drummed and sealed for proper disposal.

Best available wastewater control technology for tyre and tube industry can be summarised as below.

- Elimination/reduction of any discharge by good house keeping measures.
- Complete segregation of industrial wastewater and its collection in sumps at strategic locations for local treatment by oil trap and initial settling.
- Collection of wastewater from local sumps in centralised holding cum equalisation tank.
- Treatment of wastewater from equalisation tank in API-type gravity separator followed by multimedia filtration if required as per loading of effluent.

##### **4.6.2.1 Economical Feasibility**

###### **Cost Aspect**

The size distribution of tyre and tube manufacturing facilities is relatively confined and lie in the range of medium/large categories. Therefore, it is not necessary to study the wastewater treatment techniques as per the plant sizes for this category. The suggested treatment system is basically low cost primary treatment, which basically involves very simple mechanism of sedimentation and oil & grease removal. It is considered that such simple treatment system is not costly with respect to the investment of medium/large group of tyre and tube industries. Thus, the treatment system is economically affordable by the industries.

##### **4.6.3 Moulded, Extruded/Calendered and Fabricated Products**

As discussed earlier, very little treatability data is available for such type of industries. Based on literature survey, the best practicable control and treatment technologies currently in use in moulded, extruded/calendered and fabricated production facilities emphasize in-plant house keeping and control measures similar to the tyre and tube industry. In general these included the isolation of potential wastewater sources with retainment curbing, the elimination of drains in contaminated areas and the use of local sumps to collect wastewater streams. In-plant control measures for such type of industries are covered in detail in the preceding section. Basically the control measures consist of:

- Eliminating/Reduction of anti-tack or latex solution discharges by adhering to the following procedures:
  - ✓ Recycle of anti-tack solution
  - ✓ Installation of curbing around the antitack dipping area
  - ✓ Sealing of drains in the dipping area
  - ✓ Reuse of the re-circulating system, wash water as make up for fresh antitack solution
  - ✓ The use of curbing around latex storage and transfer areas
  - ✓ The sealing of all drains in latex use areas
  - ✓ The containment of all latex – contaminated waste streams.
  
- Isolation, control and treatment of all oily waste streams in local sumps.
 

With proper in-plant control, wastewater contains readily separable lubricating and extender oils and suspended solids. Wastewater from local sumps/contaminated areas is led to a centralised holding cum equalisation tank as this wastewater is intermittent by nature and, therefore, sizeable flow rates will hardly ever be obtained without first collecting in holding pond. Depending upon pollution load as per size of industry, this water is further treated in an API-type gravity separator, where the separable oil and solids fraction is removed. The performance and efficiency of a gravity separator can be improved by addition of a multimedia filter.

#### 4.6.3.1 Economical Feasibility

##### Cost Aspect

In general, only minor end-of-pipe treatment is used by the plants covered under this industry segment. This is largely due to the fact that wastewater contamination is limited to essentially two parameters, i.e. oil and grease and suspended solids. In addition, good effluent quality can be achieved most economically by employing good house keeping practices with well designed in-plant control measures. Unlike the tyre and tube industry, study of the production facilities under this industry segment reveals that the size differentiation is broad and ranges from approximately less than one metric tonne per day to more than twenty metric tonnes per day of raw materials.

Although the waste water characteristics and treatment methods of small, medium and large plants are similar, the impact of waste water control and treatment costs on the tiny/small plants is likely to be more critical than their effect on medium/large plants. Overall land requirements for the suggested treatment system are small. However, tiny/small industries will find it difficult to allocate space for even this minimal treatment facility.

The pollution load and volume is dependent on number and size machinery used and the amount of raw materials handled. In tiny/small plants, the wastewater flow rates and loading are low.

It can be concluded that adoption of end-of-pipe treatment by tiny/small plants under this segment will not be economical and practical and no such treatment is required also as it can be kept within limits of MINAS parameters with in-plant and good house keeping measures. However, it is necessary that small holding tanks or sumps can be used by tiny/small to act as a catch-all as well as monitoring pit for all plant waste waters in order to trap oil and suspended solids that have bypassed or escaped in-



plant controls as described previously. Even medium/large plants can prevent oils and grease spills and leaks with adequate in-plant controls and good house keeping meeting the limitation under MINAS. If end-of-pipe treatment is required for medium/large plants, the proposed treatment is basically low cost primary treatment of low volume influent, which basically involves very simple mechanism of sedimentation and oil and grease removal. It is considered that such simple treatment is not costly with respect to the investment. Cost for operation and maintenance is fairly low. Thus the treatment system is economically affordable by medium/large plants under such category.

#### 4.6.4 Latex Based Industries

As discussed in previous section, the latex-based wastes can be reduced and potentially eliminated by careful housekeeping and good latex handling practices. The benefits, in treatment costs and effluent quality, created by these techniques are appreciable. The best practicable and economically affordable treatment technology currently practised by industries is based on studies made by operating plants in India. Briefly this can be summarised as below:

- For tiny plants, small volume of wastewater is contained in small sump for settling and evaporation. No discharge is coming out from such tiny plants.
- Small plants adopt anaerobic treatment involving septic tank followed by aeration/filtration as shown in Fig. 4.4.
- Medium/large plants adopt waste water segregation, equalisation, coagulation with alum and polyelectrolyte, separation of floatable latex solids by aeration/Foam separation techniques, separation of settleable solids in settling tank followed by filtration. The flow diagrams for two existing treatment plants adopted by two medium latex based plants are schematically represented by Fig 4.1 and Fig 4.2 respectively.

The suggested treatment for tiny, small and medium/large plants under this segment of industry is in line of existing practical condition as it is the most feasible and economic treatment approach. In case of latex foam industry, chemical precipitation of zinc laden stream is suggested before filtration/sedimentation.

##### 4.6.4.1 Economic Feasibility

###### Cost Aspects

The size distribution of latex based product manufacturing facilities is broad and ranges from approximately 50 Kg per day to 10 Tonnes per day of raw material. Therefore, it is necessary to study wastewater treatment techniques of several plant sizes for this category in view of financial implication involved. As such, three types of treatment techniques have been suggested for tiny, small and medium/large size plants in order to make it affordable.

As the suggested treatment is based on currently practised treatment technology by industrial units in India, it is considered that treatment cost is well within affordability of similar size range and nature of industries elsewhere in this country.

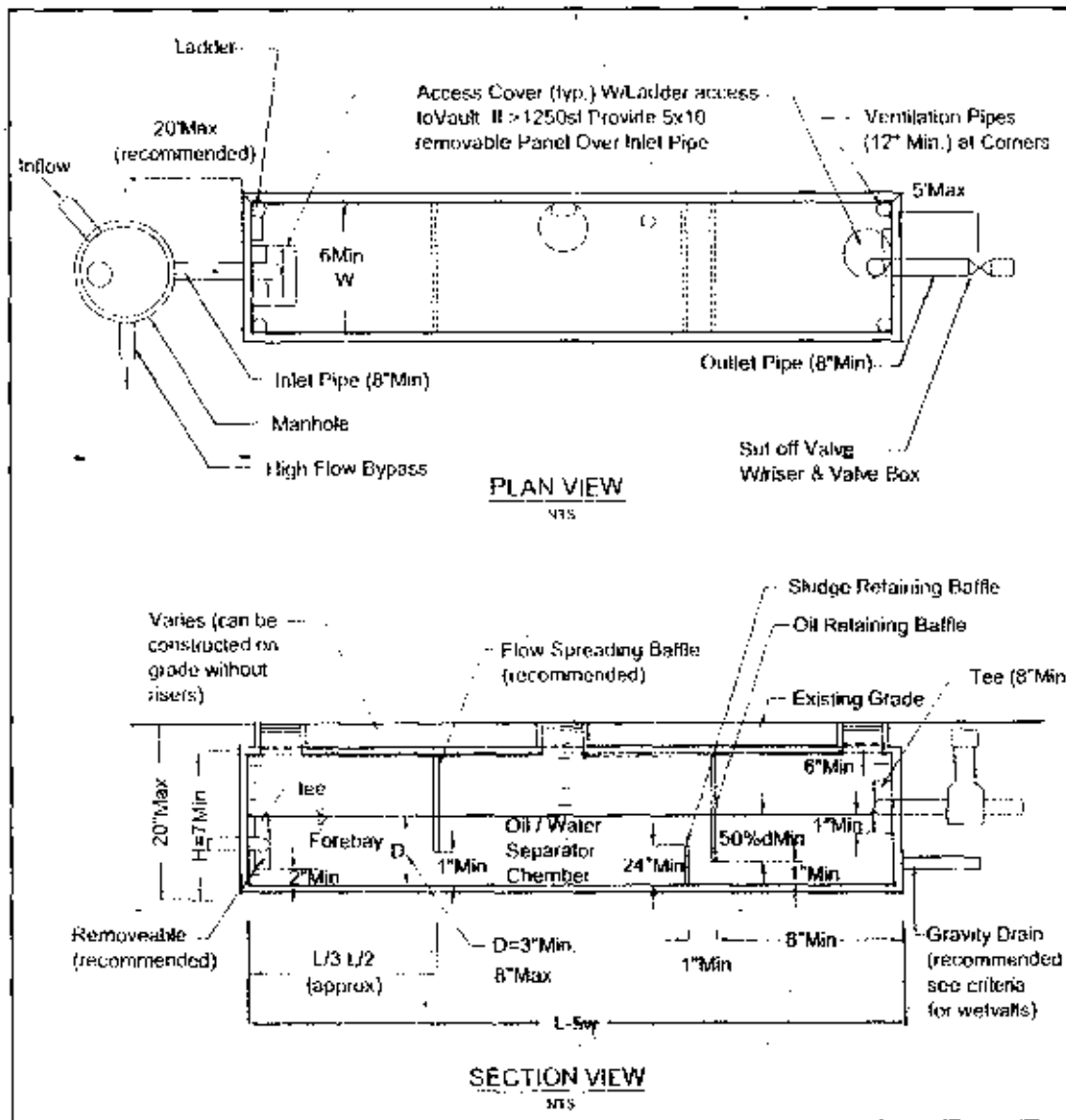


Fig. 4.3 API (Baffle Type) Separator

#### 4.6.5 Reclaim Rubber Product Industry

The wastewater types from dry reclaiming processes are essentially similar to those produced by moulded, extruded/calendared and fabricated plants with additional contribution of autoclave vapour condensates. The majority of the wastes are created by spills and leaks in the cracking, grinding and milling sections as well as around material and fuel storage areas. The contaminants are principally oil and suspended solids. The suggested control and treatment of this part of wastewater is similar to moulded, extruded/calendared and fabricated group of industries and may be referred for details.

The another stream generated from autoclave is condensed by using multiple condensers. The non-condensable gases from multiple condensers are removed using by charcoal adsorption units in series. Condensated live steam from autoclave contains high oil in free and emulsified condition as discussed in characterising data of relevant industry category. In view of the fact that little end-of-pipe treatability data exist for this segregated waste water stream, it is difficult to comment meaningfully on the merits of potential, but unproven, end-of-pipe treatments. One visited plant uses gravity separation technique (API separator) to remove free oil. The resulting effluent contains high oil content due to left emulsified nature of oil.

As per literature survey, this emulsified oil is removed by adopting any of the following widely accepted economical technique.

- Coagulation and flocculation
- Dissolved Air Flotation

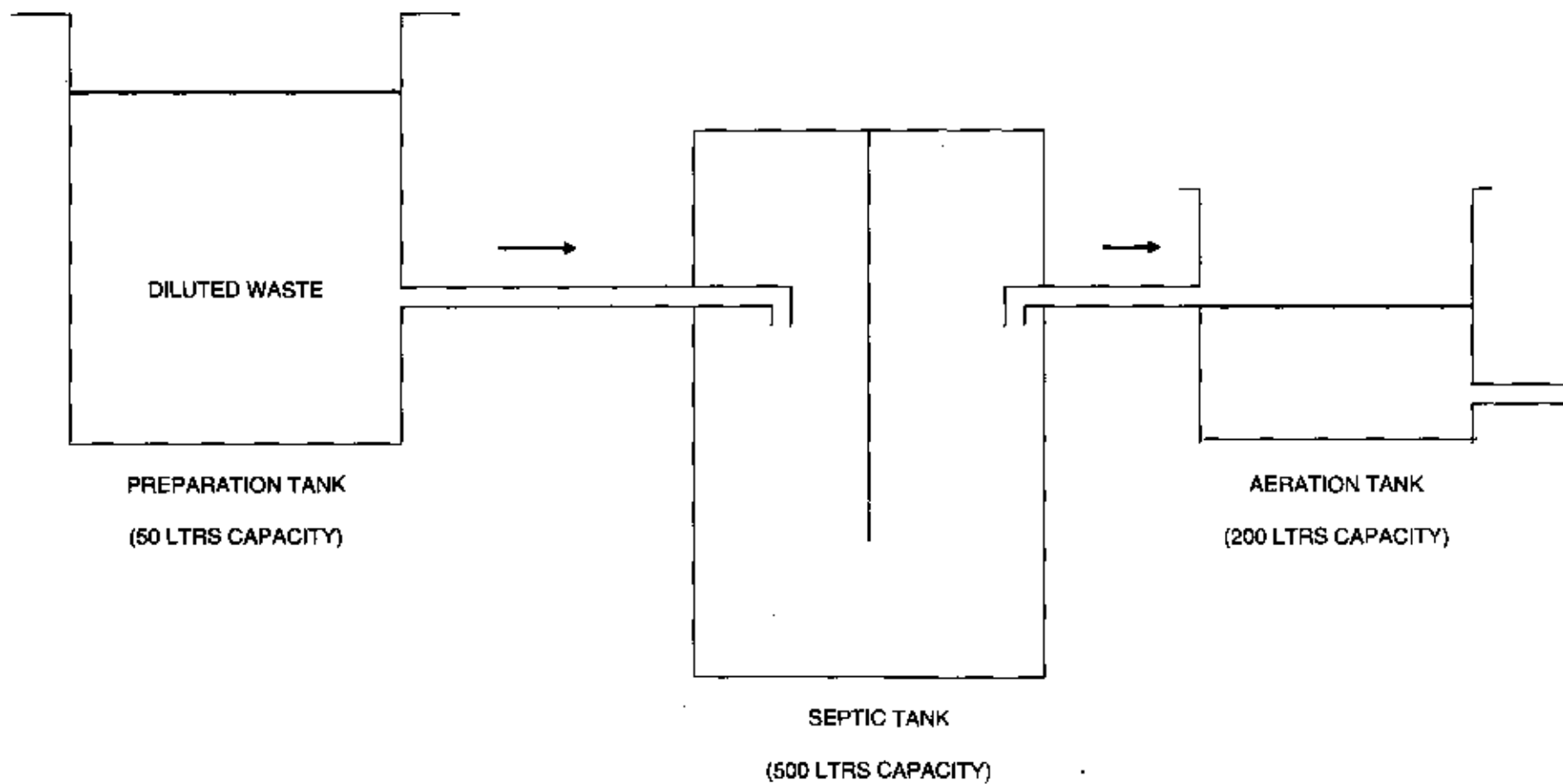
Oil droplets in such emulsion are hydrophobic and carry a negative charge, which stabilises the emulsion. To cause destabilisation, a cationic emulsion breaker is added to neutralise the charge and to allow the droplets to coalesce.

The effluent containing chemical sludge, settleable solids and high oil concentration can be treated by coagulation, flocculation and settling. Coagulants like alum,  $\text{FeSO}_4$ ,  $\text{FeCl}_3$ , with/without polyelectrolytes can be used. The coagulation process also breaks oil emulsions nullifying the zeta potential.

Diffused aeration is known to bring oily and fatty matters in suspension form in the wastewater.

After removing oil of segregated condensate wastewater, it should be mixed with treated wastewater from other sources before multimedia filtration. The flow diagram for suggested treatment methods is shown in Figure 4.5.

As per literature review, end-of-pipe treatment technology employed by this type of industry in advanced countries consists of only API type gravity separator followed by filter coalescer. The second stage of emulsified oil removal is not required there as oil content in wastewater (condensate) is much less when compared to Indian scenario. This might be due to less oil use in depolymerisation process employed in advanced country.



**Fig 4.4: Suggested Treatment Plant for Latex Based Industries (Small Plants)**

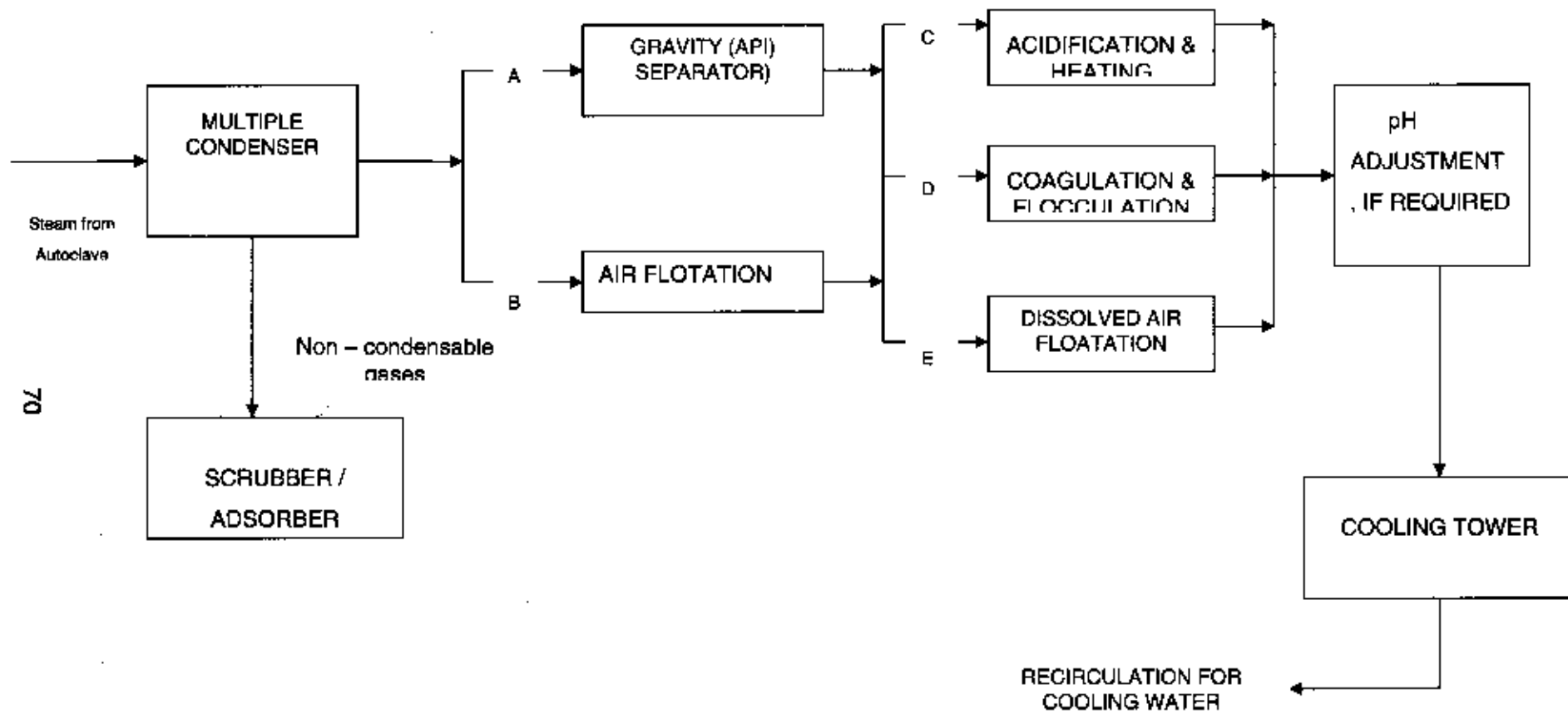


Fig 4.5 Suggested Effluent Treatment Method for Reclaim Rubber

#### 4.6.5.1 Economic Feasibility

##### Cost Aspects

The size distribution of rubber reclaimed manufacturing facilities is relatively confined and lies in the range of medium /large categories. Therefore it is not necessary to study the wastewater treatment technology of several plant sizes for this category. The average turnover of industries in this segment lies in the range of 20 to 30 crores. The suggested treatment system is basically low cost compacted primary treatment of low volume effluent, which basically involves very simple mechanism of sedimentation and oil and grease removal. Land requirement for treatment facility is also minimum. Annual burden of such treatment technique will not exceed 0.2 to 0.3 percent of annual turnover in any case, which is well within the techno-economic capability of the industry under this segment.

**CHAPTER - 5**  
**MINIMAL NATIONAL STANDARDS FOR EFFLUENT**

The Minimal National Standards for effluent of rubber products industries are as follows:

**Table 5.1 : MINAS for Tyre and Tube Industry (Category A)**

Sl	Parameter	Limiting Concentration in mg/l, except pH
01	PH	6.5 to 8.5
02	Suspended Solids	50
03	Oil and Grease *	10

Note: \* The limit of oil and grease shall be confirmed at the outlet of oil and grease trap unit. This implies that in the final treated effluent oil and grease concentration shall be lower than prescribed herein.

**Table.5.2 : MINAS for Moulded, Extruded, Calendered and Fabricated Rubber Products (Category B, C & D)**

S.No	Parameter	Limiting Concentration in mg/l, except pH
01	PH	6.5 to 8.5
02	Suspended Solids	50
03	Oil and Grease *	10
04	Lead (as Pb) **	0.1

Note:

\* The limit of oil and grease shall be confirmed at the outlet of oil and grease trap unit. This implies that in the final treated effluent oil and grease concentration shall be lower than prescribed herein.

\*\* Applicable to rubber hose product industry by the lead sheathed cure Process.

**Table 5.3 MINAS for Latex Based Products (Category E)**

S.No	Parameter	Limiting Concentration in mg/l, except pH
01	pH	6.5 to 8.5
02	BOD <sub>3-day</sub> 27 <sup>o</sup> C *	100

S.No	Parameter	Limiting Concentration in mg/l, except pH
03	Suspended Solids	100
04.	Zinc (as Zn) **	5
05	Chromium ***	0.05

**Note:**

- \* BOD<sub>5</sub> 27° C may be made stringent up to 30 mg/l if the recipient fresh water body is a source of drinking water supply. BOD<sub>5</sub> value is relaxable up to 350 mg/l, if the wastewater is discharged into town sewer where secondary treatment of sewage is carried out.
- \*\* Applicable to Latex Foam Industry
- \*\*\* Applicable to plants using chromic acid form cleaning technique.

**Table 5.4 MINAS for Reclaimed Rubber (Category F)**

S.No	Parameter	Limiting Concentration in mg/l, except pH
01	pH	6.5 to 8.5
02	Suspended Solids	100
03	Oil & Grease **	10

**Note:**

- \*\* The limit of oil and grease shall be confirmed at the outlet of oil and grease trap Unit. This implies that in the final treated effluent oil and grease concentration shall be lower than prescribed herein.



## CHAPTER - 6

### CHARACTERIZATION OF AIR EMISSIONS & NOISE

#### 6.1 INTRODUCTION

Air emissions and noise from rubber products manufacturing industries were characterized through field investigations, sampling and monitoring of selected industrial units covering all categories and sizes. Pollution levels in these units have been assessed on the basis of survey, monitoring and analysis of air samples as well as from secondary data sources wherever available and applicable. Characterization of air emissions and noise are discussed in the following sections.

#### 6.2 AIR EMISSIONS

The manufacture of rubber products exposes workers to a large variety of chemicals. These include many different powders, solids, oils and polymers used as compounding ingredients; anti-tack dusts to prevent sticking; mist, fumes and vapors generated by heating and curing rubber compounds; and solvents used for cements and process aids. The compounding and mixing area of a rubber products manufacturing facility, where dry chemicals are weighed, put into small containers, and loaded into the rubber mixer, can be a significant source of particulate emission. Volatile Organic Carbon (VOC) emissions are also an environmental concern in the rubber product manufacturing process. VOCs are added to rubber compounds in order to aid in mixing, promote elasticity, produce tack or stickiness and extend or replace a portion of the raw material. VOCs are also used as solvents to degrease equipment and tools and as a type of adhesive during building and fabrication. Typically, releases of solvents occur either when the spent solvent solutions are disposed or when degreasing solvents are allowed to volatilize. In some facilities, mold release compounds, sprayed in the cavities of compression molds, produce significant fugitive emission. However, solvents are becoming less of an issue, as water, silicon and non-solvent based release compounds are now common. Field investigation, process details, sampling and monitoring and extensive literature survey establish two types of air pollutants generally associated with different processes of rubber product manufacturing industries as mentioned below:

- Rubber Process Dust (Particulate Matter) arising as fugitive emission in the stages of rubber manufacture where ingredients are handled, weighed, added to or mixed with uncured natural or synthetic elastomers.
- Rubber Fume (VOC as main constituent) evolved as fugitive emission in the mixing, milling and blending of natural rubber and synthetic elastomers combined with chemicals and in the processes which convert resultant blends into finished products. It is a mixture of gases and vapors evolved from many individual chemicals used in the process.

Epidemiological studies have shown that chronic exposure to rubber dust and rubber fume in rubber manufacturing product industries can cause potential health hazards to

workers. This section describes detailed overview on air pollutant type and emission sources based on literature survey substantiated by field survey.

### 6.2.1 Emission Sources

All possible sources of air emissions from rubber product manufacturing processes are shown in Figure-6.1. Rubber manufacturing begins with compounding and mixing. It involves weighing and mixing the raw ingredients for each batch of rubber stock, operating the banbury mixers and drop mills or preparing the solvents and cements that will be used in latter processes. Although the cement mixing operation often takes place in an area separated from the banbury and the preparation of rubber batches, it can be included within this job title. The highest levels of rubber dust are usually found in the compounding and mixing areas of the rubber plant. During the weighing and handling of dry rubber chemicals including antioxidants, accelerators, sulphur and carbon black, chemicals can leak or spill creating airborne dust. The banbury and drop mills also add dust to the air. Hundreds of different chemicals can be present here. Workers are likely exposed to greater concentrations of these chemicals than a room sampler would indicate because workers work directly over the source of chemical dust. Workers in the cement mixing area are exposed to very different chemical hazards than the banbury operators or dry chemical weighers and mixers. In the cement mixing area, solvent vapors can pose a significant health hazard.

Another major source of air emission is process cutting and milling. Job duties in the cutting and milling area include operation of the large mills, which use heat and pressure to process the rubber batches from the banburies, and the cutting of the milled rubber into long sheets that are coated with antitackifiers to prevent sticking. These sheets are then dried and stored or they may be returned to the banbury for the addition of other ingredients before they go to the feed mills prior to extrusion or calendaring. This job also includes sometimes cutting on mills to ensure even mixing of the ingredients by breaking up and reforming the sheets of rubber. When the rubber batch comes into contact with hot rollers of the mill, fumes and vapours are released. These may include condensed droplets of extender oils and detackifiers such as talc, various reaction products and mixtures of combined chemicals. Some of the antioxidants and accelerators mixed into the rubber may be released in the fumes created by the heat and pressure of the mills. Some of these are aromatic amines, a group of chemicals, which can have serious effects. Nitrosamines are a group of chemicals that are released in this area that have shown to be carcinogenic. The materials used to dust the rubber include talc, soapstone, clay, mica and fine silica, have high potential to become air borne in this area.

Extrusion process includes operation of extruder, which transforms the rubber into various shapes and profiles. The extruder forces softened rubber through a die, which forms it into a long continuous strip. Exposure to potential health hazards in the extrusion area is similar to the milling and cutting operation. Fumes and vapours are released from the extruder. Exposure to the fumes from the extrusion process will be highest for those working close to the heated rubber, especially the operator. The extrusion area is one of the highest solvent use areas. Workers who cement the stock ends will often have high exposure to solvent fumes.

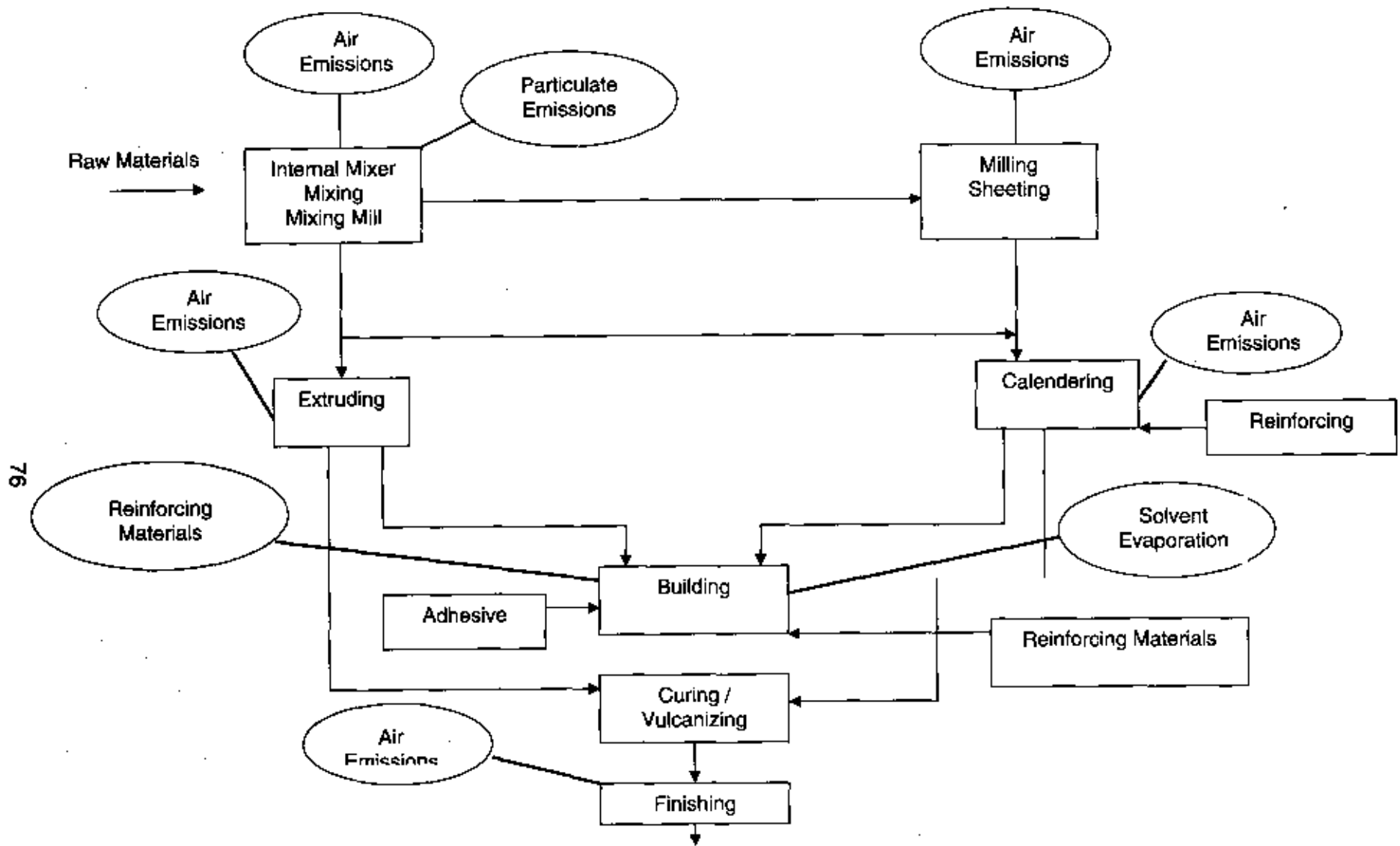


Fig 6.1 Rubber Products Manufacturing Processes showing Air Emission Sources

The calendaring operation involves the rolling of the uncured rubber on a sheet of fabric to form a continuous sheet of rubber coated fabric. The major potential health hazard in this area is exposure to fumes and vapours given off during calendaring. Concentration of fumes and vapours increases when calender speed and temperature increases. These fumes and vapours potentially contain some of the antioxidants, accelerators and chemical tackifiers, which are added to the rubber stock. Literature survey shows that nitrosamines are also formed during calendaring and very high levels may be released in this area.

In tyre and tube industry, curing preparation (Green tyre painting) involves inspecting the unformed tyres to ensure they are ready for curing. The tyres are then sprayed with mold release agents to prevent them from sticking to the curing presses. During green tyre painting, workers may be exposed to materials generated from the spray. The mold release agents sprayed on the tyres include talc, soapstone, mica and other siliceous materials. Many of the sprays are also solvent based and their use may result in relatively high levels of solvent vapours in this work area. Workers who inspect and prepare the large truck tyres are often at an increased risk of exposure to mold release agents.

Rubber products are cured or vulcanized in molds under heat and pressure to produce the final product. Exposure to potential health hazards in this area can vary greatly depending on the type of press equipment being used and whether rubber products are being cured. Operating a manual press involves loading the presses with uncured rubber products and removing them when the cure cycle has been completed. As the presses open, the operators are exposed to high levels of curing fumes. Operators of automatic presses, on the other hand, generally have a lower level of exposure to curing fumes because the operator does not have to stand near the press when it opens. Nitrosamines are used in the rubber industry and have been found in the curing area air. Talc, other detackifiers and mold release agents have also been detected in the curing area air following the opening of presses. These dusts, particularly talc, are found in greater concentration in the tube curing area.

Other operation areas in rubber product industries generally include receiving of raw materials, product fabrication, finishing, inspection, repair, maintenance, and finally loading of finished rubber products. In these areas, workers are exposed to rubber dust and solvent fumes. In the receiving operation, the raw materials used in the production of rubber products are delivered to the plant. Here workers unload and store the dry ingredients and other materials before they are distributed to where they are needed. The workers in the dispatch area, on the other hand, stockpile and eventually load the finished rubber products for transport. The major potential hazards in these jobs are the leaks and spill of raw materials during handling. Solvent fumes under fabrication are created when the rubber is coated with solvents to make it stick to itself. Finishing, inspection and repair include a number of different jobs such as trimming the finished products, removing excess rubber, labeling, classifying the products according to type and sizes and inspection of the finished products for defects and repairs. In this stage of process, workers may be exposed to a combination of vapours and particulate matters. Rubber dust is created when rubber products needing repair are ground, buffed and trimmed. Repairing also involves considerable swabbing with solvents whose fumes may accumulate in the air. Cure fumes from nearby presses may also be

present in this area. Maintenance and general service involve mold cleaning, quality control testing, power plant work and other miscellaneous works. Workers included are not constantly exposed to particular health hazards. This nature of jobs can take workers throughout the plant to areas where workers may be exposed to high concentrations of potential hazards for short periods of time.

## 6.2.2 Characterization (Analysis Results)

Particulates (SPM and RSPM) and air emissions in the rubber products manufacturing industries were characterized by undertaking air monitoring by paying visits to selected industries. Results of air monitoring in selected industrial units undertaken for in-depth study are presented in **Annexure-6.1** through **Annexure-6.4**.

Air quality is monitored at 6 locations in most of industries as per facilities available. These are at:

- i) Upwind location
- ii) Downwind location
- iii) Mixing/Milling unit
- iv) Moulding/Extrusion/Calendering unit
- v) Vulcanization/Devulcanization unit
- vi) Fabricating/grinding unit

### 6.2.2.1 Particulates

Airborne particulates, synonymously termed as "airborne dust" may be defined (ISO 4225-ISO, 1994) as small solid particles, conventionally taken as those below 75  $\mu\text{m}$  in diameter, which settle under their own weight but may remain suspended for sometime in the air. Particles with aerodynamic diameter larger than 50  $\mu\text{m}$  do not usually remain airborne very long as they have a terminal velocity larger than 7 cm/sec. The terminal velocity of a 1  $\mu\text{m}$  particle is about 0.03 mm/sec

Particle aerodynamic diameter is the diameter of a hypothetical sphere of density 1 g/cm<sup>3</sup> having the same terminal settling velocity in calm air as the particle in question, regardless of its geometric size, shape and true density.

In the present context, two categories of airborne particulates are considered. One equal to or above 10  $\mu\text{m}$  diameter and the other below 10  $\mu\text{m}$ . The former is termed as Suspended Particulate Matter (SPM) and latter as Respirable Suspended Particulate Matter (RSPM) for convenience.

Fibrous particulates, as emitted from cracking and grinding of nylon/rayon bearing scrap tyres in reclaimed rubber industries have been shown to present special health problems primarily related to the shape of the particles. In relation to health, particles with diameter lesser than 3  $\mu\text{m}$ , length larger than 5  $\mu\text{m}$  and aspect ratio (length to width) greater than or equal to 3 to 1, are classified as fibres (WHO, 1997).

#### a) Suspended Particulate Matter (SPM)

Pertinent results of SPM analyses are presented in the form of a data sheet in **Annexure-6.1**. SPM statistics is summarized in **Table-6.1**.

**Table-6.1 SPM Concentration of Rubber Products Manufacturing Industries in  $\mu\text{g}/\text{m}^3$**

Category	No of Industries	AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
A	8	132-262	125-343	420-1850	150-949	229-993	218-728
B	5	110-223	164-317	720-1542	455-953	1289	493-561
C	5	101-252	151-584	450-1649	200-1284	310-1117	471-1217
D	5	131-323	197-384	353-1462	210-923	115-323	300-732
E	6	158-358	175-286	Not Sampled	131-430	65-300	296-336
F	2	132-297	268-445	3113-4812	Not Sampled	706-1815	1482-3514

**Note:** AQAU- Upwind Location  
 AQAD- Downwind Location  
 AQP1- Near Mixing/Milling Unit  
 AQP2- Near Moulding/Extrusion/Calendering Unit  
 AQP3- Near Vulcanization/Devulcanization Unit  
 AQP4- Near Fabricating/Grinding Unit

Perusal of data sheet in Annexure 6.1 and summary results in above Table 6.1 shows higher values of SPM concentration levels at most of downwind locations for all categories of rubber product industries confirming contribution of SPM levels to ambient air quality by such type of industries. Further examination of results reveals that concentration levels get diluted even in close vicinity of working rooms and it hardly exceeded the prescribed ambient air quality standards in industrial areas by Central Pollution Control Board (CPCB). No definite co-relation could be established among upwind and downwind concentration values even for a particular type of industry as fugitive emission is governed by many factors varying from industry to industry and site to site. Sampling results in working rooms particularly closer to mixing/milling units show higher values of SPM concentration exceeding 500 micro gram per cubic meter at most of times. Among all type of industries, reclaimed rubber units show higher SPM values due to cracker/grinding units and latex based industries show minimum SPM concentration in working rooms. Among processes, mixing/milling/fabricating/cracking/grinding units are major sources of contributing SPM.

**b) RSPM**

Analysis results of RSPM values are presented in the form of a data sheet in Annexure-6.2. Summary table showing RSPM statistics is given in Table-6.2 below.

**Table-6.2 RSPM Concentration of Rubber Products Manufacturing Industries In  $\mu\text{g}/\text{m}^3$** 

Category	No of Industries	AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
A	8	42-144	69-232	273-1259	72-562	121-342	98-466
B	5	61-145	93-219	349-833	120-537	657	152-232
C	5	53-87	100-209	304-987	158-719	87-588	160-548
D	5	32-194	148-269	159-614	167-517	29-145	102-322
E	6	35-197	98-216	Not Sampled	46-241	25-114	63-100
F	2	113-184	160-423	1385-1463	Not Sampled	227-1180	334-1379

**Note:** AQAU- Upwind Location

AQAD- Downwind Location

AQP1- Near Mixing/Milling Unit

AQP2- Near Moulding/Extrusion/Calendering Unit

AQP3- Near Vulcanization/Devulcanization Unit

AQP4- Near Fabricating/Grinding Unit

Similar trend in the values of RSPM as in the case of SPM has been observed as clear from above summary table. Although ambient air RSPM values are within the safe limit in most of the cases, proportion of respirable dust in the air of working rooms is alarming in most of the industries due to absence of effective control measures. It is expected to be in higher side of breathing zone of workers as sampling was carried out with fixed sampler at about 7 to 10 meter away from the main contributing sources. One of reclaimed industry sampled shows higher values of RSPM even in vulcanizing/devulcanization unit, as it is located very close to cracker section without any partition. Close examination of data sheet shows that large and medium scale industries show higher values compared to small and tiny industries due to handling of raw materials at large and continuous basis.

**c) Sulphur Dioxide ( $\text{SO}_2$ )**

Eight industries in this category were monitored of which four are large-scale, two medium-scale and one each in small-scale and tiny industries. Sampling was done at 53 locations, of which 16 are ambient air samples, 7 at Process Type-1, 5 at Process Type-2, 7 at Process Type-3, 6 at Process Type-4, 7 at Boiler unit and 5 at generator unit. Pertinent results of  $\text{SO}_2$  analyses are presented in the form of a data sheet in **Annexure-7.5**. The  $\text{SO}_2$  statistics are summarized in **Table-6.3**.

**Table-6.3 SO<sub>2</sub> Concentration of Rubber Products Manufacturing Industries in µg/m<sup>3</sup>**

Category	No of Industries	AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
A	8	5-11	4-23	23-36	10-31	14-32	16-33
B	5	4-8	4-14	6-29	6-21	23	8-15
C	5	6-9	7-19	10-46	9-35	19-32	8-58
D	5	7-30	14-25	24-80	10-22	21-63	14-21
E	6	4-6	3-19	Not Sampled	9-15	8-13	53-55
F	2	17-18	11-16	13-59	Not Sampled	51-60	35-38

**Note:** AQAU- Upwind Location  
 AQAD- Downwind Location  
 AQP1- Near Mixing/Milling Unit  
 AQP2- Near Moulding/Extrusion/Calendering Unit  
 AQP3- Near Vulcanization/Devulcanization Unit  
 AQP4- Near Fabricating/Grinding Unit

No appreciable change in background level of SO<sub>2</sub> data in downwind ambient air quality is reflected and all values observed are well within permissible limit as stipulated by CPCB for ambient air quality standard. However, slightly higher values of SO<sub>2</sub> are observed in working rooms particularly closer to vulcanization/devulcanization units. Among all type of industries, devulcanization units of rubber reclaim industry show higher values.

**d) Oxides of Nitrogen**

Eight industries in this category were monitored, of which four are large-scale, two medium-scale and one each in small-scale and tiny. Sampling was undertaken at 54 locations of which 16 at ambient air samples, 8 at Process Type-1, 4 at Process Type-2, 7 at Process Type-3, 6 at Process Type-4, 7 at Boiler unit, and 6 at generator unit. Pertinent results of NO<sub>x</sub> analyses are presented in the form of a data sheet in **Annexure-6.4**. NO<sub>x</sub> statistics is summarized in **Table-6.4**.

**Table-6.4 NO<sub>x</sub> Concentration of Rubber Products Manufacturing Industries in µg/m<sup>3</sup>**

Category	No of Industries	AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
A	8	9-16	15-31	15-49	15-45	18-37	20-44
B	5	9-17	9-24	13-36	11-32	31	12-28
C	5	8-12	11-30	12-41	12-33	23-28	13-62
D	5	10-46	20-49	28-52	23-35	27-43	17-30
E	6	9-17	11-29	Not Sampled	10-19	10-15	58-62
F	2	24-25	24-27	24-68	Not Sampled	64-68	44-47

**Note:** AQAU- Upwind Location  
 AQAD- Downwind Location  
 AQP1- Near Mixing/Milling Unit  
 AQP2- Near Moulding/Extrusion/Calendering Unit  
 AQP3- Near Vulcanization/Devulcanization Unit  
 AQP4- Near Fabricating/Grinding Unit



A perusal of summary data given in above table and detailed examination of individual industry data provided in annexure indicate that NO<sub>x</sub> is not contributed significantly by manufacturing processes of rubber product industries and observed to be well within permissible limit in ambient and working room air. No appreciable change in values of NO<sub>x</sub> values in downwind and upwind air as well as in working rooms is observed except for some cases, which may be attributed due to locations of other sources of NO<sub>x</sub> such as boilers and generator sets.

**e) Rubber Dust and Rubber Fume**

Eight industries were monitored, of which one is tyre & tube industry and moulded product industry each, three are extruded product industries, one is fabricated product industry and two are from rubber reclaim industries. Industries were selected from large and medium scale group as per the facilities available for sampling. Analysis results have been compiled in Table 6.5 as below.

**Table-6.5 Rubber Dust and Rubber Fume Concentration of Rubber Products Manufacturing Industries in mg/m<sup>3</sup>**

Category	Location	Code No.	Rubber Dust	Rubber Fume
A	Mixing/Milling	AL03	6.84	0.35
B	Mixing/Milling	BM01	5.31	0.23
C	Calendering/ Fabricating	CM01	4.24	0.33
C	Mixing/Milling	CM02	6.12	0.18
C	Mixing/Milling	CM05	8.35	0.28
D	Calendering/ Fabricating	DM02	7.64	0.25
F	Cracking/ Devulcanization	FM01	11.39	0.29
F	Cracking/ Devulcanization	FM02	12.24	0.31

Source: Field Survey by CES

A perusal of above data shows variation of concentration levels of dust monitored from personal sampler from that of fixed samplers. Although these values are not reflecting total inhalation quantity as these are monitored away from breathing zone of workers, but it represents closer values as these are monitored at breathing height very close to process activity. As the dust and fumes mix from different process areas due to its proximity and absence of any isolation, process associated variation in its concentration level is not clearly reflected in analysis results. However, mixing/milling/cracking and calendering/devulcanization activities are associated with slightly higher values of rubber dust and rubber fume respectively. Productwise, rubber reclaim industries show higher values of air pollutants rubber dust and rubber fume.

**6.3 NOISE**

Noise levels in the rubber products manufacturing industries were characterized by undertaking noise monitoring by paying visits to selected industries.

### 6.3.1 Noise Sources

Process operations involving machineries are a source of noise in the in-plant environment. The sources of noise in the rubber products manufacturing industry are attributed to.

- Machine Operation
- Generator Operation
- Boiler Operation
- Mechanical Workshop
- Cutting, Grinding and Finishing Operations, etc

Industrial clusters may also contribute to ambient noise levels. Locations selected for noise monitoring are shown in **Table-6.6**.

**Table-6.6 Noise Monitoring Locations**

SNo	Location ID	Location
1	NQ-1	Front side (Near main gate) of the Industry
2	NQ-2	Rear side of the Industry
3	NQ-3	Amid Industry Premises
4	NQ-4	Mixing/Milling/Compounding/Ball-milling*/Cracking Unit
5	NQ-5	Moulding/Extrusion/ Calendaring / Vulcanizing/ Devulcanizing** Unit
6	NQ-6	Fabricating/Building Unit
7	NQ-7	Grinding*/Cutting/Finishing/ Packing Unit
8	NQ-8	Boiler Unit
9	NQ-9	Generator Unit

**Note:** \* Latex-based Industry; \*\* Reclaimed Rubber Industry; \$ Moulded and Fabricated Industry

### 6.3.2 Characterization

Noise measurements made for all six categories of Industries. In this ambient noise refers to NQ1 and NQ2, genset to NQ9 and process noise corresponds to NQ3, NQ4, NQ5, NQ6, NQ7 and NQ8 locations. The same convention is followed in all categories. The locations are highest in process units and minimum in the ambient. The number of samples taken at various locations in different categories of industries is shown in **Table-6.7**. Maximum samples are taken in the process units.

**Table-6.7 Noise Samples Analysed for Determination of Noise Quality**

Category	Number of Samples			
	Ambient Noise	Process Noise	Noise Level at Genset	Total
A	16	45	5	66
B	14	35	6	55
C	12	33	5	50
D	10	36	4	50
E	12	26	6	44

Category	Number of Samples			Total
	Ambient Noise	Process Noise	Noise Level at Genset	
F	4	12	1	17
<b>Total</b>	<b>68</b>	<b>187</b>	<b>27</b>	<b>282</b>

Pertinent results of noise monitoring in selected industrial units are presented in **Annexure-6.5**.

#### Category A

Eight industries in category-A were monitored, out of which four are large-scale, two are medium-scale and one each in small-scale and tiny industries. Noise level monitoring undertaken at 66 locations out of which, 16 are ambient locations, 45 at process locations and 5 at generator sections. Summary table showing noise statistics is shown as **Table-6.8** below.

**Table-6.8 Summary of Noise Levels Monitored for Category-A Type Industries**

Noise Statistics	Ambient Noise* in dB(A)	Process Noise* In dB (A)	Noise Level at Genset in dB(A)
No. of Samples	16	45	5
Min. Noise Level	58.20	48.60	68.40
Max. Noise Level	80.70	90.60	111.80
Average	67.67	76.33	91.62
No. of Violations <sup>@</sup>	2	27	4
% Violation <sup>@</sup>	12.5	60	80

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e., 75 dB (A)

Ambient noise levels around tyre and tube manufacturing industries varied between 58.20 and 80.70 dB(A). Ambient noise samples violated the prescribed noise standard at two locations. This amounted to 12.5% violation in noise levels. Out of 45 sampled locations within the industrial work-sheds having various process units, 27 locations indicated higher noise level in comparison to the ambient standard of 75 dB (A). This resulted 60% violation in noise levels. On the other hand, 80% violation in noise levels was indicated by 4 locations at generator units. Noise levels at process units range between 48.60 and 90.60 dB(A) whereas for locations at generator units, it varied between 68.40 and 111.80 dB(A). Average levels of noise at ambient locations, process locations and at generator section calculated are 67.67, 76.33 and 91.62 dB (A) respectively.

#### Category B

Seven industries in this category were monitored out of which one is large-scale, 1 medium-scale, four small-scale, and one is Tiny. Noise level monitoring undertaken at 55 location, out of which, 14 are ambient noise samples 35 at process locations and 6 at generator sections. Summary table showing noise statistics is shown as **Table-6.9** below.

**Table-6.9 Summary of Noise Levels Monitored for Category-B Type Industries**

Noise Statistics	Ambient Noise* In dB(A)	Process Noise* In dB (A)	Noise Level at Genset In dB (A)
No. of Samples	14	35	6
Min. Noise Level	52.60	51.20	74.20
Max. Noise Level	76.30	83.20	109.90
Average	62.85	74.68	94.04
No. of Violations <sup>@</sup>	1	17	5
% Violation <sup>@</sup>	7.14	48.57	83.33

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e, 75 dB(A)

Ambient noise levels around moulded product industries varied between 52.60 and 76.30 dB(A). Ambient noise sample violated the prescribed noise standards at one location. This amounted to 7.14% violation in noise levels. Out of 35 samples locations within the industrial worksheds having various process units, 17 locations indicated higher noise levels in comparison to the ambient standards of 75 dB (A). This indicated 48.57% violation in noise level. On the other hand, 83.33% violation in noise levels was indicated by five locations at generator units. Noise levels at process units range between 51.20 and 83.20 dB (A), whereas those at generator units varied between 74.20 and 109.90 dB(A). Average noise levels at ambient locations, process locations and at generation section are 62.85, 74.68 and 94.04 dB (A) respectively.

### Category C

Two large-scale, three medium-scale and one small-scale industry were monitored out of 6 industries in category-B. Noise level monitoring undertaken at 50 locations, out of which, 12 are ambient noise samples, 33 at process locations and 5 at generator units. Summary table showing noise statistics is shown as Table-6.10 below.

**Table-6.10 Summary of Noise Levels Monitored for Category-C Type Industries**

Noise Statistics	Ambient Noise* in dB(A)	Process Noise* In dB(A)	Noise Level at Genset in dB(A)
No. of Samples	12	33	5
Min. Noise Level	40.30	62.80	88.40
Max. Noise Level	75.00	84.60	106.10
Average	58.58	75.73	97.88
No. of Violations <sup>@</sup>	0	18	5
% Violation <sup>@</sup>	0	54.55	100

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e, 75 dB(A)

Ambient noise level around extruded product industries varied between 40.30 and 75 dB(A). Out of 33 sample locations within the industrial worksheds having various process units, 18 locations indicated higher noise levels in comparison to the ambient standard of 75 dB (A). This resulted 54.55% violation in noise levels. On the other hand, 100% violation in noise level was indicated by five locations at generator units of category-C type industries. Noise levels at process units range between 62.80 and 84.60 dB (A). Whereas, for locations at generator units, it varied between 88.40 and 106.10 dB (A). Average levels of noise at ambient locations, process locations and at generation section calculated are 58.58, 75.73 and 97.88 dB (A) respectively.

#### Category D

Five industries in this category were monitored, out of which 2 are medium-scale, 3 are small-scale. Noise level monitoring undertaken at 50 locations, out of which 10 are ambient noise samples, 36 are process locations and 4 are at generator sections. Summary table showing noise statistics is shown as Table-6.11 below.

**Table-6.11 Summary of Noise Levels Monitored for Category-D Type Industries**

Noise Statistics	Ambient Noise* in dB(A)	Process Noise* In dB(A)	Noise Level at Genset in dB(A)
No. of Samples	10	36	4
Min. Noise Level	58.80	60.80	78.10
Max. Noise Level	83.00	89.30	108.30
Average	69.48	79.22	94.02
No. of Violations <sup>@</sup>	3	18	4
% Violation <sup>@</sup>	30	50	100

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e, 75 dB (A)

Ambient noise level around calendered/fabricated industries varied between 58.80 and 83 dB(A). Ambient noise samples violated the prescribed noise standard at 3 locations. This amounted to 30% violation in noise levels. Out of 36-sampled location within the industrial worksheds having various process units, 18 locations indicated higher noise level in comparison to ambient standard of 75 dB (A). This resulted 50% violation in noise levels. On the other hand 100% violation was indicated by locations at generator units.

Noise level at process units range between 60.80 and 89.30 dB (A) whereas for locations at generator units, it varied between 78.10 and 108.30 dB (A). Noise levels at ambient locations, process locations and generator section averaged as 69.48, 79.22, 94.02 dB (A) respectively.

#### Category E

Six industries in this category were monitored, out of which two are large-scale, one each in tiny and medium-scale and two small-scale industries. Noise level monitoring undertaken at 44 locations, out of which, 12 are ambient noise samples, 26 are

process noise and 6 at generator sections. Summary table showing noise statistics is shown as Table-6.12 below.

**Table-6.12 Summary of Noise Levels Monitored for Category-E Type Industries**

Noise Statistics	Ambient Noise* in dB(A)	Process Noise* in dB(A)	Noise Level at Genset in dB(A)
No. of Samples	12	26	6
Min. Noise Level	48.40	62.50	70.40
Max. Noise Level	78.20	79.80	98.20
Average	61.58	69.98	85.72
No. of Violations <sup>@</sup>	1	3	5
% Violation <sup>@</sup>	8.33	11.54	83.33

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e., 75 dB (A)

Ambient noise level around latex based industries varied between 48.40 and 78.20 dB (A). Ambient noise samples violated the prescribed noise standard at one location. This amounted to 8.33% violation. Out of 26 sampled locations within the industrial worksheds, 3 locations indicated higher noise levels in comparison to the ambient standard of 75 dB (A). This resulted 11.54% violation in noise levels. On the other hand, 83.33% violation in noise levels at process units range between 82.50 and 79.80 dB (A) whereas for locations at generator unit it varied between 70.40 to 98.20 dB (A) average levels of noise at ambient locations, process locations and at generator section calculated are 61.58, 69.98, 85.72 dB (A) respectively.

#### Category-F

Two industries in this category were monitored where both are medium-scale industries. Noise level monitored at 17 locations. Out of these, 4 are ambient noise samples, 12 at process locations and one at generator sections. Summary table showing noise statistics is shown as Table-6.13 below.

**Table-6.13 Summary of Noise Levels Monitored for Category-F Type Industries**

Noise Statistics	Ambient Noise* in dB(A)	Process Noise* in dB(A)	Noise Level at Genset in dB(A)
No. of Samples	4	12	1
Min. Noise Level	69.80	75.20	93.20
Max. Noise Level	79.20	86.60	93.20
Average	73.55	79.54	93.20
No. of Violations <sup>@</sup>	1	12	1
% Violation <sup>@</sup>	25	100	100

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e., 75 dB (A)

Ambient noise around reclaimed rubber industries varied between 69.80 and 79.20 dB(A). Ambient samples violated the prescribed noise standard at one location. This amounted to 25% violation in noise levels. On the other hand, 100% violation was indicated by generator noise where it varied between 93.20 and 93.20 dB (A). Average levels of noise at ambient locations, process locations and at generator section calculated are 73.55, 79.54, and 93.20 dB (A) respectively.

#### All Categories of Industries

Consolidated summary of Noise Levels observed for all categories of industries and locations are given in Table 6.14.

**Table-6.14 Summary of Noise Levels Observed for All Category of Industries**

Noise Statistics	Ambient Noise <sup>a</sup> in dB(A)	Process Noise <sup>f</sup> in dB(A)	Noise Level at Genset in dB(A)
No. of Samples	68	187	27
Min. Noise Level	40.30	48.60	68.40
Max. Noise Level	83.00	90.60	111.80
Average	64.61	75.26	92.61
No. of Violations <sup>g</sup>	8	92	19
% Violation <sup>g</sup>	11.76	49.20	70.37

**Note:** \* Daytime noise level outside the industry premise; # working shift noise level inside the industry; @ wrt noise standard, i.e., 75 dB (A)

#### 6.4 Solid Waste Generations and Disposal

Rubber product industries have most of waste with salvage value and face no problem for its disposal. Cured and off-specification rubber wastes serve as raw materials for inferior quality products in industry. Solid waste like discarded materials other than rubber such as sludge from wastewater treatment plant is disposed as land filling.

## **CHAPTER- 7**

### **AIR EMISSIONS AND NOISE MITIGATION AND CONTROL**

#### **7.1 INTRODUCTION**

The rubber product industries have most of the solid waste with salvage value and face no problem for its disposal. Airborne contaminants from rubber product manufacturing processes occur in the gaseous form (gases and vapors) or as aerosols. No significant change in ambient air quality could be observed in the vicinity of industrial units as fugitive emissions coming from working rooms get diluted. Rubber dust (Inhalable and Respirable) and rubber fume (VOC as main constituent) are observed to be main critical pollutants in working rooms. They are associated with classical occupational ailments (respiratory and non-respiratory) as well as with systemic intoxications, especially at higher levels of exposure to workers. Similarly, occupational noise is another major area of concern observed in working area. Therefore, it is important to reduce the occupational health risks by aiding better control of airborne contaminants and noise in the work environment of rubber product industries. Present status of control techniques in India and developed countries has been reviewed and based on such findings; best practical, economical and technological viable control technology has been suggested in present chapter.

#### **7.2 EXISTING STATUS OF CONTROL TECHNOLOGY IN INDIA**

In most of rubber product industries visited in Indian scenario, air and noise pollution control measures in the process area are not found satisfactory. Presently, most of the industries adopt general ventilation system to keep air pollutants low in working areas. In some of medium and large scale industries, local exhaust ventilation has been provided at some strategic locations consisting of hood and duct mechanism, but its performance was not found effective in containing the air contaminants. In one of the rubber reclaim industry visited, activated carbon adsorbent is used to collect organic vapour gas stream from depolymerisation process before venting it out to ambient air. Similarly, no effective measure has been observed for keeping high noise sources under control particularly in old plants. Based on the review of control and treatment technologies currently available as per literature survey, the following section will describe the best practicable control measures, which can be economically adopted by Indian Rubber Product Industries.

#### **7.3 The Air Pollution Process**

Prevention of emission is source controls. Transmission or path control interferes with transfer. Worker or operated oriented controls reduce exposure and uptake by the receiver. Source control is generally accepted as being most effective. Putting control in the transmission or exposure/uptake stages, without controlling the source, means that someone else could be unexpectedly exposed from the same source. Thus the classification according to pollution based process provides a classification of the



solutions in terms of where the intrusion takes place. The present study concentrates on this approach. Following this approach, control of occupational hazards from emissions can take place at any of three locations:

- At the source of the hazard (source emission control)
- Along the path from the source to the worker (transmission control) and
- At the worker (reception exposure control)

If workers' health is to be protected, maximum emphasis should be placed on those controls that eliminate hazards at the source. A description of some of the available methods for control of emission hazard follows.

### **7.3.1 Source Control**

Source Control can be achieved by eliminating the use of materials causing air emissions by reducing the amount of material used (if possible) by substituting them with less polluting ones, or by changing their form. Some of measures at source control are described below:

#### **i) Elimination**

Elimination generally means avoidance of hazardous substances so that workers are no longer exposed to contaminated air. Elimination can be encouraged by local and national legislation. Many substances used in rubber industries have been banned completely or for certain uses (UN, 1994).

#### **ii) Substitution**

If elimination is impossible, substitution of less hazardous materials by nature and form is potentially the best way to reduce pollution risk. Elimination or substitution of harmful materials is perhaps the most effective means of engineering control of hazards in rubber manufacturing. For example, beta-naphthylamine was removed from use because it is known to be carcinogen. Another known carcinogen, benzene, was once widely used as a solvent throughout the rubber industry; it is being steadily replaced by toluene. Other substitute of benzene is naphtha or white gasoline in which benzene content has been steadily reduced from 4-7 % to commonly less than 0.1 % of the mixture. Heptane has been used as a substitute for hexane and works just as well and better. Lead sheathing is being replaced by other materials for curling hose. Rubber compounds are being designed to reduce dermatitis and the formation of nitrosamines in curing. Talc used for anti-tack purposes is selected for low asbestos and silica content. Safer substitutes, if they are seriously investigated, can often be found.

#### **iii) Reducing Toxic Chemical Usage by Reformulation**

Reformulation of compound master batch through trial may help to reduce use of toxic chemical without compromising the quality of product. For example, one manufacturer claims to have reduced zinc waste simply by reducing the amount of zinc added to the

compound master batch. Industry kept reducing the amount of zinc added until the quality of the product suffered. The manufacturer then assumed that last zinc level at which no decrease in product quality was discovered was the best "waste minimized" operating level. Since manufacturers may use several hundred compounding formulae on a regular basis, formulae review may not only reduce waste production, but also provide for increased quality control.

**iv) Nature**

Substitution should not introduce new unknown hazards into workplace. Efforts at substitution should be carefully explored. Substitution has often been used with great success. The factors, which should be kept in mind in substitution, are:

- The substitute material must have well known and appreciably lower toxicity.
- The substitute should be technically feasible.
- The substitute material should be cost effective

**v) Form**

It may be possible to effectively eliminate or decrease hazardous exposure by changing the form in which a substance is used, such as:

- Some dusty materials (fine powders) can be palletized or used in liquid suspension. This control method is particularly useful in the compounding and mixing area of a rubber plant.
- Powdered raw materials can be pre-packed according to batch intake.
- Powdered materials and chemicals in rubber industry can be incorporated in a rubber pre-mix for addition to the process, which can minimize the possibility of exposure.
- Organic solvent can be substituted by water based solvents.

**vi) Isolating the chemical**

Work processes that isolate and enclose chemicals while they are being used, can also prevent exposure to hazards. Systems, which utilize closed vats, have been used in the chemical industry to greatly reduce exposure to carcinogenic or hazardous chemicals such as vinyl chloride.

**vii) Process Control**

Significant reductions in fume levels may be achieved by avoiding compound temperatures in excess of process requirements. Fuming products should be cooled as soon as they have finished processing using water, air or by passing cured items over chilled surfaces. Alternatively they may be allowed to cool in an area controlled by ventilation. Flash and scrap from freshly moulded items can be quenching cooled in cold water as a cheap and easy means of fume control. Personal exposures can be reduced by limiting the time spent close to dust and fume e.g. by use of automatic feed and take-off devices at two-roll mills. By segregating dusty processes, the number of workers at risk can be reduced. This principle can also be applied to fume control i.e. in some circumstances fuming freshly produced rubber can be moved away from the

areas occupied by people into a separate ventilated area to cool. Rubber sheets taken off mills and calendars are coated to keep them from sticking together. This is sometimes done by dusting the rubber with powder, but is now more often done by dipping it in a water bath. Applying the anti-tack compound this way greatly reduces dust exposure and improves housekeeping.

**viii) Handling and Working Methods**

Methods of work can significantly reduce dust and fume exposures by adopting good working practices. The compounding and mixing of a rubber products manufacturing facility, where dry chemicals are weighed, put into small containers, and loaded into the rubber mixer, can be a significant source of particulate emissions. Some mixing facilities have practically eliminated particulate emissions by purchasing their chemicals in small pre-weighed, sealed polyethylene bags. The sealed bags are put directly into the banbury mixer and the bag itself becomes part of rubber matrix, thus eliminating this formerly dusty operation. For facilities not purchasing their chemicals in pre-weighed bags, sealed containers for all open materials should be provided. Sealed containers should have air space between chemical and container cover to minimize 'puffing' losses when the container is opened. Similarly, placing secondary containment mechanisms around all storage containers provides further protection from spills and leaks. Chemical piles should be stored inside the facility to ensure that any fugitive emission can be contained within the facility. The amount of stock purchased should be minimized by providing computer inventory control methods. Double handling of powders at the weighing stage i.e. weighing them into the weigh scale pan and then into the required container should be avoided. Automatic dispensing and weighing equipment should be utilized whenever possible. Automatic dispensing minimizes waste due to spills from manual dispensing and provides quality control. Sacks, bags etc. should be opened, emptied, rolled up, and where possible disposed of, under local exhaust ventilation (LEV). Receptacles are properly designed and stationed so that workers do not have to bend into deep and dusty containers. Cured products should preferably be trimmed when cool. If they must be worked on when still fuming, local exhaust control will be needed. As per USEPA document, three general methods of VOC emission reduction are available to rubber products manufacturing industry particularly tyre and tube industry:

- Emission Reduction System consisting of General Ventilation and LEV (Capture and Control Unit)
- Low Solvent Consumption cement application technique
- Low VOC content materials.

Water based green tyre spraying; tread end cementing and bead cementing which employs low solvent use techniques involve reduced organic solvent consumption. Consequently, VOC emissions may be so small that further emission reduction through the use of capture/control systems may not be warranted.

### 7.3.2 Transmission Control (Control Along the Path)

If emissions cannot be eliminated or reduced to the desired level by control of the source, transmission throughout the work environment can be prevented by separating the workers from the emissions, either by containment, or by using general or local exhaust ventilation.

#### i) Containment (or Isolation) and Enclosures

Containment or Isolation consists basically of placing a barrier between the emission source and the workers.

It is always preferable to enclose the source than to isolate the worker. Source enclosures coupled with exhaust ventilation remove contaminants from the workplace. Automated production and remotely controlled operations can be carried out inside enclosures without the presence of workers. However, such systems are to be checked routinely for leaks or any other type of loss of containment.

#### ii) Ventilation Principles

Properly designed and maintained ventilation is one of the more effective ways of reducing exposure to harmful chemicals in the form of gases, fumes and dusts. There are two basic types of ventilation: general ventilation and local exhaust ventilation (LEV). Of these two ventilation systems, only local exhaust operations are effective at controlling exposure to toxic chemicals. General ventilation can help to provide a more comfortable working environment and can be useful in preventing fires or explosions. General ventilation should not substitute for local exhaust ventilation systems. Reducing air concentrations of hazardous chemicals by means of general ventilation systems does not mean that workers' health will be protected from hazards other than fire and explosions. The resultant dilution may simply make the presence of hazardous substances in the air less obvious. Another negative effect of general ventilation is the possible distribution of toxic contaminants through the plant; thus, even more workers may be exposed to hazard. In some instances, general ventilation can interfere with local exhaust systems. Because general ventilation creates air movement, it can, if improperly designed, disrupt the flow of air into an exhaust canopy. The exhaust hoods over banbury mixers are one location where this often occurs. Care should be taken to ensure that general ventilation and local exhaust systems are compatible.

Quality assurance on installation of the system and routine checks thereafter are essential, in order to ensure effective and continued performance. Faulty and indifferent maintenance is a major cause of failure of ventilation systems. Ventilation system should be examined and tested at least once in a year. The performance of such systems should be checked against design specifications as part of this maintenance schedule. In addition, it is recommended that LEV plant should be inspected weekly by a responsible person for signs of leaks and damage. The following section provides details for individual systems.

iii) **General ventilation**

General ventilation refers to the supply and exhaust of large volumes of air at a workplace, for diluting or displacing airborne contaminants, with or without local exhaust ventilation, and for ensuring thermal comfort. However, there is always a danger that general ventilation will increase exposure of people away from the large dust source or outside the workplace.

Contaminants should be directed away from the workers' breathing zones, which may be difficult to achieve, particularly when operations are scattered.

In order to be effective, clean air should sweep through the work area, between the floor and a height of 3 metres. In many situations, particularly for very large workrooms that require a high rate of air exchange, natural ventilation alone will not be adequate and motor driven fans must be used to provide the desired air velocities and flow patterns.

iv) **Local Exhaust Ventilation (LEV)**

Local exhaust ventilation extracts air close to the source of the dust, and aims to capture the dust and remove it before it can spread through the workplace and reach the breathing zones of the workers. It also serves to recover process materials (which can be economically important), protect process equipment, maintain product quality, and contribute to good housekeeping. LEV system comprises:

- A hood, which captures the contaminant at its point of generation
- A duct system with appropriate airflow
- An air cleaning system (Control Unit) to prevent pollution of the general atmosphere
- An exhaust fan
- A stack or other means of dispersion of the decontaminated air to the atmosphere

Local exhaust ventilation involves a controlled and directional airflow across an emission point and into a hood that is connected to a ductwork system.

a) **System Design**

If properly designed, LEV systems can greatly reduce exposure to harmful fumes, gases and dusts. The principle of these systems is that a fan in a hood placed at or near the source of the contaminant pulls the chemically contaminated air away from breathing zone. In a simple system, the fan produces a negative pressure in the duct immediately upstream, and this draws air through the system. These systems work very much like a vacuum cleaner, pulling air from an area of high pressure to an area of low pressure created by a fan in the exhaust system. There is a pressure drop across the air cleaner, and along each section of the duct. Finally there is a pressure drop at the entrance to the hood, which draws air in from the workplace. In anything but the simplest system, ducts from several hoods are likely to lead to the same cleaner and fan, and skilled design is required to ensure that the pressures in the system are 'balanced', so that the velocity at every hood is high enough to capture the dust and to

keep it airborne in the ducts. It is also necessary to design so that pressure losses are a minimum, so that the total flow can be provided by a properly designed fan. The wrong fan can be more expensive, noisier, and consume more energy. A careful maintenance programme is required to ensure that the system stays effective.

**b) Capturing the Particulates**

The distance from the hood to the source of the contaminant must not be too long. If this distance, called a capture distance, is greater than the diameter of the hood, very little contaminant will be extracted. The air velocity at the point of particulate generation must exceed the *capture velocity*, i.e. it must be sufficient to carry the particulate from the point of emission into the hood. The velocity at the opening of the hood (the *face velocity*) must be sufficient to maintain the capture velocity against disruptive air movements. The face velocity must also exceed the *control velocity*, the velocity necessary to keep the particulates inside the hood against these disruptive draughts: 0.5 to 0.75 m/s is usually sufficient for this. The disruptive draughts may be generated by, for example, movement of work pieces into and out of ventilated enclosures, movement of workers and machines in the immediate vicinity of the hood, and air currents from open windows, doors, and fans. Air currents generated by work activities seldom exceed 0.5 m/s near hoods, but air currents that sweep into the workroom from nearby open doors and windows may reach several times this value. Therefore, operations requiring local exhaust ventilation should be placed in areas that are protected from draughts. For a given airflow, good hood design can increase the control air velocity at the emission source.

The required capture velocity for a certain situation can be established in an empirical manner by utilizing a nozzle of any suction device and moving it closer to the emission source until the contaminant is efficiently captured. The range of required capture velocities goes from 0.5 m/s to capture the evaporation of a solvent to 10 m/s to collect particles being generated by a grinding wheel. An example in Table-7.1 provides guidelines for capture velocities.

**Table 7.1 Examples of Capture velocities**

S.N	Speed of Release of Contaminant	Ambient Air Movement	Required Capture Velocity (m/s)
1	Low	Slight	0.5-1.0
2	Medium	Rapid	1.0-2.5
3	High	Very rapid	2.5-10

It is important to keep in mind that farther the capture point from the particulate source, the higher the required face velocity and airflow for the same hood. The air velocity towards a hood falls off as the square of the distance from the hood face opening. This means that it becomes increasingly difficult to achieve adequate capture velocities as the distance from the hood face increases, and the position of the work in relation to the hood must be carefully controlled - maintaining the hood-work distance is a constant

problem of local exhaust ventilation. The problem of disturbing airflows also increases with distance.

c) **Exhaust Hoods**

Hoods range in size from small nozzles to large booths and may be positioned above, below or to the side of the particulate source. The hood type and the required airflow rate depend on the physical configuration of the equipment and on the emission characteristics of the process, such as the type of contaminant and rate of generation, as well as on workroom conditions, such as crosswinds, position of workers, available space, and other operations in the vicinity.

The main types of hood are the following:

**Enclosing hoods** that surround the emission source so that air contaminants are prevented from being released into the work environment by a continuous inflow of air;

**Exterior hoods** that are located at some distance from the source; air contaminants are drawn into the hood by an airflow that establishes an effective capture velocity;

**Receiving hoods**, that are exterior hoods utilizing the motion of an ejected air stream to carry contaminants from the source into the collection hood;

**Push-pull or jet assisted hoods**, which are a form of receiving hood utilizing a jet of clean air from a local supply duct to sweep the contaminants into the exhaust hood.

**Moveable hoods** are useful for many non-repetitive tasks such as welding, casting chipping, and grinding or sanding with a motorized hand tool.

The hood captures as much of the contaminant as possible. Hood designs vary a great deal. It should be specifically designed for particular operation. For example, the enclosure type of hoods surrounds the source of the contaminant and physically prevents the dispersal of the chemical. These systems are especially useful in material handling areas such as the compounding and mixing area. Booths, special types of enclosure hoods, which leave one side open, are frequently used in green tyre painting area. For locations where there is a stream of contaminated air from hot processes, such as the curling, calendaring and extrusion areas, receiving hoods should be used. These hoods are placed above the operation and capture the hot contaminated air as it rises. Slot ventilation hoods can also be used in various operations particularly in the finishing, inspection and repair area. Specific designs for different processes can be found in the American Conference of Governmental Industrial Hygienists (ACGIH) book, *Industrial Ventilation: A Manual of Recommended Practice*. With a good hood design that encloses the operation as much as possible and draws the contaminants away, exposure to chemical contamination can be greatly reduced. Important characteristics to be considered in designing hoods for local exhaust ventilation systems are:

*Source characteristics*

- Size, shape and the position of the emission source;

- Nature of the operation which generates the particulates;
- Particle size;
- Speed and direction of the contaminant
- Generation rate of the contaminant (how much is being produced?).

*Worker characteristics:*

- Position and movements of the worker and equipment.  
Work environment characteristics
- Local air movements due, for example, to general ventilation of the workroom, openings, operation of nearby machinery, passing persons, workers' movements, and so on.

**d) Ducts**

After the contaminated air has been collected into the hood, it must be transported through the duct system. Ducts must be designed properly to ensure the efficiency of the system. If their diameter is too small, if they are too long or they have frequent elbows, the ducts will be less effective.

The ductwork should be so designed that the air velocity is high enough to keep the particles from settling. This applies particularly to long horizontal runs of ducting, where the build-up of settled dust particles could reduce the airflow in the duct and adversely affect control performance at the inlet to the system. Occasionally, vertical duct runs may be designed with a low air velocity so that the larger dust particles fall out of suspension into a collecting bin at the bottom of the duct. In addition to the deterioration of the system and the inconvenience of frequent cleaning, certain particulate accumulations may pose a fire hazard. Recommended carrying velocities for particulates are given in Table-7.2.

**Table 7.2 Recommended Air Velocities in Ducts for Carrying Particulates**

S. no	Type of contaminant	Duct velocity (m/s)
1	Light/medium density particulates	15
2	Average industrial particulate (e.g., grinding dusts, asbestos, silica)	20
3	Heavy particulates (e.g., lead, metal turnings, damp dusts or those which tend to agglomerate)	25

Ductwork should be made of material, which is sufficiently strong and well supported to be rigid and to stand the wear and tear it is likely to receive. The fixing of ducts to walls and ceilings requires vibration absorbing supports of rubber or similar material in order to avoid noise.

**d) Fans**

The fan is the central part of the exhaust system because it provides the suction necessary to remove the contaminant. The fan's effectiveness in creating suction can be greatly reduced by improper hoods and ducting.



Centrifugal fans with a backward-curved impeller are the most widely used fans in industry because they cannot overload the fan motor and cause stoppages and because they are rugged and give trouble-free service for decades with minimal service needs. If corrosive gases are present, centrifugal fans can be made of plastic, and, for service with potentially explosive gas concentrations, they can be constructed of non-sparking materials.

Axial flow industrial fans are mainly suitable for small systems containing little or no corrosive gases or erosive particulate material. However, axial fans are inherently noisier than centrifugal fans.

Propeller fans are frequently installed in factory windows to provide some amount of general room exhaust capacity.

Important considerations in selecting fans are size and weight, energy consumption and fan noise. The fan should be placed so that air passes through the air cleaner before reaching the fan. This will prevent the fan from becoming clogged and dirty. Fan should be mounted on antivibration mounts and placed in a sound dampening enclosure to avoid noise hazards. Fan selection is based on calculations of the total air volume the system has to handle and the required static pressure to overcome all pressure losses, usually with an allowance of 10-20% excess for future expansion needs.

**e) Replacement Air**

A vital part of any local exhaust system is a source of make up air to replace the contaminated air removed from the plant. If make up air is not supplied, the air pressure difference between the plant and the exhaust system will be reduced. As a result, the ventilation system will be less effective. Make up air can be provided by open doors or windows, but it is probably best supplied by a special make up air system, which can cool, humidify or heat the incoming air. Unfortunately, the make up air part of local exhaust system is frequently neglected.

**f) Down flow Booths**

In recent year downflow booths have been developed, which offer a different approach to traditional local exhaust ventilation in control at powder handling processes. The systems provide clean laminar airflow from the ceiling, to control airborne particulates within a contained work area. The contaminated air moves downwards and away from the operator breathing zone into a low level exhaust grille. A high quality filtration system captures any particulate before the particulate is recirculated to the overhead inlet. Most systems are self-contained with integral filters and fans.

Thus, the key elements of an effective **local exhaust ventilation system** are, therefore, as follows.

- A well-designed hood, enclosure or other inlet to collect and remove the contaminant from its source, so it does not reach the breathing zone of the

- workers or disperse into the work environment. The hood should be suitable for all the jobs for which it is to be used, permitting them to be carried out without interference and without generating significant breathing-zone concentrations. The design will take into account airflow generated by tools, the process, or worker movement.
- Properly designed and constructed ductwork, to convey the contaminant away from the source. The duct will only have smooth bends and as few changes of direction as possible. Where the ducting serves several hoods, it will be designed to maintain adequate face velocity at all the hoods simultaneously, while using as little fan power as possible
- Immediately upstream of the fan, an appropriate filter or other air-cleaning device to remove the contaminant from the extracted airstreams
- A correctly selected and rated fan or other air-moving device to provide the necessary airflow at the hoods, and also velocity in the ducts to keep the particulate airborne.
- A properly designed and constructed discharge system.
- An effective checking and maintenance programme to ensure continued satisfactory performance.
- Properly designed arrangements for providing replacement air.

If a system fails to achieve the expected level of control, its failure can usually be traced to one of the above points.

#### v) **Cleaning the Exhaust Ventilation**

The final component of the exhaust system is capture unit (air cleaning device), which may be optional depending upon the type and load of pollutant in exhaust flue gas emission governed by efficiency of source control as discussed above and regulatory requirement.

To protect the wider environment, appropriate disposal of collected particulates is indispensable. In some cases, it may be economical to recover materials. In the case of fabric filters, the disposal of the filters themselves is of concern, particularly if they have been used to collect toxic dusts. For wet scrubbers, the treatment and legal disposal of the wastewater, including the space required for the liquid handling facilities, should be taken into consideration. Often, cleaning out and maintaining dust collectors are itself a very dusty job and appropriate controls for the workers involved must be carefully considered.

Air-cleaning devices for particulates must be properly selected so that the airflow through the ventilation system is maintained and the emission standards met as the air cleaner accumulates particulates.

### **7.3.3 Control at Worker — Personal Protective Equipment (PPE)**

Personal Protective Equipment (PPE) for protection from exposure to chemicals should only be used in unusual situations. The emphasis should always be on controlling health hazards at the source or by means of ventilation systems. Unfortunately, employers frequently rely upon PPE to protect workers because it is cheaper than making engineering or production changes. During accidents, spills and other non-routine situations when existing controls will not protect workers from exposures to harmful chemicals, respirators and other protective equipment should be supplied by the company. PPE may also be necessary in the short term until engineering controls or substitutions have been instituted. The five types of clothing that may be required are:

- Chemical Protective Clothes
- Coveralls
- Protective Footwear
- Face or eye shields
- Respiratory Protective Equipment (RPE)

Not all the materials give protection against all chemicals. Some chemicals pass through protective materials over a period of time. It is to be ensured that the equipment is changed when necessary. Workers should be trained and it should be ensured that they follow the instructions. The following is a description of precautions while utilizing PPE.

#### **General Precautions**

- Check PPE for damage both before and after use.
- Clean and maintain all PPE regularly
- Use disposable protective equipment only once and dispose of it safely after use.
- Wash cotton type overalls on a regular basis.
- Store protective clothing in a clean cupboard or locker
- Store clean and dirty clothing separately.
- Provide a good standard of personal washing facilities

#### **Chemical Protective Gloves**

- The gloves must be sufficiently robust not to tear or cut while undertaking the work activity.
- Leather or stitched working gloves are not suitable for working with chemicals.
- Make sure workers do not touch the outside of a contaminated glove with a naked hand when putting gloves on or taking gloves off.

#### **Coveralls**

- The material selected should be resistant to the penetration of liquids, dusts or granules as appropriate.
- For corrosive materials such as acids, an impervious apron gives good protection.

- Overalls should be washed at work or at a specialist laundry. They should not be taken home and washed with the 'family' wash.
- Coveralls should normally be worn over boots rather than be tucked in.
- Gloves should normally be worn over the sleeves to help stop contamination getting on the inside of the PPE.

#### **Protective Footwear**

- Protective footwear may be necessary for safety reasons as well as for protection against chemicals. Toe cap protection, heat protection and a metal sole plate may be needed.
- Ensure protective footwear complies with the appropriate standard.

#### **Eye and Face Protection**

- When handling open containers of corrosive liquids, full face shields should be worn.
- Chemical splash goggles may be more practicable when wearing a respirator.

#### **Respiratory Protective Equipment (RPE)**

The US Occupational Safety and Health Administration stipulate that full time use of respirators is not an acceptable solution to a contaminated air problem except in those very rare cases where ventilation and other controls are not feasible. Workers should be provided with information on the limitations and proper use of the equipment. All respirators should be individually fitted to face. Two main types of respirators are in use: air supplying and air purifying. Air supply respirators have an independent air supply. They are used in situations where there is a deficiency in oxygen or when a chemical is so dangerous that absolutely no exposure to it should occur. Cleaning and maintenance of large tanks where high concentrations of vapors and gases are present is one situation where this type of respirator should be used. Air purifying respirators contain filters, which are designed to remove particular toxic substances from breathing air. An incorrect filter may provide with a false sense of security. Proper maintenance of the equipment should be done regularly by trained personnel. Respirators should be stored in an area away from dust, sunlight, extreme cold, moisture and damaging chemicals.

### **7.4 SUITABLE CONTROL MEASURES OF WORK AREAS**

Details of air emission mitigation and control measures have been covered in preceding section. Each work area in a rubber plant requiring control measures must be specifically designed for that particular purpose. The present section deals with feasible measures and practices generally adopted in rubber product industries. The following section lists area wise suitable control measures.

## **Compounding and Mixing**

This area requires local exhaust ventilation to prevent exposure to chemical dusts during weighing and mixing. The Banbury mixer requires an effective enclosing hood to capture dust from charging and to collect the fumes and oil mist coming from the heated rubber as it mixes. Well-designed hoods are often disrupted by drafts from pedestal fans used to cool the operator. With good work practices and ventilation designs, exemplary industries contain dust exposures usually well under 2 mg/cubic meter.

### **a) Cutting and Milling**

Fumes and vapor created in this area should be removed by canopy hoods. Mills are provided with canopy hoods to capture emission of oil mists, vapors and fumes rising from the hot rubber. Unless more enclosed, these hoods are less effective in capturing dust when compounds are mixed on the mill or the mill is dusted with anti-tack powders. They are also sensitive to drafts from pedestal fans or misdirected general ventilation make-up air. A push-pull design is used which places an air curtain in front of an operator directed up into the canopy. Mills are often raised to put the roller nip point out of the operator's reach, they also have a trip wire or bar in front of the operator to stop the mill in an emergency. Dust and fumes are ducted to bag house dust collectors.

### **b) Cement Mixing**

Exposure to solvent fumes in this area can be greatly reduced with local exhaust systems. Making and applying rubber cement presents special engineering control requirements for solvents. Mixing chums are sealed and vented to a solvent capture system, while dilution ventilation controls vapor levels in the work area. The highest operator exposures come from reaching into chums to clean them. In applying rubber cement to fabric, a combination of LEV at emission points, covered containers, general ventilation in the workroom and properly directed make-up air controls worker exposure. Drying ovens are exhausted directly. Carbon adsorption solvent recovery systems are the most common air-cleaning device used for such process areas. Automation of processes and equipment often lowers exposure to airborne contaminants and physical agents by placing the operator at a greater distance, by confining the source or by reducing the generation of the hazard.

### **c) Extrusion and Calendaring**

Both of these operations involve hot gases and fumes, which contain potential hazards. Local exhaust hoods are often used at extruder heads to capture mist and vapors from the hot extrusion, which may then be directed into a water bath to cool it and suppress the emissions.

### **d) Fabrication of Beads, Tubes and Tyres**

Talc and solvent fumes in these work areas can be controlled with LEV. The numbers and physical configurations of building stations for tyre and other products usually make them unsuitable for LEV. Confinement of solvents to covered containers as much as

possible; along with careful work practices and adequate dilution air volume in the work area are important for keeping exposures low. Gloves or applicator tools are used to minimize skin contact.

#### **e) Curling Preparation Area (Green Tyre Spraying)**

Spray booths are generally used to prevent exposure to talc and other hazards in this area.

#### **f) Curling**

Curling presses and vulcanizers release large amounts of hot curing fumes when they are opened. Most of the visible emission is oil mist, but the mixture is also rich in many other organic compounds. Dilution ventilation is the control measure most often used, often in combination with canopy hoods or curtained enclosures over individual vulcanizer or group of presses. Large volumes of air are required which, if not replaced by adequate make-up air, can disrupt ventilation and hoods in connecting buildings or departments. Operators should be positioned outside the hood or enclosure. If they must be under the hood, downdraft fresh air ventilators can be placed over their workstations. Otherwise, replacement air should be introduced adjacent to the enclosures but not directed into the canopy. The British occupational exposure limit for rubber curing fumes is 0.8 mg/cubic meter of cyclohexane soluble material, which is normally feasible with good practice and ventilation design.

#### **g) Finishing and Warehouse**

Finishing processes involving buffing and grinding activities are potential sources of exposures to workers. Slot type ventilation can reduce exposure to particles and fumes. Proper general ventilation in warehouse is needed to prevent the buildup of fumes from stored cured products.

### **7.5 CODE OF GOOD PRACTICE**

The existing requirements to follow good practice are generally covered under following principles.

- Design and operate processes and activities to minimize emission, release and spread of substances hazardous to health.
- Take into account all relevant routes of exposure – inhalation, skin absorption and ingestion-when developing control measures.
- Control exposure by measures that are proportionate to the health risk.
- Choose the most effective and reliable control options, which minimize the escape and spread of substances hazardous to health.
- Where adequate control of exposure cannot be achieved by other means, provide, in combination of other control measures, suitable personal protective equipment.
- Check and review regularly all elements of control measures for their continuing effectiveness.

- Inform and train all employees on the hazards and risks from the substances with which they work and the use of control measures developed to minimize the risks.
- Ensure that the introduction of control measures does not increase the overall risk to health and safety.

Many control measures under good work practices have already been covered in preceding section. The following section describes some more good work practices. Control measures include everything that stops contamination from being spread. One important complementary measure is good housekeeping, which involves keeping the workplace clean, controlling waste, cleaning up spillages and maintenance.

Management and workers should give housekeeping a high priority, so that the workplace is kept as clean as possible, at all times. It should be kept in mind that:

- a dirty or untidy workplace demonstrates low priority given by management to careful work practices, and creates an attitude of carelessness in the workforce;
- leaks or spills, if not attended to promptly, may appreciably contribute to air contamination, including by re-entrainment of settled dust; and
- Surface contamination, visible or not, can be a major source of ingestion and skin contamination, leading possibly to absorption or skin disease.

The following practices should encourage good housekeeping.

- Clean-up tools, absorbents, etc., should be readily available, inspected, and replenished frequently.
- Clean-up of spills should have a high priority.
- Housekeeping tasks should be regarded as part of the job - a 'clean as you go' attitude - rather than as tasks to be done only when the work is finished. Workers should be responsible for keeping their own work area clean.
- As a back up to the previous point, but not replacing it, maintenance procedures should also include a check on housekeeping.
- The cleanliness of work areas, and all the above practices, should be evaluated and encouraged by management during inspections of the workplace.

Prevention of spillages should be a first priority, but adequate cleaning methods should be available in case a spillage occurs. Damp sweeping is often proposed to minimize raising dust and subsequent air contamination. Compressed air and dry sweeping should not be used to remove settled dust, because these practices make much of the dust airborne again. This is particularly dangerous if the dust contains hazardous constituents, such as free silica or lead.

Vacuum systems are better. Portable vacuum cleaners may be used, if the filtration efficiency of the filter element is adequate for the material to be cleaned up. If the bag is torn, or the filtration unit missing, the vacuum cleaner will become an aerosol generator, dispersing a dust cloud into the workplace atmosphere. If the filtration unit is not effective for very small particles (as is true for typical domestic vacuum cleaners), the situation may be even more dangerous since, although the cloud may not be as

visible; the small particles released are more readily inhaled and usually contain a higher proportion of respirable particles.

Procedures to prevent spread of contamination may include decontamination at the end of the work period. In this way all contaminated clothing and work tools are left within clearly defined segregated areas. The workforce may have to transit through a properly constructed decontamination facility. Control features might include the need for a shower or comprehensive wash before the worker is allowed to put on normal clothing. Processes where particularly toxic dusts are handled may need this sort of arrangement.

### **7.5.1 Storage**

Storage rooms are not hazard-free areas as there may be a build-up of airborne contaminants to dangerous concentrations if poorly ventilated. Depending on the materials or products stored, the resulting health risk may be high. Unless the storage area is well ventilated, adequate precautions should be taken when entering, particularly if the chemicals likely to be released are fast acting and have ceiling values for permissible exposure levels.

Intermittent exhaust ventilation, to be turned on some time before entering the storage area, can be a solution. If personal protective equipment is used, it should be adequate for the gases that may be present.

Storage of raw materials, chemicals and products in appropriate places and in adequate containers is essential both for health and safety reasons. Containers should preferably be unbreakable, have no leaks and have well-fitted lids, which should be kept closed except when materials are being used. Where raw materials are stored in bags, a detailed inspection should be carried out on receipt and handling of the bags to identify split and damaged bags. All spillages should be cleared as soon as possible by appropriate techniques. Dry sweeping of dusty spillages should be avoided. Damaged bags should be placed in undamaged outer bags in order to prevent further spillages. Empty bags, which have contained carbon black, should be placed in a closed container immediately after emptying by a method, which minimizes the emission of particulate matter into the air. Container design and work practice should be such as to avoid spillage when materials are being removed. Emission from fixed solvent storage tanks should be vented to suitable arrestment equipment if necessary. Fixed storage tanks should be fitted with a high-level alarm or volume indicator to warn of overfilling. The handling, transfer and internal transport of raw materials and wastes should be carried out by methods to prevent or minimize the fugitive emission of particulate matter to the atmosphere. A regular, thorough cleaning programme should be instituted in areas subject to localized deposits of carbon black.

### **7.5.2 Labeling**

Adequate labeling of any container with a chemical agent is of the utmost importance. Management should ensure through a purchase policy that materials bought are adequately labeled.



Labels should indicate, clearly and in a language perfectly understandable by the users, the degree of toxicity of the chemical in question, possible routes of entry, main symptoms resulting from overexposure, safety and fire hazards, possible dangerous reactions, main precautions for use, and first-aid procedures in the case of overexposure or ingestion. Adequate symbols (e.g. fire, corrosive liquids, explosives, etc.) and other visual messages on labels are very important, particularly if there are illiterate workers.

Toxic or reactive materials should never be dispensed into, or from unlabelled containers, and in particular any containers formerly used for foodstuffs.

Labeling of personal protective equipment is one safeguard against its misuse; for example, labeling helps to prevent the use of a respiratory protective device designed to protect from dusts and fumes, in a work situation where there is exposure also to gases or vapors or inadequate oxygen.

### **7.5.3 Warning Signs and Restricted Areas**

Warning and caution signs are indispensable for work areas where potential hazards exist. These should convey a clear message, be easily understood by the workers, including the illiterate, be as pictorial as possible, and be adequately located in visible and well illuminated areas. Workers' education and training are necessary; visual signs should be considered as reminders.

There may be a need for restricted areas, for example, where highly toxic, radioactive or carcinogenic materials are handled. Such areas should be well defined, be kept under negative pressure, and should be very clearly indicated with adequate warning signs. Only workers wearing highly efficient personal protection should enter such areas; moreover, they should previously receive adequate instruction in safe work practices and in the use of the required personal protection. Strict medical surveillance is also necessary.

It may be that a process or a substance is particularly difficult to control at the source, but at the same time it may be that there is little need for an operator to be constantly in attendance. If it is too difficult to control contamination in certain areas of a workplace, one effective way of reducing workers' exposure is to isolate the highest concentration areas, and prevent workers from entering, unless strictly protected. Operators who only need to ensure that a process is working normally can be well protected just by remaining in a purposely-built refuge (with air access only from clean areas). Such refuges can also serve to protect against other workplace hazards, e.g., noise or extremes of temperature. Control rooms and refuges can even be built away from the main plant, with operations being monitored by closed-circuit television cameras.

Of course, if a control room is well designed and comfortable, the operator is more likely to remain within its protective confines and not be tempted to enter areas of high exposure. In the event of plant breakdown, the operator should be provided with appropriate personal protective equipment and be thoroughly trained to use it. This

approach has been shown to be effective in the quarry industry, refuse incineration and at mechanized grain terminals. Another example along the same lines is the development of clean air cabs on combine harvesters, although filtration efficiency needs to be monitored in this case.

Administrative and management elements are very important aspects of a control strategy, especially when there is the possibility of residual exposure after other control measures have been applied. Procedures should be adopted to segregate and indicate hazardous areas, enforce wearing of personal protective equipment, ensure that cleanliness and housekeeping are up to standard, and that engineering controls are used and working properly.

## **7.6 NOISE**

Process operations involving machineries are a strong source of noise in the in-plant environment.

### **7.6.1 Noise Sources**

The sources of noise in the rubber products manufacturing industry are attributed to.

- Machine Operation
- Generator Operation
- Boiler Operation
- Mechanical Workshop
- Cutting, Grinding and Finishing Operations, etc

### **7.6.2 Mitigation and Control Measures**

The noise levels can be mitigated by adopting following measures:

- a) Engineering Measures
- b) Administrative Measures

Engineering control measures involve:

- Structural and mechanical modifications
- Proper maintenance of the machines
- Provide silencers on compressed air exhausts
- Replace old gear drive motors with new belt drive ones
- Plug air leaks
- Reducing the transmission path of noise from the source to the receiver
- Providing proper acoustic enclosures, vibration insulator paddings for the noise generating machines, generators etc.

Administrative control measures involve:

- Ear muffers/plugs for workers working in the noisy area

- Regulating the length of noise exposures by proper shift scheduling, job rotation and/or by restricting the operation of the noise source
- Education of workers

Workers who face a risk of exposure to potentially hazardous noise level shall be educated on:

- a) Possible consequences of excessive exposure
- b) Personal Protective Equipments (PPE) and their usage
- c) Limitations of PPEs (e.g., improper use of earmuffs).

It is essential that the correct hearing protection be worn properly. Safety glasses and sideburns can prevent a seal around the ear and drastically reduce the effectiveness of earmuffs. Cotton earplugs have very little effect in reducing noise, even if inserted properly. These plugs can often provide a false sense of security when entering noisy areas resulting in hearing damage. Foam earplugs are more effective than cotton ones and when combined with earmuffs can decrease noise. Ear infections, however, can result from earplug use. No amount of personal protection can substitute for removal or reduction of a noise source.

## CHAPTER - 8

### MINIMAL NATIONAL STANDARDS (MINAS) FOR AIR EMISSIONS & NOISE

#### 8.1 INTRODUCTION

In preceding two chapters, air emissions and noise from rubber products manufacturing industries have been characterized and their existing status of pollution and control measures have been assessed on the basis of field visit and literature survey. International and national currently available best available techniques not entailing excessive cost for containing air emission and noise levels within safe levels have been reviewed and discussed in detail. Based on findings, best practical, economical and technological viable measures have been suggested. The present chapter aims at finalizing safe limits (MINAS) for air emissions and noise economically achievable by the industries based on the findings of discussions contained in preceding chapters.

#### 8.2 MINAS FOR AIR EMISSIONS

- Processes must be operated in order to protect persons at work as well as the environment. Therefore, control limits proposed in MINAS, must, at least, not impose any risk to the health, safety or welfare of persons at work. It can be made further stringent in view of recipient environment and economical feasibility of control measures. As discussed in preceding chapters, workers in rubber product industries are exposed to mainly rubber dust and rubber fume having health hazards. Health related occupational exposure limits of harmful pollutants in such industries are required to be maintained to protect health of workers. Very little data exists on control measures, its performance efficiency and emission rate in Indian scenario. Hence, development of emission limits cannot be based on practicing examples in Indian Scenario. The approach adopted is based on review of existing economically achievable limits adopted by other countries with good working practices and low cost pollution control systems. Before arriving at MINAS for air emission, overview of findings on exposure and emission limits of common air pollutants from rubber product industries as per standard International practices is summarized in following section.

#### 8.3 Strategy for MINAS for Air Emission

As clear from above discussion, rubber dust (Suspended Particulate Matter) and rubber fume (VOC as main constituent) are two type of air pollutants found in the vicinity of working areas as fugitive emission and are having potential health hazard risks to workers. Hence, it is required to ensure that the exposure of workers to substances hazardous to health be either prevented, or where that is not reasonably practicable, adequately controlled. In general, no adequate and dependable data on type of air pollution control measures and its performance efficiency exists for rubber product industries in Indian scenario. The British occupational exposure limit for rubber dust and rubber fumes (cyclohexane soluble material) are 6.0 and 0.6-mg/cubic meter respectively, which are normally feasible with good practice and ventilation design. As per international experience, occupational exposure to rubber process dust and rubber

fumes has been effectively reduced in the past three decades, to well below existing health based occupational exposure limits (OELs). In most situations, it would be expected that by taking reasonable steps, it would be possible to achieve levels of exposure considerably below the workplace exposure standards. It is recommended to follow existing occupational limits as MINAS for air emission control in working areas. Two most important air pollution indicators used in rubber product industries are rubber dust and rubber fume. Monitoring results of these two parameters reflect overall condition of air quality in working area and its containment within prescribed OELs ensures safe exposure of many of its constituent health hazard chemicals to workers. British OSHA limits for individual chemicals forming rubber fume and rubber dust have also been compiled and given in Table 8.1. Occupational exposure limits for individual chemical substances such as carbon black, commonly used solvents, etc. that may be present will also apply. Many substances that may be encountered in the workplace have not been assigned exposure standards under British COSHH Regulations. US NIOSH and OSHA limits as compiled in Table 8.2 together with British OSHA limits provide exhaustive list of air pollutants likely to be present in working areas of rubber product industries. Occupational limits are fixed on personal sampling results and can only be compared with monitoring results by personal samplers. Determination of rubber process dust and rubber fume in air will be as per approved methodology by Health Executive Agency, UK. Personal samplers worn on workers' lapels, together with static samplers placed around the workrooms, will give the most complete picture of dust and fume emissions and exposures.

In tiny/small rubber product industries where small quantity of raw material is processed, fugitive emission of rubber dust and rubber fume is not high due to processing of less quantity of raw material and can be kept well within the occupational exposure limit with good working practices and proper general ventilation design and its maintenance as discussed in preceding chapters. Capture and control units may not be required for keeping exposure levels to workers under permissible limit. In the case of medium/large industries, it would be necessary to use local exhaust ventilation at strategic locations in addition to other measures for keeping working environment within safe level. It is, thus, necessary to fix emission concentration limit of Particulate Matter and VOC in exhaust gas of local exhaust ventilation in order to prevent ambient air quality deterioration. In absence of stack monitoring data, emission standards of SPM for other polluting industries such as cement, ceramic, aluminum, smelters, foundries, fertilizers, lime kilns, etc. have been reviewed in Indian scenario and in all cases, it is found to be 150 mg/cubic meter. It thus appears reasonable to adopt SPM concentration limit as 150-mg/cubic meter for rubber product industries also, which can be economically achievable with available control techniques (filter/cyclone). No such emission data is available in case of VOC. Based on the performance efficiency of VOC control techniques (Adsorbers/incinerators) and data compiled on European Countries experience as discussed in preceding section, VOC level can be kept within 50 mg/cubic meter irrespective of its inlet level of concentration to control measures. Hence, strategy for implementing emission standards (MINAS) can be summarized as below:

- All rubber product industries, irrespective of its size, will comply to OSHA limits prescribed for rubber dust, rubber fume and individual chemical to avoid health

hazards to workers by adopting good working practices and other control measures.

- It is expected that tiny/small industries would achieve OSHA limits by adopting good working practices and proper general ventilation design in working rooms without any capture and control units as quantity of raw material for process is small.
- In case of medium/large industries, local exhaust ventilation (LEV) consisting of hood, duct, fan and stack at strategic locations such as mixing/grinding/curing/solvent spraying etc. would be required to install for keeping exposure to plant personal under OSHA limits. Stack should be of suitable height and equipped with stack monitoring facilities.
- In case of SPM concentration limit exceeding 150-mg/cubic meter in flue gas through stack, control unit (filter/cyclone) has to be integrated with local exhaust ventilation system so as to achieve emission level.
- Similarly, Emission limit of VOC from Stack of LEV may be fixed as 50-mg/cubic meter, which is well within the techno-economic affordability of medium/large rubber product industries to achieve with control measures such as Activated Carbon Adsorber/Incineration technology integrated with LEV system, if required.
- Emission limits of SPM and VOC should be reviewed based on the periodic stack monitoring results of LEV and techno-economic feasibility of pollution control measures when such facilities would be available in rubber product industries for further investigation in Indian scenario.
- Flue gas emission from other sources such as Boiler and DG sets in the premises of rubber product industries should meet the Standards prescribed in the Emission Regulation of CPCB.

#### 8.4 MINAS for NOISE

Noise sources and its levels observed in Rubber Product Industries have been discussed in preceding chapters. Rubber processing generally does not contribute to ambient noise levels significantly. It has been observed that noise levels in very few cases violate OSHA limits. Noise occupational exposure limits set by US OSHA and NIOSH are well within the techno-economic capability of industry to achieve with good housekeeping and primary noise control measures as discussed in preceding chapter.

**Table 8.1: Workplace Exposure Limit Under COSHH Regulation, UK**

Sr No	Volatile Organic Compound	TWA (8 hourly)		STEL (15 Minutes)	
		Mg/cu m	ppm	Mg/cu m	ppm
1	1,1,1-Trichloroethane (Methyl Chloroform)	680	125	NA	NA
2	Acetone	1185	500	2375	1000
3	Carbon Disulfide	31	10	NA	NA
4	Dichloromethane (methyl chloride)	103	50	207	100
5	Methanol	262	200	328	250
6	Methyl Ethyl Ketone	445	150	890	300
7	Methyl Isobutyl Ketone	205	50	307	75
8	Styrene	213	50	426	100
9	Toluene	188	50	NA	NA
10	Xylene(Mixed Isomers)	350	80	655	150
11	Benzene, a known carcinogen	-	10	-	-
12	Heptane	1600	400	-	-
13	Hexane	-	50	-	-
14	Carbon Black	3.5	-	-	-
15	Zinc Oxide	5	-	-	-
16	Zinc Stearate	10	-	-	-
17	Talc	0.25	-	-	-
18	Lead	0.05	-	-	-

Source: British OSHA Limit

**Table 8.2 Rubber Dust and Rubber Fumes**

Sl. No.	Chemical Name	Chemical Composition	NIOSH REL	OSHA PEL	Remark
1.	1,1,1 Trichloroethane (Methyl Chloroform)	CH <sub>2</sub> Cl <sub>3</sub>	C 350ppm (1900 mg/m <sup>3</sup> ) (15 minutes)	TWA 350ppm (1900 mg/m <sup>3</sup> )	NIOSH considers Methyl Chloroform as a potent occupational carcinogens and should be treated with caution at workplace
2.	Acetone	(CH <sub>3</sub> ) <sub>2</sub> CO	TWA 250ppm (590 mg/m <sup>3</sup> )	TWA 1000ppm (2400 mg/m <sup>3</sup> )	-
3.	Carbon Disulfide (Carbon disulfide)	CS <sub>2</sub>	TWA 1ppm (3mg/m <sup>3</sup> ) ST 10ppm (30mg/m <sup>3</sup> ) (Skin)	TWA 20ppm C 30ppm	OSHA PEL 100ppm (30-minute maximum peak)
4.	Dichloromethane (Methylene Chloride)	CH <sub>2</sub> Cl <sub>2</sub>	-	TWA 25ppm ST 125ppm	1ppm = 3.47 mg/m <sup>3</sup>
5.	Methyl Chloride (Chloromethane)	CH <sub>3</sub> Cl	-	TWA 100ppm C 200ppm 300ppm (5minutes Maximum peak in any 3 Hours)	1ppm = 2.07 mg/m <sup>3</sup>
6.	Methanol (Methyl Alcohol)	CH <sub>3</sub> OH	TWA 200ppm (260 mg/m <sup>3</sup> ) ST 250ppm (325 mg/m <sup>3</sup> ) (Skin)	TWA 200ppm (260 mg/m <sup>3</sup> )	-
7.	Methyl Ethyl Ketone (2- Butanone)	CH <sub>3</sub> COCH <sub>2</sub> CH <sub>3</sub>	TWA 200ppm (590 mg/m <sup>3</sup> ) ST 300ppm (885 mg/m <sup>3</sup> )	TWA 200ppm (590 mg/m <sup>3</sup> )	-
8.	Styrene	C <sub>6</sub> H <sub>5</sub> CH=CH <sub>2</sub>	TWA 50ppm (215 mg/m <sup>3</sup> ) ST 100ppm (425 mg/m <sup>3</sup> )	TWA 100ppm C 200ppm	OSHA PEL 600ppm (5minutes Maximum peak in any 3 Hours)

Sl. No.	Chemical Name	Chemical Composition	NIOSH REL	OSHA PEL	Remark
8.	Toluene	$C_6H_5CH_3$	TWA 100ppm (375 $mg/m^3$ ) ST 150ppm (560 $mg/m^3$ )	TWA 200ppm C 300ppm	OSHA PEL 500ppm (10 minutes Maximum peak in any 3 Hours)
10.	m-Xylene	$C_6H_4(CH_3)_2$	TWA 100ppm (435 $mg/m^3$ ) ST 150ppm (655 $mg/m^3$ )	TWA 100ppm (435 $mg/m^3$ )	-
11.	o-Xylene	$C_6H_4(CH_3)_2$	TWA 100ppm (435 $mg/m^3$ ) ST 150ppm (655 $mg/m^3$ )	TWA 100ppm (435 $mg/m^3$ )	-
12.	p-Xylene	$C_6H_4(CH_3)_2$	TWA 100ppm (435 $mg/m^3$ ) ST 150ppm (655 $mg/m^3$ )	TWA 100ppm (435 $mg/m^3$ )	-
13.	Methyl Isobutyl Ketone (2-Hexanone)	$CH_3CO(CH_2)_3CH_3$	TWA 1ppm (4 $mg/m^3$ )	TWA 100ppm (410 $mg/m^3$ )	-
14.	Naptha (coal Tar)	-	TWA 100ppm (400 $mg/m^3$ )	TWA 100ppm (400 $mg/m^3$ )	-
15.	Benzene	$C_6H_6$	TWA 0.1ppm ST 1ppm	TWA 1ppm ST 5ppm	1ppm = 3.19 $mg/m^3$
16.	Heptane	$CH_2(CH_2)_5CH_3$	TWA 85ppm C 440ppm (15-Minutes)	TWA 500ppm (2000 $mg/m^3$ )	1ppm = 4.10 $mg/m^3$
17.	Hexane	$CH_2(CH_2)_4CH_3$	TWA 50ppm (180 $mg/m^3$ )	TWA 500ppm (1800 $mg/m^3$ )	1ppm = 3.53 $mg/m^3$
18.	Pentane	$CH_2(CH_2)_3CH_3$	TWA 120ppm (350 $mg/m^3$ ) C 610ppm (1800 $mg/m^3$ ) (15-Minutes)	TWA 1000ppm (2850 $mg/m^3$ )	-
19.	Carbon black	C	TWA 3.5 $mg/m^3$ (Carbon black in presence of polycyclic aromatic hydrocarbons)	TWA 3.5 $mg/m^3$	-
20.	Zinc Oxide	ZnO	Dust: TWA 5 $mg/m^3$ C15 $mg/m^3$ Fume: TWA 5 $mg/m^3$ ST 10 $mg/m^3$	TWA 5 $mg/m^3$ (fume) TWA 15 $mg/m^3$ (total dust) TWA 5 $mg/m^3$ (resp. dust)	-
21.	Zinc Stearate	$Zn(C_{18}H_{35}O_2)_2$	TWA 10 $mg/m^3$ (total) TWA 6 $mg/m^3$ (resp.)	TWA 15 $mg/m^3$ (total dust) TWA 6 $mg/m^3$ (resp. dust)	-
22.	Talc	$Mg_3Si_4O_{10}(OH)_2$	TWA 2 $mg/m^3$ (resp.)	TWA 20 mppcf	The PELs for Talc (not containing asbestos) are applicable if the material contains less than 1% Crystalline silica
23.	Lead Oxide	PbO	TWA (10-hr) 0.05 $mg/m^3$	TWA 0.50 $mg/m^3$	Air concentration should be maintained so that worker blood lead remains less than 0.60 $mg/100g$ of whole blood
24.	Calcium Oxide	$CaSiO_3$	TWA 10 $mg/m^3$ (total) TWA 5 $mg/m^3$ (resp.)	TWA 15 $mg/m^3$ (total dust) TWA 5 $mg/m^3$ (resp. dust)	-
25.	Magnesium Oxide	MgO		TWA 15 $mg/m^3$	-

Source : NIOSH Pocket

Note :  
REL : Recommended exposure Limit  
PEL : Permissible exposure Limit  
C : Ceiling Exposure Limit  
TWA : Time weighted average  
ST : Short term Exposure Limit  
mppcf : million particles per cubic foot



It is recommended to adopt permissible noise exposure levels of workers as per US OSHA and NIOSH as given in Table 8.3 and 8.4 respectively.

**Table 8.3 Permissible Noise Exposures (OSHA)**

Duration per Day (Hours)	Sound Level dB (A)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

**Table 8.4 Permissible Noise Exposures (NIOSH)**

Permitted Daily Duration (Hours)	Sound Level dB(A)
16.0	85
13.9	86
12.1	87
10.6	88
9.2	89
8.0	90
7.0	91
6.1	92
5.3	93
4.6	94
4.0	95
3.5	96
3.0	97
2.6	98
2.3	99
2.0	100
1.74	101
1.52	102

Source: NIOSH (1998)

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ANNEXURE

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ANNEXURE-I.1

Unit Process Operations In Rubber Products Manufacturing

No.	Products Category	Type of Products	Name of the Product(s)	Compounding			Extrusion	Calendering	Fabrication			Building	Moulding			Dipping	Finishing		Vulcanising/ Curing	Devulcanising	Solution Molding	Bonding Agent Application	
1.	A	Tyre Products Tyres & Tubes		Mastication	Mixing	Milling	Extrusion	Calendering	Fabrication	Cementing	Cutting	Dusting	Building	Metal Prep.	Moulding	Braiding	Dipping	Finishing	Gnding	Vulcanising/ Curing	Devulcanising	Solution Molding	Bonding Agent Application
		a) Automotive Tyres & Tubes	i) Automotive Tyres	◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆		◆	◆	◆	◆		
		b) Cycle Tyres & Tubes	ii) Cycle & Rickshaw Tyres	◆	◆	◆	◆	◆				◆	◆		◆			◆	◆	◆	◆		
			iii) ADV Tyres	◆	◆	◆	◆	◆		◆			◆		◆					◆	◆		
			iv) Tubes	◆	◆	◆	◆	◆							◆			◆	◆	◆	◆		
			v) Flaps	◆	◆	◆	◆	◆							◆			◆	◆	◆	◆		
		c) Retreads	i) Tread Rubber (Hot/Cold*)	◆	◆	◆	◆	◆							◆			◆	◆	◆	◆		

S. No.	Products Category	Type of Products	Name of the Product(s)	Compounding	Extrusion	Calendering	Fabrication	Building	Moulding	Dipping	Finishing	Vulcanising/Curing	Devulcanising	Solution Molding	Bonding Agent Application
				Mastication	Mixing				Metal Prep.		Finishing				
									Moulding						
2.	B	Non-Tyre Products Moulded Products	ii) Pre cured Patches for Tyres & Tubes iv) Retreading Cement & Solution. v) Cushion Gum Compound i) Automotive Parts ii) Rubber to Metal Bonded Parts iii) Industrial Rubber Products iv) Ebonite Products v) Rings, Gaskets, Seals, Diaphragm	Mastication Mixing Milling	Extrusion	Calendering	Fabrication Cementing Cutting Dusting	Building	Moulding Metal Prep. Moulding Brading	Dipping	Finishing Grinding	Vulcanising/Curing	Devulcanising	Solution Molding	Bonding Agent Application



S. No.	Products Category	Type of Products	Name of the Product(s)	Compounding	Extrusion	Calendering	Fabrication	Building	Moulding	Dipping	Finishing	Vulcanising/ Curing	Devulcanising	Solution Molding	Bonding Agent Application
				Mastication		Calendering	Fabrication		Metal Prep.		Finishing				
				Mixing		Extrusion	Cementing		Moulding		Dipping	Grinding			
				Milling			Cutting		Braiding						
			iv) Adhesives & Tapes	◆			Dusting							◆	
			v) Foot Wear Products	◆											
			vii) Sports Products	◆											
			viii) Rubber Covered Rollers	◆											
	E	Latex Based Products		◆											
			i) Rubberized colt, Jute & Woolen Products											◆	
		a) Dipped Goods	ii) Surgical/ Industrial/Household Gloves, Condoms, Ballons, Nipples & Finger Stalls	◆											
		b) Latex Foam		◆											

S. No.	Products Category	Type of Products	Name of the Product(s)
2.	F	Reclaimed Rubber	c) Latex Threads
			<b>Mixtion</b>
		◆	<b>Mixing</b>
		◆	<b>Milling</b>
		◆	<b>Extrusion</b>
			<b>Calendering</b>
			<b>Fabrication</b>
			<b>Cementing</b>
		◆	<b>Cutting</b>
			<b>Dusting</b>
			<b>Building</b>
			<b>Metal Prep.</b>
			<b>Moulding</b>
			<b>Braiding</b>
			<b>Dipping</b>
			<b>Finishing</b>
		◆	<b>Grinding</b>
		◆	<b>Vulcanising/ Curing</b>
		◆	<b>Devulcanising</b>
			<b>Solution Molding</b>
			<b>Bonding Agent Application</b>

## ANNEXURE-6.1

**DATA SHEET SHOWING TSPM CONCENTRATION OF RUBBER PRODUCTS  
MANUFACTURING INDUSTRIES**

S.N	Industry ID	SPM (in $\mu\text{g}/\text{m}^3$ )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
1	AL01	134.32	125.00	419.75	150.00	295.80	218.27
2	AL02	147.84	221.76	962.20	NS	229.36	727.60
3	AL03	180.96	211.44	1678.60	NS	302.58	439.00
4	AL04	132.00	198.00	1012.50	820.50	511.25	NS
5	AL05	262.25	343.00	1850.00	540.00	NS	550.00
6	AM06	181.44	272.16	1080.10	949.48	846.24	NS
7	AM07	199.88	299.52	1048.80	NS	993.12	724.56
8	AM08	189.60	234.40	1336.48	856.23	764.47	NS
9	BM01	132.00	165.60	948.50	455.24	NS	NS
10	BS02	201.60	316.80	805.00	780.60	NS	560.50
11	BS03	223.12	164.16	1046.24	953.25	NS	492.76
12	BS04	144.48	216.72	1541.80	NS	1288.95	NS
13	BT05	110.16	246.88	720.00	650.60	NS	NS
14	CM01	133.76	200.64	1317.30	1284.10	1117.04	1217.24
15	CM02	116.64	583.83	1648.74	1247.86	1020.06	NS
16	CM05	252.00	288.00	1262.00	NS	1033.45	602.00
17	CS06	123.12	184.68	450.00	360.00	310.00	NS
18	CS07	100.80	151.20	1244.00	200.00	NS	471.00
19	DL01	160.00	218.88	370.00	210.00	227.68	732.12
20	DM02	220.08	281.12	614.50	455.17	NS	395.17
21	DS03	305.33	327.00	910.67	278.80	114.80	NS
22	DS04	131.20	196.80	353.00	344.40	323.00	300.00
23	DS05	323.12	384.24	1461.78	923.18	NS	NS
24	EL01	256.00	184.00	NS	147.00	65.00	NS
25	EM02	187.36	231.04	NS	429.74	NS	336.00



S.N	Industry ID	SPM (in $\mu\text{g}/\text{m}^3$ )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
26	ES03	250.45	275.56	NS	332.42	300.38	NS
27	ES04	357.60	286.40	NS	251.20	NS	NS
28	ET06	170.00	174.88	NS	131.04	99.84	NS
29	ET07	157.60	186.40	NS	NS	215.20	296.00
30	FM01	131.68	286.33	4812.42	NS	1815.48	3514.80
31	FM02	296.96	445.44	3113.26	NS	706.20	1462.26

Note:

NS- Not Sampled

AQAU- Upwind Location

AQAD- Downwind Location

AQP1- Near Mixing/Milling Unit

AQP2- Near Moulding/Extrusion/Calendering Unit

AQP3- Near Vulcanization/Devulcanization Unit

AQP4- Near Fabricating/Grinding Unit

**DATA SHEET SHOWING RSPM CONCENTRATION OF RUBBER PRODUCTS  
MANUFACTURING INDUSTRIES**

SNo	Industry ID	RSPM (in $\mu\text{g}/\text{m}^3$ )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
1	AL01	94.02	68.75	272.84	72.00	121.28	98.22
2	AL02	94.62	124.19	625.43	NS	147.86	465.66
3	AL03	112.20	108.44	1258.95	NS	127.08	185.00
4	AL04	108.24	118.80	746.38	410.25	178.94	NS
5	AL05	113.73	232.25	944.00	246.00	NS	253.00
6	AM06	42.35	146.97	828.87	562.27	341.85	NS
7	AM07	143.77	179.71	659.14	NS	231.76	363.57
8	AM08	117.55	165.86	1029.09	556.55	298.14	NS
9	BM01	69.52	92.74	348.78	280.39	NS	NS
10	BS02	145.15	218.59	509.80	404.14	NS	152.23
11	BS03	109.78	95.21	452.83	537.16	NS	231.60
12	BS04	101.14	134.78	832.57	NS	657.36	NS
13	BT05	60.81	111.10	403.04	119.70	NS	NS
14	CM01	87.21	175.56	574.00	719.10	301.60	547.76
15	CM02	68.82	124.86	987.35	574.02	316.22	NS
16	CM05	86.64	209.00	807.68	NS	568.40	221.20
17	CS06	71.41	100.07	303.75	158.40	86.80	NS
18	CS07	53.42	113.40	733.96	172.00	NS	160.14
19	DL01	32.40	186.05	203.50	170.40	140.86	322.13
20	DM02	136.45	165.11	234.00	245.18	NS	102.07
21	DS03	128.24	145.80	611.14	167.28	28.70	NS
22	DS04	64.29	147.60	158.85	199.75	145.35	132.00
23	DS05	193.87	269.29	613.95	516.98	NS	NS

SNo	Industry ID	RSPM (in $\mu\text{g}/\text{m}^3$ )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
24	EL01	34.72	160.00	NS	65.00	49.10	NS
25	EM02	37.74	98.28	NS	240.65	NS	100.15
26	ES03	167.80	186.00	NS	149.59	105.13	NS
27	ES04	197.40	216.00	NS	128.00	NS	NS
28	ET06	32.55	139.86	NS	45.86	24.96	NS
29	ET07	113.47	128.00	NS	NS	114.06	63.00
30	FM01	113.31	159.93	1385.30	NS	1180.06	1378.70
31	FM02	184.12	423.17	1463.23	NS	227.40	334.08

Note:

NS- Not Sampled

AQAU- Upwind Location

AQAD- Downwind Location

AQP1- Near Mixing/Milling Unit

AQP2- Near Moulding/Extrusion/Calendering Unit

AQP3- Near Vulcanization/Devulcanization Unit

AQP4- Near Fabricating/Grinding Unit

**DATA SHEET SHOWING SO<sub>2</sub> CONCENTRATION OF RUBBER PRODUCTS  
MANUFACTURING INDUSTRIES**

SNo	Industry ID	SO <sub>2</sub> (In µg/m <sup>3</sup> )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
1	AL01	7.63	7.00	26.63	10.20	21.73	15.91
2	AL02	8.40	23.16	29.31	NS	23.92	17.51
3	AL03	10.28	13.93	23.40	NS	29.27	32.70
4	AL04	7.50	4.25	26.17	22.44	21.35	NS
5	AL05	9.20	19.13	32.12	27.54	NS	19.18
6	AM06	10.31	12.06	35.98	30.84	29.35	21.49
7	AM07	11.35	11.32	31.03	NS	32.30	23.65
8	AM08	5.09	5.40	NS	15.23	14.49	NS
9	BM01	8.00	6.58	16.42	14.08	NS	NS
10	BS02	4.50	13.93	13.56	6.46	NS	8.10
11	BS03	4.66	6.17	16.27	13.95	NS	15.40
12	BS04	8.21	11.27	28.65	NS	23.37	NS
13	BT05	4.17	4.31	6.30	21.40	NS	NS
14	CM01	7.60	15.24	46.10	22.74	21.64	15.84
15	CM02	6.63	11.60	20.50	19.83	18.87	NS
16	CM05	8.64	15.50	30.14	NS	24.59	58.40
17	CS06	7.00	19.26	42.00	35.00	32.00	NS
18	CS07	5.73	6.70	9.40	8.97	NS	8.00
19	DL01	30.00	22.08	80.00	10.00	23.60	17.28
20	DM02	6.82	17.55	48.40	20.41	NS	14.22
21	DS03	23.03	25.00	26.01	22.30	21.22	NS
22	DS04	7.45	13.80	44.00	22.30	63.00	21.00

SNo	Industry ID	SO <sub>2</sub> (In µg/m <sup>3</sup> )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
23	DS05	7.00	19.26	24.41	20.93	NS	NS
24	EL01	6.18	3.15	NS	9.52	13.46	NS
25	EM02	4.96	19.14	NS	14.85	NS	52.60
26	ES03	6.00	12.10	NS	8.57	8.15	NS
27	ES04	5.30	12.40	NS	9.79	NS	NS
28	ET06	4.20	8.08	NS	8.49	8.08	NS
29	ET07	5.30	12.40	NS	NS	9.32	54.50
30	FM01	18.00	10.90	13.43	NS	51.25	37.52
31	FM02	16.87	16.04	58.88	NS	60.40	35.17

Note:

NS- Not Sampled

AQAU- Upwind Location

AQAD- Downwind Location

AQP1- Near Mixing/Milling Unit

AQP2- Near Moulding/Extrusion/Calendering Unit

AQP3- Near Vulcanization/Devulcanization Unit

AQP4- Near Fabricating/Grinding Unit

**DATA SHEET SHOWING NO<sub>x</sub> CONCENTRATION OF RUBBER PRODUCTS  
MANUFACTURING INDUSTRIES**

SNo	Industry ID	NO <sub>x</sub> (In µg/m <sup>3</sup> )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
1	AL01	10.68	19.60	15.00	14.79	25.70	19.88
2	AL02	11.76	31.27	32.83	NS	24.99	20.13
3	AL03	14.39	16.02	33.93	NS	36.59	44.26
4	AL04	10.50	16.38	32.72	32.54	21.80	NS
5	AL05	12.89	22.00	36.94	37.18	NS	29.74
6	AM06	14.43	15.08	48.57	44.72	30.82	22.56
7	AM07	15.88	19.58	36.00	NS	32.95	29.56
8	AM08	9.13	17.29	23.98	22.09	18.05	NS
9	BM01	16.59	24.00	23.81	17.60	NS	NS
10	BS02	9.44	18.81	16.00	11.31	NS	NS
11	BS03	9.53	9.26	21.97	20.23	NS	11.80
12	BS04	11.49	18.93	35.81	NS	30.85	25.66
13	BT05	9.84	16.25	13.47	32.10	NS	NS
14	CM01	10.64	22.86	34.20	32.97	27.05	19.80
15	CM02	9.28	13.40	31.90	24.79	25.47	NS
16	CM05	12.09	25.58	40.69	NS	27.54	62.30
17	CS06	9.79	29.85	28.00	19.00	23.00	NS
18	CS07	10.02	11.39	11.56	11.89	NS	12.77
19	DL01	11.61	40.00	40.00	33.00	28.33	21.60
20	DM02	9.55	25.45	52.10	23.27	NS	17.21
21	DS03	45.51	48.00	28.82	30.11	26.53	NS
22	DS04	10.44	20.01	51.00	34.57	43.00	30.00

SNo	Industry ID	NO <sub>x</sub> (in µg/m <sup>3</sup> )					
		AQAU	AQAD	AQP1	AQP2	AQP3	AQP4
23	DS05	9.79	24.65	27.83	28.05	NS	NS
24	EL01	10.10	14.20	NS	10.00	15.48	NS
25	EM02	16.95	22.97	NS	18.56	NS	58.40
26	ES03	9.01	12.36	NS	10.71	11.82	NS
27	ES04	14.58	22.32	NS	12.04	NS	NS
28	ET06	9.50	11.31	NS	11.10	9.50	NS
29	ET07	14.58	21.08	NS	NS	12.10	62.10
30	FM01	25.20	27.44	23.56	NS	63.55	46.89
31	FM02	23.62	25.66	67.71	NS	68.10	43.96

Note:

NS- Not Sampled

AQAU- Upwind Location

AQAD- Downwind Location

AQP1- Near Mixing/Milling Unit

AQP2- Near Moulding/Extrusion/Calendering Unit

AQP3- Near Vulcanization/Devulcanization Unit

AQP4- Near Fabricating/Grinding Unit