FOREWORD

Tea Processing is a crucial industrial activity in India. This is so because the country is one of the major producer, consumer and exporter of tea. The environmental status of the sector had however not been studied in past. The Central Pollution Control Board therefore undertook a study covering the environmental issues involved in Tea Processing and formulation of standards for the discharges/emissions therefrom.

The present Report covers, national and international scenario of Tea Processing, brief description of activities and the associated environmental issues, details of the study conducted and its findings, and the proposed discharge/emission standards as formulated on the basis of these findings.

The able execution of the project by The Environmental Engineers Consortium, Calcutta, is gratefully acknowledged.

We hope that the document would be useful to the those concerned directly or indirectly with the Tea Processing activities in India and abroad.

(J.M. MAUSKAR)

May 22, 2007

Comprehensive Industry Document
on
Tea Processing Industry

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1.0 Introduction

Tea processing is an agro based non conventional industrial sector with activities concentrated mostly in hilly areas. The environmental status of the sector has not been compiled so far even though it is already recognized as an industrial activity by the Government. The Central Pollution Control Board has therefore undertaken a project for preparation of "Comprehensive Industry Document on Tea Processing Industry". The report covers the national and international scenario of tea processing industry, and its categorization, process details, environment aspects related to wastewater, air pollution and solid waste management along with the proposed environmental standards.

2.0 Tea Processing Industry – National And International Scenario

2.1 National Scenario

One of the important agro-industrial crop, which supports Indian economy largely, is tea. Tea is indigenous to India and is an area where the country can obviously take a lot of pride. Not only because tea is a major player in the earning of foreign exchange but also contribute substantially to the country's GNP. The technology of tea cultivation and processing has been developed within the industry aided by applied research which was largely funded by the tea companies themselves. This has helped to grow tea industry as a technically competent entity and also allowed the generation of more academic and fundamental investigations which might bring future rewards. Now, when global market has opened, all commodities are facing stiff competitions tea is not an exception. In fact, one of the major reason for the refusal of Indian tea by the consumer world wide is the cost of production and marketing.

Tea gardens and tea industries are largely scattered covering a major part of India. The crop is grown in the certain districts located in Assam, West Bengal, Kerala, Karnataka and Tamil Nadu and to some extent in Tripura, Uttar Pradesh and Himachal Pradesh. Relevant details of the tea growing areas in India are presented in Table-2.1. The total area under tea in our country is about 5,07,000 hectares (ha) and over 840 million kg of product is obtained annually. Certain details like number of tea estates, area under tea cultivation and extension, replacement and replanting area relating to different tea growing areas in the country are presented in Table-2.2, 2.3 and 2.4 respectively. Total production and state wise production of tea in India are presented in Table-2.5 and Table-2.6 respectively. Average yield (in kg/hectares) and category wise (orthodox, CTC and green tea) tea production are presented in Table-2.7 & 2.8 respectively.

Table - 2.1
Tea Growing Areas in India

Region	Site	State	Distribution
N-E India	Darjeeling Dooars Surma Valley Tripura	West Bengal West Bengal Assam Tripura	Darjeeling District Jalpaiguri, Coochbehar Cachhar Agartala, Dharmapur, Badamura, Maheshpur
	Brahamaputra Valley	Assam	Lakhimpur, Kamrut Darrang, Shivsagar, Nagaon, Tejpur, Goalpara
	Chhoto Nagpur	Bihar	Ranchi, Hazaribag, Purnea
North India	Tarai	Uttar Pradesh & Himachal Pradesh	Narendra Nagar, Garwal, Almora, Dehradun, Nahar Solan, Mandi
South West India	Nilgiri, Annamalai and adjacent highland	Kerala, Karnataka, Tamil Nadu	Nilgiri, Cochin, Coimbatore, Madurai, Tirunelveli, Nagar coil etc.

Table – 2.2
Number of Tea Estates in India

States	**Y E A R**									
	1961	**1971**	**1981**	**1986**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Assam	744	750	777	844	851	850	1012	1196	2472	2472
West Bengal	301	298	305	322	347	347	348	343	453	453
Tripura	55	53	57	58	57	57	57	57	60	60
Bihar	3	3	3	4	1	1	1	17	17	17
Uttar Pradesh	33	30	31	31	8	8	8	11	11	11
Himachal Pradesh	1285	1385	1385	1660	1660	1660	1660	3679	3679	3679
Manipur	-	-	1	2	4	4	5	5	5	5
Sikkim	-	-	1	1	1	1	1	1	1	1
Arunachal Pradesh	-	-	1	3	14	14	22	21	37	37
Nagaland	-	-	1	1	5	5	8	8	9	9
Orissa	-	-	1	1	1	1	2	2	2	2
Tamilnadu	4989	6450	6725	6798	6830	6845	25807	25811	25797	25796
Kerala	1976	3032	4109	4080	4105	4106	6131	6131	6126	6126
Karnataka	13	16	15	16	34	37	37	37	36	36
Total All India	9399	12017	13412	13821	13918	13938	35099	37319	38705	38704

Table – 2.3

Area (in Hectares) Under Tea Cultivation in India

States	YEAR									
	1986	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Assam	222618	233648	231942	227120	226280	228205	229843	251625	257735	267392
West Bengal	99129	100971	100489	99967	101190	102650	103008	105624	108754	109690
Tripura	6453	6058	5991	5938	5952	6064	6235	6355	6482	6623
Bihar	444	22	25	76	76	76	76	762	1348	1350
Uttar Pradesh	1804	892	848	914	1068	1068	1068	1068	1068	1068
Himachal Pradesh	2063	2063	2063	2063	2312	2325	2325	2325	2325	2325
Manipur	104	154	180	343	347	347	347	536	746	907
Sikkim	233	170	163	172	172	172	172	202	296	296
Arunachal Pradesh	5	687	687	1151	1361	1818	1818	1953	2179	2176
Nagaland	8	187	187	237	256	415	472	472	1012	1214
Meghalaya	-	-	-	-	-	-	-	145	215	351
Mizoram	-	-	-	-	-	-	-	350	360	391
Orissa	100	14	214	219	219	219	218	214	214	214
Tamilnadu	38041	38673	38831	48854	48958	48984	49671	63543	69155	74331
Kerala	34736	34525	34683	36817	36775	36762	36817	36748	36752	36762
Karnataka	1909	2015	2060	2095	2099	2099	2104	2105	2106	2106
Total All India	407647	420289	418363	425966	427065	431245	434294	474027	490747	507196

Table – 2.4

Extensions, Replacement & Replanting Area (in Hectares) in India

Year	North India			South India			All India		
	Extensions	**Replacements**	**Replant-ings**	**Extensions**	**Replacements**	**Replan-tings**	**Extensions**	**Replacements**	**Replant-ings**
1992	2179.74	462.08	1199.95	212.97	56.54	82.20	2392.71	518.62	1282.15
1993	2124.77	397.23	1300.74	337.76	53.24	37.91	2462.53	450.47	1338.65
1994	2160.56	400.74	1314.35	1342.77	63.81	10.05	3503.33	464.55	1324.40
1995	1465.52	235.46	1243.98	176.74	-	36.49	1642.26	235.46	1280.47
1996	4799.30	1362.36	1762.57	80.33	47.30	13.39	4879.63	1409.66	1775.96
1997	1920.00	945.00	1419.00	719.45	61.57	2.17	2639.45	1006.57	1421.17
1998	3893.57	1096.96	1490.53	125.80	12.25	5.36	4019.37	1109.21	1495.89

Table – 2.5

Total Production of Tea (in thousand Kg) in India

Year	North India	South India	All India
1995	568628	187385	756013
1996	597228	181999	779227
1997	604967	205646	810613
1998	670658	203450	874108
1999	623097	201311	824408
2000	641961	204522	846483

Table – 2.6

Statewise Production of Tea (in thousand Kg) in India

States	YEAR									
	1986	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Assam	335492	412010	410430	400732	402617	423965	425115	467046	432925	451236
West Bengal	141270	150690	162669	158825	157522	164768	170158	193789	180212	180724
Tripura	3427	5484	5927	5827	5679	5474	6435	6199	6385	6431
Bihar	17	100	116	136	130	127	135	138	473	538
Uttar Pradesh	407	471	379	338	341	345	350	359	309	264
Himachal Pradesh	636	1192	1303	1314	1359	1423	1442	1701	1222	1247
Manipur	50	32	42	60	74	21	27	76	97	96
Sikkim	50	97	84	96	102	67	105	112	102	105
Arunachal Pradesh	-	308	522	569	704	853	875	965	1063	993
Nagaland	-	7	7	12	17	69	31	29	39	43
Meghalaya	-	-	-	-	-	-	-	127	135	140
Mizoram	-	-	-	-	-	-	-	23	35	39
Orissa	-	33	55	46	83	116	24	94	100	105
Tamilnadu	86742	103066	112832	117520	117915	115840	130761	132046	128088	129699
Kerala	48616	54627	62003	63127	64778	61581	69776	65943	67796	69355
Karnataka	4146	4205	4457	4293	4692	4578	5379	5461	5427	5468
TotalAll India	620853	732322	760826	752895	756013	779227	810613	874108	824408	846483

Table – 2.7
Average Yield of Tea (in Kg/hectares) in India

States	YEAR								
	1986	**1992**	**1993**	**1994**	**1995**	**1996**	**1998**	**1999**	**2000**
Assam	1507	1763	1770	1764	1779	1858	1856	1680	1688
West Bengal	1426	1492	1619	1589	1557	1605	1835	1657	1648
Tripura	531	905	989	981	954	1068	975	985	971
Bihar	38	4545	4620	1790	1711	1671	181	351	399
Uttar Pradesh	225	528	447	370	319	323	327	289	247
Himachal Pradesh	308	578	632	637	588	612	736	526	536
Manipur	-	208	233	175	213	193	142	130	106
Sikkim	281	571	515	558	593	674	554	345	355
Arunachal Pradesh	-	448	760	494	519	469	494	488	456
Nagaland	-	37	37	51	66	46	61	39	35
Meghalaya	-	-	-	-	-	-	876	628	399
Mizoram	-	-	-	-	-	-	66	97	100
Orissa	-	154	257	210	379	315	439	467	491
Tamilnadu	2282	2665	2906	2406	2408	2365	2078	1852	1745
Kerala	1399	1582	1788	1715	1761	1675	1794	1845	1887
Karnataka	2172	2087	2164	2049	2235	2181	2594	2577	2596
TotalAll India	1523	1742	1819	1768	1770	1809	1844	1680	1669

Table – 2.8
Category wise tea production in India (in M. Kg)

Year	North India			South India			All India		
	CTC	**Ortho**	**Others**	**CTC**	**Ortho**	**Others**	**CTC**	**Ortho**	**Others**
1961	117.6	125.2	29.3	3.3	76.2	1.6	120.9	201.4	30.9
1971	210.2	103.5	18.6	28.9	71.4	2.0	139.1	174.9	21.4
1981	298.7	131.5	7.0	58.2	63.8	0.6	356.9	195.3	7.6
1989	400.9	121.3	7.4	99.6	56.4	2.5	500.5	177.7	9.9
1990	447.1	92.0	6.0	128.1	44.9	2.2	575.2	136.9	8.2
1991	461.9	93.4	7.6	141.7	47.4	2.2	603.6	140.8	9.8
1992	485.1	78.3	7.0	125.6	33.9	2.4	610.7	112.2	9.4
1993	507.0	68.7	5.8	139.3	38.5	1.5	646.3	107.2	7.3
1994	498.8	61.9	7.3	137.0	47.4	0.5	635.8	109.3	7.8
1995	520.7	40.5	7.4	141.7	45.2	0.5	662.4	85.7	7.9
1996	542.8	47.6	7.8	138.1	43.4	0.5	680.9	91.0	8.3
1997	549.5	47.2	8.0	150.6	54.2	0.5	700.1	101.4	8.5
1998	594.1	69.8	6.8	144.1	58.8	0.5	738.2	128.6	7.3
1999	575.7	41.1	6.3	169.5	29.9	1.9	745.2	71.0	8.2
2000	590.9	45.0	6.0	167.7	35.0	1.8	758.6	80.0	7.8

Estimates of (internal) consumption of tea in India are presented in Table-2.9. Tea Estates in India categorised on size basis for the year 1997 is presented in Table- 2.10.

Table – 2.9

Estimates of (internal) Consumption of tea in India
(Quantity in million kg.)

Year	Internal Consumption
1971	221
1972	233
1973	244
1974	258
1975	272
1976	287
1977	302
1978	320
1979	332
1980	346
1981	360
1982	372
1983	386
1984	400
1985	415
1986	431
1987	446
1988	462
1989	480
1990	500
1991	520
1992	540
1993	560
1994	580
1995	595
1996	618
1997	633
2000	653
2001	673

Table – 2.10

Sizewise Categorisation of Tea Estates in India for 1997

State-wise	Upto 8.09 Hect.			Above 8.09 & Upto 100 Hect.			Above 100 & Upto 400 Hect.			Above 400 Hect.		
	No. of Estates	Area in Hect.	Pdn. in thousand Kg	No. of Estates	Area in Hect.	Pdn. in thousand Kg	No. of Estates	Area in Hect.	Pdn. in thousand Kg	No. of Estates	Area in Hect.	Pdn. in thousand Kg
Assam	1697	1936	5714	114	10520	16677	322	72385	128426	239	145002	274298
West Bengal	157	1305	3313	31	1669	2877	152	35316	46796	113	64718	11772
Tripura	6	39	5	27	1381	1564	26	4325	4155	1	490	711
Bihar	16	51	20	1	25	115	-	-	-	-	-	
Uttar Pradesh	2	13	-	5	136	45	4	919	305	-	-	-
Himachal Pradesh	3679	3225	1442	-	-	-	-	-	-	-	-	-
Manipur	1	5	-	3	133	-	1	209	27	-	-	-
Sikkim	-	-	-	-	-	-	1	172	105	-	-	-
Arunachal Pradesh	4	14	3	27	790	434	6	1014	438	-	-	-
Nagaland	2	9	-	6	194	17	2	319	14	-	-	-
Orissa	1	5	-	-	-	-	1	213	24	-	-	-
Tamil nadu	25526	17067	49667	177	4393	5753	77	19639	53082	16	8572	20506
Kerala	5965	4740	2161	64	2195	1747	76	18415	36831	21	11466	29037
Karnataka	14	61	-	14	317	549	8	1726	4800	-	-	-
Total All India	37070	28470	62325	469	21753	29778	676	154652	275003	390	230248	336324

2.2 International Scenario

The available data namely (i) area under tea cultivation, (ii) production of tea and (iii) average yield of tea (in kg/ha) relating to different tea growing areas of the world are presented in Table-2.11, 2.12 and 2.13 respectively.

Table-2.11
Area Under Tea in Different Countries
(Area in hectares)

Country	1986	1990	1992	1994	1995	1996	1997
India	407647	416269	420289	425966	427065	431245	NA
Bangladesh	46703	47650	47781	47847	48036	47889	NA
Sri Lanka	222905	221758	221836	NA	NA	NA	NA
Indonesia	124093	134934	138736	128503	NA	514185	NA
China	1023933	1061864	1084200	1134600	1115300	1103000	NA
Japan	60200	58500	56700	54500	53700	52700	NA
Turkey	83470	90575	89345	76971	76609	76743	NA
Vietnam	58100	59900	60000	64000	71000	64000	NA
Kenya	84400	97020	101845	110222	112556	117457	NA
Malawi	18790	18204	18587	18801	18963	18986	NA
Tanzania	18875	18875	19415	19881	20153	20564	NA
Uganda	20905	20905	20500	20500	20500	20500	NA
Argentina	42350	41276	41406	NA	40000	39000	NA
USSR/cls	81400	NA	NA	NA	NA	NA	NA

NA : Not Available

Table-2.12
Production of Tea in Different Countries
(Quantity in Thousand Kg)

Country	1986	1990	1992	1994	1995	1996	1997
India	620853	720338	732322	752895	756013	779227	810613
Bangladesh	37593	45894	48931	51655	145422	53406	53495
Sri Lanka	212705	234074	178870	243563	246424	258969	277428
Indonesia	-	-	-	-	-	166256	153619
China	460468	540100	559827	588468	588423	593386	613366
Japan	93601	89903	92103	86303	84804	88709	91211
Turkey	143849	126768	156269	134350	104680	114540	139523
Vietnam	301000	32200	34000	36000	40000	40000	42000
Kenya	143317	197008	188072	209422	244552	257162	220722
Malawi	38976	39059	28136	35140	34526	38312	43930
Tanzania	15079	18414	18365	23764	23705	19768	22475
Uganda	3335	6704	9432	3000	12692	17418	21075
Argentina	40920	43000	44000	42000	32000	43000	55000
USSR/cls.	146600	131000	55000	18000	10000	8000	16000

Table-2.13
Average Yield of Tea per hectare in Principal Producing Countries
(Yield in kg per hectare)

Country	**1986**	**1990**	**1992**	**1994**	**1995**	**1996**	**1997**
India	1523	1780	1742	1768	1770	1809	NA
Bangladesh	805	963	1024	1079	992	1115	NA
Sri Lanka	954	1056	806	NA	NA	NA	NA
Indonesia	1043	1076	1050	1010	NA	1078	NA
Japan	1597	1537	1624	1584	1579	1683	NA
Turkey	1723	1448	1749	1745	1366	1493	NA
Kenya	1846	2031	1847	1900	2172	2189	NA
Argentina	966	NA	NA	NA	800	1103	NA
USSR/cls.	1801	NA	NA	NA	NA	NA	NA

2.3 Export Trade

India is one of the major exporters of black tea. Productions of black tea during 1995 & 1996 in the major tea growing countries are presented in Table- 2.14. The table also indicates the quantum of tea exported by the countries during this period. The quantum of tea exported by India during 1991 to 1997 and the value of such exports are presented in Table- 2.15.

Table-2.14
World Production and Export
(Figures in M. Kg)

Countries	Production		Export	
	1996	**1995**	**1996**	**1995**
India	780	756	162	164
Sri Lanka	258	246	234	235
Indonesia	166	145	102	79
Bangladesh	53	48	26	25
China	593	588	170	167
Kenya	257	245	244	237
Tanzania	20	24	18	21
Malawi	38	35	37	33
Argentina	43	32	41	41
Others	496	449	21	83
Total	2704	2566	1115	1084

Table-2.15
Exports of Tea From India

Calendar Year	Quantity (M. Kg)	Value (Rs./Crs.)	Unit Price (Rs./Kg.)	**Financial Year**	Quantity (M. Kg)	Value (Rs./Crs.)	Unit Price (Rs./Kg.)
1991	202.92	1134.55	55.91	**1991-92**	216.45	1212.27	56.01
1992	174.96	995.33	56.89	**1992-93**	180.69	1058.70	58.56
1993	175.32	1161.26	66.24	**1993-94**	154.55	1062.04	68.72
1994	150.69	989.14	65.64	**1994-95**	152.16	986.41	64.83
1995	167.14	1190.81	71.24	**1995-96**	166.24	1218.43	73.29
1996	162.0	1206.20	75.44	**1996-97**	167.17	1256.82	75.18

3.0 Scope and Methodology of the project

3.1 Scope of the project

The scope of work includes the followings:

(i) Inventorization of the large, medium and small tea processing industries, their capacity & location.

(ii) Classification of the type of tea processing units based on different technologies & processes capacities.

(iii) Description of process, pollution control technologies, guidelines, and environmental standards followed in other countries, and

(iv) Crop patterns of tea cultivation – and its environmental impact on soil, ground water, nearby surface water bodies etc.

3.2 Methodology

Representative industries were selected from large, medium and small tea manufacturing industries based on different technologies, processes & capacity for in-depth studies. The aspects covered in the detailed studies are as follows:

- General description of manufacturing process with detailed flow diagram;
- Genesis of pollution & identification of pollutants in effluents, emissions and solid waste and their probable quantities
- Preparation of overall material, energy & water balance;
- Identification of sources of fugitive emissions;
- Identification of appropriate technologies for the control of (i) water pollution, (ii) air pollution and (iii) fugitive emissions;
- Guidelines for identification of waste disposal site;
- Identification of suitable clean technologies for tea manufacturing units under Indian conditions;
- Formulation of standards for wastewater discharge and air emissions in terms of concentration and quantum of pollutants on the basis of the findings and suggesting of the rationale for achieving the formulated standards.

4.0 Tea Plantation and related Aspects

4.1 Soil

Tea is grown in a wide range of soil types found in tropical, subtropical and temperate climate conditions. These soil types have developed from diverse parent rock material and under different climate conditions. In China, Indonesia, Sri Lanka, South India, Turkey and Georgia (USSR) tea is mostly grown on sedimentary soils derived from gneiss or granite. In north-east India, except in Darjeeling, tea is grown on flat alluvial lands which occupy the vast area of the Brahmaputra Valley in Assam. Peat (bheels) soils that have been drained are successfully used in Cachar to grow tea. But in Kyoto and Kanaya, the main areas of Japanese tea, the crop is grown on soil types derived from volcanic ash and in Taiwan, tea occupies a tract of tertiary rocks derived from a residual formation. However, all these soils have one common characteristic i.e. they grows best in acid soils. The characteristics of soil of the World are presented in Table-4.1 and Table-4.2 respectively.

Despite the diversity of soil types on which tea is grown, all the soils exist in high rainfall conditions, as this is the most important climatic factor for successful tea growing. These soils get formed under special type of weather (permanent moist conditions) combined with intensive leaching of the products of weathering. The degree of leaching and hence the character of the resulting soil depends not only on the rainfall but also on the temperature. Because of differences in temperature, soils formed in tropical climates are likely to have certain characters different from those formed in the sub-tropical or semi-tropical conditions. The tea areas in tropical climates experience minimal temperature variations as compared with those in sub-tropical climates.

Table-4.1
General Chemical Properties of some Tea Soils of the World

Country (Area)	Soil depth (cm)	PH (Soil water)	Organic matter (%)	Total N (%)	C/N ratio	Available P (ppm)	Exchangeable bases (meq/100 g)			Excha n. H (meq/ 100)	CEC (meq/ 100 g)
							K	Mg	Ca		
India (Assam)	0-30	4.73	1.66	0.10	10.05	15	0.96	0.35	0.78	-	5.83
Kenya (Kericho)	0-23	4.75	3.68	0.19	8.24	4	3.08	2.01	0.46	-	20.78
Malawi	0-23	4.15	2.66	0.14	11.46	14	0.69	-	-	-	-
Sri Lanka		4.0	5.40	0.33	9.63	24	0.36	-	1.125	-	-
Taiwan		4.4	1.38	0.08	10.00	1.0	0.15	0.07	0.41	18.50	-
South India	0-15	4.9	7.55	0.28	-	22	0.51	1.73	8.83	0.30	11.20
	15-90	4.7	2.18	-	-	4	0.45	1.40	4.24	1.05	10.40
	90-125	4.6	1.41	-	-	3	0.19	1.48	3.54	4.90	10.40

Table-4.2
Physical Properties of some Tea Soils of the World
(0-30 cm depth on average)

Parameters	A	B	C	D	E	F	G	H	I	J
Texture-Fractions (%)										
Coarse sand/gravel	16	-	32	21	20	34	24	21	2	-
Fine sand	34	7	18	20	19	33	39	32	4	14
Silt	27	33	28	25	36	22	29	10	11	34
Clay	17	11	5	20	25	10	6	37	82	52
Organic matter	6	33	3.4	5.2	-	-	-	4.2	8.5	2.3
Texture grade	SaL	SiL	SiL	SiL	SiL	SaL	SaL	SaL	C	CL
Particle density	-	-	2.0	2.13	-	-	-	2.61	2.6	2.71
Apparent density	-	-	1.03	1.07	-	-	-	1.23	0.85	1.39
Porosity (%)	-	-	54.3	51.6	-	-	-	53.0	73.0	48.7
Water holding capacity (%)	-	-	59.3	65.5	-	-	-	22.5	59.0	28.2

A : Bramaputrah Alluvium, Assam
B : Peat (bhee) soil, Cachar
C : Anamallais, South India
D : Nilgiris, South India
E : Central Province, Sri Lanka
F : Uva, Sri Lanka
G : Java, Indonesia
H : Usambaras, Tanzania
I : Kiambu, Kenya
J : Hsing-hua series, Taiwan
SaL : Sandy Loam
SiL : Silty Loam
CL : Clay Loam
C : Clay

4.2 Rainfall

The relationship between tea production and rainfall is well known. Tea grows well in areas having a precipitation of about 1,150 to 8,000 mm. The effect of rainfall is perhaps more manifested by its influence on moisture status of the soil and in inducing vegetative growth. Therefore, distribution of rainfall is as important as the total annual rainfall. It is difficult to say what exactly is the water requirement of tea in different phases of its growth and development. It is natural to expect that water requirement of tea would vary according to the prevailing environmental conditions, but it is reasonably assumed that tea on an average may transpire 900 mm per annum. Ideally, the crop water requirement should be such that it does not cause any stress in the plant system.

4.3 Humidity

Humidity is of importance in tea physiology primarily because of its influence in determining the loss of moisture by evapo-transpiration. High humidity reduces water loss, but low humidity increases it, and also increases water stress during rainless drought period. In relation to temperature, low humidity may be advantageous because by increasing transpiration rate it also reduces leaf temperature, though the effect will be more pronounced in unshaded conditions. In north-east India the humidity level generally remains high during the harvesting period and this is generally considered to be conducive to growth.

4.4 Air Temperature

Tea is grown in tropical to temperate conditions, under a regime of air temperature that varies between –8°C and 35°C; the suitable temperature for growth being the one common to the habitat of the plant, that is, where it grows. But photosynthetic rate of tea is at maximum between 30°C and 35°C, falls rapidly at 37°C, and between 39°C and 42°C there is virtually no net photosynthesis. There is also no uptake of carbon dioxide at about 42°C; respiration may continue up to about 48°C but the leaf is irrevocably damaged. Therefore, there has to be an optimum range of temperature for growth and productivity of tea.

In north-east India the air temperature remains above 30°C for long periods during harvesting season, and hence the need for shade to keep the temperature below a level where it cannot affect photosynthesis adversely. It is important that a high vapour-pressure deficiency is also associated with high temperatures; and it would be useful to partition the effects of these two components on plant growth.

4.5 Land Preparation

Environmental considerations discourage the replacement of rain forest by tea. However, it is worth recalling that a properly managed tea plantation causes only a temporary disturbance of many of the characteristics of the rain forest. Whilst tea cannot be rain forest as the plant species and associated fauna are different, the stream flows and evapo-transpiration revert to the same as the forest when the tea is mature.

Photograph – 4.1 : Like any other agricultural practices land preparation also is very important in tea cultivation. The instant picture depicts the land preparation & new plantation activity. One important observation - paddy fields are being converted to tea cultivation.

Clearance of any type of vegetation disturbs the soil and leaves it unprotected. Clearance and planting must be timed with the minimum of intervening delay. The mechanics of planting depend on the density of vegetation to be removed. Trees should be killed in advance of clearing to minimise the risk of root disease remaining alive to infect the tea. Trees should be ring barked or frilled; the trees need inspection at intervals because the bark tends to regrow across such cuts. Trees may take as long as three years to die. Chemicals used at one time to kill trees have been withdrawn for safety reasons.

Trees and other heavy material should be moved off the field. The accumulation of quantities of organic material in heaps must be avoided as it may raise the pH of the soil to an unacceptable level. Light material may be ploughed in, or burnt if well spread out. Large fires must be avoided as the ash will raise the pH of the soil. A low pH will be more tolerant of ash and vegetation than soil with pH close to the upper limit for tea.

4.6 Erosion Control And Drains

Drains should be put in as needed on flat land. These are particularly necessary on swampy ground and should be deep enough to allow for the settlement which often occurs when such land is drained. Roadway formations should be leveled with drains and culverts put in place.

4.7 Water Requirement

Theoretically, the water requirement of tea is the amount needed to balance the water lost by transpiration, which is a continuous process. Though rainfall is essential for growth & productivity of tea, it must be of the right quantum and intensity. The effect of rainfall is perhaps more manifested by its influence on moisture status of the soil. Normally a part of rainwater is lost by surface run off, percolation and evaporation, only a portion of the heavy & high intensity rain percolates to the root zone of tea to cause appreciate physiological effects.

Soil conditions also react with rainfall in more than one way. The ability of the soil to withstand long dry season without adverse effect depends on the quantity of rain water that the soil is capable of retaining and can make available to the plants. This depends, apart from the capacity of the soil to retain water, on the spread and depth of tea roots. On the other hand, excessive rainfall in shallow soil and depressions may cause localised waterlogging - the latter affects both root efficiency and photosynthesis. Heavy rainfall may also affect pollination. However, the adverse effects of either excess rainfall or lack of adequate rainfall can be compensated by drainage and irrigation respectively.

Normally in tea plantation water is supplied in the form of spray by water sprinkler. This measure controls the soil moisture and also allows coverage of large sectors from limited resources.

Drainage and irrigation are very closely linked with each other. A well-drained land will provide better conditions for tea roots to grow deeper and to proliferate well. A deep rooting system will thus be able to explore a much bigger volume of soil for water and nutrients and will be able to withstand drought better and longer.

On the other hand, in poorly drained lands the roots remain very shallow and tea starts showing symptoms of soil moisture stress much earlier. This also demands for more frequent irrigation for survival. To obtain optimum benefits of irrigation, it is therefore essential to provide adequate drainage in the area to be irrigated.

4.8 Soil Chemistry

4.8.1 Acidity

It is generally agreed that optimum range of soil pH for the tea plant is 5.0 to 5.6. Soil those above pH 5.6 require correcting with acid materials such as Aluminium sulphate, Sulphate of ammonia, elemental Sulphur. On the lower end of the scale tea grows in as low a pH as 4.0 or below. The main causes of soil acidity are Hydrogen and Aluminium ions. In an intensively leached soil in which tea grows best, cations (Ca^{2+}, Mg^{2+}, K^{+}) are replaced by H^{+} from the water molecule and can be washed off the mineral. This is the main source of acidity in tea soils. Aluminium ions also react with water, produce acidity. Nitrogenous fertilizers and decomposed organic matter in soils also supply Hydrogen ions cause acidity to soil. In case of soil pH less than 5.0, use of lime to bring the pH to about 5.0 is quite convenient.

4.8.2 Organic Matter

Different Organic Matters accumulate into the soil from plant & animal tissue through well decomposition, acts as the binding material joining soil particles to form a stable soil structure. Under natural condition it is the main source of plant nutrient. Tea soils vary in their OM contents ranging from less than 1% to over 30%. However, the tea plant once established and well maintained generates a lot of OM from leaf fall and prunings (10 - 20 tonnes biomas produced per hectare per year).

4.8.3 Water Logging

Water logging is a physical factor, which can render a soil to be unsuitable for tea. This is very important because it is known that tea roots will not grow when the soil or subsoil is water logged for a prolonged period. Thus, a soil which has poor drainage should be avoided.

4.8.4 Water Holding Capacity

The water-holding capacity of a given tea soil and its availability to plants is dependent on soil textural composition, their aggregation (structure) and the rooting depth of the tea plant. The coarser the texture (higher content of coarse material) the less the water-holding capacity. The less the water-holding capacity the shorter times such a soil will be able to supply water to the tea plant, especially in an extended period without rain or irrigation.

4.9 Fertilizer

Fertilisation is an important part of the normal intensive production of tea. Tea is normally grown as a long-term monoculture. Without applied fertilizer the supply of nutrients available in the soil will become exhausted leading to mineral deficiencies in the plants, severe reduction in yield and ultimately, to the death of plants and a degraded plantation.

Nutrients are removed from a field of tea in a number of ways. There is an irreversible loss in the crop. The net loss of nutrients in old leaves and prunings depend on the extent to which these items are retained in the field. Soil erosion, drainage of excess water containing nutrients in solution and decomposition to gases create further losses. Uncontrolled weeds also absorb substantial quantities of nutrients.

In addition to oxygen, hydrogen and carbon which are obtainable in air & water, tea plant requires fourteen (14) mineral nutrients for its ideal growth. These are Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Manganese (Mn), Zinc (Zn), Copper (Cu), Aluminium (Al), Iron (Fe), Boron (B), Molybdenum (Mo) and Chlorine (Cl). Of these essential nutrients mentioned above, the first nine are considered principal nutrients as they are required in relatively larger amounts. The details of plant nutrients is being presented below in Fig.: 4.1

Fig.:4.1

PLANT NUTRIENTS

MAJOR NUTRIENTS | MINOR NUTRIENTS

Primary Nutrients	**Secondary Nutrients**	**Micro Nutrients**	**Beneficial elements**
Carbon	Magnesium	Zinc	Aluminium
Hydrogen	Calcium	Manganese	Silicon
Oxygen	Sulphur	Boron	
Nitrogen		Iorn	
Phosphorus		Copper	
Potassium		Molybdenum	
		Chlorine	

4.9.1 Sources Of Plant Nutrients

Major Nutrients

Primary nutrients:

Carbon	-	Atmospheric Carbon-dioxide and soil organic matter
Hydrogen	-	Water
Oxygen	-	Air and water
Nitrogen	-	Organic matter and fertilizers
Phosphorus	-	Soil and fertilizers
Potassium	-	Soil and fertilizers

Secondary nutrients:

Calcium	-	Soil and liming
Magnesium	-	Soil, liming and Magnesium sulphate
Sulphur	-	Soil, Ammonium sulphate and Zinc sulphate

Micronutrients

Zinc	-	Through soil and Zinc sulphate foliar application
Aluminium, Manganese, Iron	-	Abundant in acid soil
Copper	-	Through blister blight sprays
Chlorine	-	Through Muriate of potash
Molybdenum, Boron, Silicon	-	Through soil

4.9.2 Functions Of Crop Nutrients

Primary nutrients :

Nitrogen (N)
Induces vegetative growth
Essential constituent of protein, chlorophyll, hormones, alkaloids and Vitamins
Governs the ultisation of Phosphorus and Potassium

Phosphorus (P) :
Stimulates root growth
Carrier of energy
Essential for synthesis of starch, protein and fat
Constituent of nucleic acids and enzymes
Related to cell division and development

Potassium (K) :
Essential for frame development
Regulates water metabolism in plants
Provides resistance against drought, frost, pests and diseases
Acts as an accelerator of enzyme action
Counteracts the ill-effects of excess Nitrogen

Secondary nutrients :

Calcium (Ca) :
Constituent of cell wall
Necessary for normal mitosis (cell division)
Essential to active growing points
Activator of enzymes

Magnesium (Mg) :
Constituent of chlorophyll
Imparts dark green colour to leaves
Helps in synthesis of carbohydrates, protein, fat and vitamins

Sulphur (S) :
Constituent of Sulphur bearing amino acids
Helps in stabilizing protein structure

4.9.3 Deficiency Symptoms Of Nutrients

Primary nutrients :
Nitrogen (N) :
Young flush shows a lighter than normal green colour-yellowing
Marked decline in crop

Phosphorus (P) :
Mature leaves loose their glossiness and appear dull
Stunted appearance of plants

Potassium (K) :
Marginal necrosis in mature leaves
Premature leaf fall leaving a crown of tender foliage
Development of thin and twiggy wood
Poor recovery after plucking and pruning

Secondary nutrients :
Magnesium :
Seen on mature leaves
Leaves appear bright yellow with a conspicuous inverted dark green "V" down the mid rib

Sulphur :
Chlorotic symptoms (yellowing) occur in younger and recently formed leaves – Tea yellows
Lateral extension of leaves is restricted leading to formation of narrow laves

Micronutrients :

Boron :
Terminal bud remains dormant and die early
Clusters of small shoots develop in the upper axils
Development of translucent oil spots on the lower surface of mature leaves
Formation of cork mound on the leaf stalk

The details of fertilizer use against respective minerals are presented in **Table-4.3**.

Table – 4.3
Nutrient Content in Commercial Fertiliser used in Tea

Fertiliser	**Nutrient Content**
Ammonium sulphate	20.6% N
Calcium Ammonium Nitrate	25.0% N
Urea	46.0% N
Rock phosphate	20-24% P2O5
Ammonium phosphate (16:20)	16% N and 20% P2O5
Ammonium phosphate (20:20)	20% N and 20% P2O5
Potassium chloride	58.0% K2O
Potassium sulphate	48% K2O
Magnesium sulphate	16% MgO
hepthahydrate	38% MgO
Magnesite (80% MgCO3)	21.6% Zn
Zinc sulphate hepthahydrate	

Organic Fertilizer

Organic manure is applied to tea as green manure or as one of many other organic materials. Organic materials limits the deterioration of the soil and improves soil fertility and structure. A bed of humus is formed which supports an active micro fauna which speeds decomposition converting nutrients to an available from. Erosion is reduced and the infiltration of water improved.

Green Manure

Manure from plants in the field :
The tea plants provide some green manure from leaf-fall. The leaves of shade also form green manure. Leguminous or other trees planted in lines as windbreaks are trimmed frequently in some areas; leguminous trees, planted as hedges separated by a few lines of young tea as temporary shelter, can provide up to 100 kg Nitrogen per hectare per annum within 25-30 tonnes organic matter. These close hedges have to be removed before the tea comes into production.

Removal of the prunings takes a large quantity of nutrients out of the plant soil system. This loss will not be replaced by normal fertilizer applications. If prunings are removed regularly the tea will develop nutrient deficiencies, yield will fall and the health of the plants will decline. Grice and Malenga reported that removal of prunings produced a 4% reduction in crop yield in the cycle after a down prune.

5.0 Tea Processing - Green Plant To Finished Product

In India, black (CTC and orthodox) is manufactured and used. Green leaf tea is also manufactured which is mainly exported. This document is mainly eccentric to black tea manufacturing.

5.1 Nursery

A good plant can be developed and grown only under a regime of good agro-management in the nursery, till it is transplanted to the field. Therefore, a nursery must not only to provide the most optimum conditions for growth of the plants but the chosen sites should also be convenient for the area to be planted to minimise any damage to the plants during transit, and indeed minimise transport cost. It should be reasonably leveled with no risk of waterlogging during heaviest of rains. The soil should be chemically suitable with a good structure. A deep top soil normally ensures a good depth of fertile soil in the bed. A useful nursery requires all weather access, shade, drained beds and water.

Sandy loam soil is the best for raising a nursery on orthodox beds though virgin soil will provide the best medium. Extreme soils at best are avoided. On heavy soils seedling growth is rather slow, though by adding sand or cattle manure, plant growth in these soils could be hastened within limits. Dark coloured top soil is normally rich in fertility but soil very poor in organic matter may do with a little dry cow dung or a fine compost blended in. A useful practice is to sieve the soil through No. 3 mesh to remove undesirable elements like old bits of roots. It is equally important that the soil is not drying out, turning muddy or is compressed as these might affect the growth of the plants. To facilitate growth, 500 gm of super-phosphate per cubic metre soil would be advantageous; other fertilisers may be incorporated if analysis shows a specific need. In any case, no soil should be used which has a high proportion of eelworms.

Current trend is to grow tube nurseries rather than bed nurseries as the management of plants is much easier when they are grown in tubes. Although size of the tube is a matter of convenience, an optimum size should ensure good growth. Six to eight weeks before their use the sleeves are filled ideally with good textured medium-loam soil which ensures that water does not accumulate within the sleeves. If more than half of the soil is fine silt the sleeve soil will have to have sand. The pH value of the soil should remain between 4.5 and 5.5. Extreme values outside this range should be adjusted with lime or aluminium sulphate.

For nursery plants, a low level of shade is essential but they should give a clearance of 25 cm above sleeve tops. Shade used in Assam and the Dooars consists of 1.30 x 1.30 m bamboo basket laid across the bed fences. Winter planting of nurseries can be started without shade, but a light mulch is needed to prevent drying out of the bed.

Eventually, a shade has to be provided not only to prevent desiccation of the soil but also to provide appropriate growth stimuli to the nursery plants as well. But more than shade per se, a proper regulation of shade is essential for the growth of the nursery plants. In general, as the nursery plants get themselves established shade, can be selectively reduced, and is finally removed when it interferes with the growth sequence of the plants. The latter is done when the nursery plants have produced four to five good leaves but prior to that the process has to be gradual to allow the growing nursery plants in getting accustomed and adjusted to intense sunlight. Shade is removed differentially first when there is a two leaf growth. This is done first on a cloudy day and finally the shade is removed when the plants have four to five leaves growth. At higher elevations, 1,400 m and above, a polythene tent (200 gauge) supported on bamboo strips and hoops 45 m above the bed would be useful.

Application of fertilisers will increase the rate of growth. When soil in the tube or bed is fertile, nitrogen alone will have a significant effect. Phosphate is also effective is most situations. A soluble NPK mixture for foliar application (10 kg urea plus 20 km ammonium phosphate plus 8 kg murate of potash) is applied from unfolding of two leaves till plants have eight leaves.

Weeds can be a problem when plants are small. At the very incipient stage weeds can be removed physically, though a some herbicide will effectively control the weeds for a longer duration. Applications of insecticides, acaricides and fungicides will depend on specific pest and disease situations.

Disbudding or tipping is useful for encouraging laterals, but this should be done cautiously to avoid any damage to growing plants. This is best done when plants are 30 to 35 cm high with step up.

5.2 Field Planting

From all accounts planting is a most crucial operation as it basically determines the development and productive level of tea throughout its economic life. Wrong planting of good planting materials is doubly unproductive as investment is lost both on account of producing the plants and in the failure to put them up for productivity. Therefore, care, planning and refinement of techniques are essential for long-term benefit.

The very fundamental to planting, apart from good planting materials, is that the planting hole should be of adequate size. The size of the hole partly depends on the consistency of the soil but a diameter of 45 cm and a depth of 75 cm is ideal; the hole could be dug in three phases - the first phase is dug to 15 cm involving cutting of top soil with a hoe and placing it separately; the second phase involves digging up to 30 cm which involves subsoil layer -the excavated portion is also maintained separately. In the third phase the balance 30 x 15 cm across is loosened with posthole auger or deep forking. The size of hole also depends on the consistency of the soil but in general a standard size of 45 x 75 cm ought to be maintained. When the holes are being dug the crumb structure of the soil is often damaged, but alternate wetting and drying of the puddle system corrects this. However, if the excavated holes are exposed for a long time without refilling, the excavated soil may be lost due to erosion. Therefore, the holes should be dug with sufficient time in hand to allow the soil to settle down. For closer spaced planting and heavy soils, an alternative to holing is trench planting. Trenches 30 cm wide and 45 cm deep are dug along rows either manually or mechanically. Trenches provide a lower volume of soil for root expansion.

The holes are refilled two or three weeks before planting with top soils mixed with dry old cattle manure (4 kg) or 5 kg well-composted organic matter mixed with 30 to 40 gm of superphosphate.

Since the initial growth of the plants is dependent on their food reserve rather than mineral nutrition of the soil, organic manures would be valuable. However, care must be taken to avoid having a layer of compost at the bottom of the pits as it may cause localised water logging and ensure that high concentration of mineralising organic matter does not produce a high level of pH.

5.3 Bringing up of young tea plants and Bush Formation

When a young plant is established in the field it is essential to train or modify it to form a low bush of good spread and of convenient height for plucking. The essence therefore is to establish a good frame and ensure a good coverage of ground within the shortest possible time. This is achievable either by de-centering and pruning, or by bending or pegging, or by a combination of de-centering and bending. The de-centering and pruning combination involves cutting off of the main stem at a height between 7 cm and 20 cm - the few laterals remaining on the stem are cut at 35 cm above ground level. This excision stimulates the plants to throw out more laterals from the lower portion of the stem, thus increasing the number of pruning sticks. The plants are next pruned within two years after the first prune for de-centering, and this is done about 5 cm above the last prune mark. This part of the operation, that is, de-centering, can be done as soon as the plants start producing new growth after transplanting, and in more vigorous plants this can be done even earlier than in weaker plants. In hilly areas, where plant growth rate is generally slow de-centering is done in spring or autumn after planting. A drawback of de-centering process is that it might cause high mortality unless the full vigour of the plants is assessed.

Photograph – 5.1 : In Dooars & Darjeeling rarely new plantation is grown from seed. Here Separate nursery is maintained to grow small plant through Transplanting clone. Picture depicts the activity.

The argument in favour of bending and pegging is that they do not cause heavy mortality during the operation, provide quick ground cover, apart from producing a substantial yield by the second year. For vigorous plants, pegging can be done two to three weeks after planting. Shoots that are 30 to 60 cm high are bent at angles 30° to 45° to the ground, and are then pegged down to the ground. All lateral shoots produced subsequent to the bending are also bent and pegged. But bending could be difficult with overgrown plants and is risky in un-shaded areas because of scorching risks.

Moreover, in contour planting, it is always desirable to have the `bends' along the contour, preferably turned towards west or south. The pegged main steam and the laterals are first pruned 30 to 40 cm from the ground within two to three years, and are then raised by 5 cm in each successive prune till the permanent frame height is reached. Three variants of pegging are practiced, at least in north-east India. First, bending with single pegs, which is a laborious process involving repeated pegging using single pegs either of bamboo, wood or bamboo. It is always difficult to keep the pegs in position as often they are removed by the growing pressure of the branches. In the ring pegging method after the initial bending of the plant by a single peg, or following a de-center, the laterals that emerge are allowed to spread out by putting a ring of bamboo strips 25 to 30 cm diameter in the middle. This ring is often kept in position by three to four pegs but the process is rather cumbersome. In `rail' pegging method, the laterals and re-growth are repeatedly bent pushing them beneath two rails of bamboo strips. Though easy to operate, the main drawbacks here are the difficulties in maintaining the desired angle.

Yet a third approach towards frame formation is to de-centre first and then go for pegging. This essentially involves de-centering of the main stem with the laterals being bent to the sides and pegged. Subsequently, pruning is done at 35 to 50 cm from the ground and then the frame is raised by 5 cm at each successive prune till a permanent frame is established. One advantage of this system is that it is easier to train the branches as less number of pegs are needed. On account of de-centering in the first year there could be an initial yield loss of about 18 percent, but the subsequent rise in crop well compensates the earlier losses.

As pointed out earlier, the main objective in rearing young tea is to divert apical dominance of the main stem and force the plants to develop well-spread lateral branches. To achieve this twain objective a "low tipping method" was advocated. This technique involves total avoidance of pruning in the first four years of planting, centering out within 10 weeks after planting and initial plucking at a low level of 40 to 50 cm from the ground, followed by a gradual rise or stepping up of the plucking table. The first pruning is considered only when the plants are above 85 cm high at the end of the fourth or fifth year with pruning height varying between 55 and 65 cm from the ground. This technique resulted in high yield in the early years but it failed to give a food frame so essential for long-term productivity of tea. Therefore, by giving a prune, rather than totally avoiding it in the early years, a good frame could be established. With the introduction of bending or pegging, good ground cover, ideal frame and early crop are possible to achieve. Whether pegging would be ideal with high plant populations, irrespective of the growth habits of different cultivars, is not clear.

Three other systems used in varying degrees are centering out, lung-pruning and de-budding. Centering out involves cutting out of the main stem at a height of 15 to 20 cm to force lateral growth from below the cut. This operation can be done six to eight weeks after planting or when the plants have produced a few flushes or leaves indicating that they have established themselves. Since the operation is rather drastic, it is most important that starch reserve of the plants is at its optimum. If, per chance, only a few leaves have developed, then it is better to avoid this system and go for either lung-pruning or de-budding.

Lung-pruning or thumb-pruning as it is popularly known, is a mechanical operation. When plants are between 15 and 20 cm high, they are held between the thumb, and the stem is half broken, making sure that one side is kept intact for movement of food and nutrient. The upper part of the stem is then bent towards the ground and the broken portion is removed only after the plant produces a flush of new growth. Unlike centering out operation, lung-pruning can be done even if starch content is not at its optimum. De-budding, as the name implies, consists of removal of the apical bud and all buds in leaf axils, 15 to 25 cm above the ground. This ensures that no laterals grow from the upper part of the plant and after laterals have grown from the lower portion, the stem is removed at 15 to 20 cm. De-budding is an extremely delicate operation and can even be done in the nursery in situations where growth of laterals is a problem.

It is difficult to generalise on the relative merits and demerits of different systems of raising young tea because the principal source of variation, that is, the growth characteristics of different cultivars have not been considered in most studies, despite marginal evidence that some tea varieties behave alike under a particular system of bush management. This needs thorough elaboration using cultivars of different genotypic origin. Nonetheless, by adopting one or other system, the growth rate of young tea can be enhanced ensuring early yield. On relative efficacies of the four principal methods -- low tipping and step up plucking; low tipping with frame forming prune and step up plucking; pegging and step up plucking; and pegging after de-centre with step up plucking, the general views are:

i) Low tipping produces good early crop but frame formation is poor, and frame formation prune 18 months after planting produce good frame with high yields from fifth year onwards.

ii) Pegging has an advantage in terms of crop increase only in the two initial years. Thereafter, this advantage is lost and the system's overall performance equals the combination of low tipping and frame formation pruning.

iii) De-centering before pegging causes an immediate crop loss but this is well-compensated later. This apart, pegging by itself may cause serious sun scorch which in some cases may even remain permanently on the frame.

5.4 Necessity of Pruning

Perhaps from a productive point of view no field operation is as important as pruning is, as it basically helps in maintaining the plant as low bush in a phase of continuous vegetative growth. Pruning therefore is considered as "at best a necessary evil" as it both stimulates and controls growth. The other principal objectives of pruning are :

i) Shaping the tree to make the best use of space between trees.

ii) Reestablishing the initial vigour of the shoot system to stimulate growth, and control undue rise in bush frame and plucking table, that is, control growth.

iii) Removing dead, diseased and overage wood, thus help rejuvenate bushes that have crossed the period of maximum productivity.

iv) Providing an environment within the plant which is conductive to maximum crop production but minimises the spread of pests and diseases.

v) Having the crop formed where it can be harvested easily and cheaply.

vi) Renewing the actively growing branches and maintaining sufficient volume of maintenance foliage to meet physiological needs of the plant.

vii) Maintaining quality in made tea.

It is generally accepted that bushes are best pruned during December to January and must not be rested earlier than October. Resting during a phase of slow growth is essential to create a favourable carbohydrate balance, but this principle does not hold good for all countries, that is, the timing of pruning varies depending on local growing conditions. The correct timing for pruning is decided basically from an assessment of the growth rate of the plants. It should be at a point when growth has sufficiently slowed down to create a favourable carbohydrate balance, so that, a layer of foliage could grow and get established well before the hot spell.

The other factors that influence pruning time are prevention from potential dangers of sun-scorch, drought or attacks from pests and diseases, apart from the more mundane considerations like the re-growth time desired and the crop planned. In summarising, pruning is a means for reducing the number of stalks on the bushes, so that, an optimum quality of wood is left for giving the best and most vigorous shoots the following year. The amount of wood left will again vary according to the growth characteristics and vigour of the cultivars but leaving 3 to 4 cm of wood may be useful under certain situations.

5.5 Cutting Types

5.5.1 Pruning

Collar Pruning : Collar pruning is the severest form of pruning, requiring as it does, cutting the bole of the bush near or at the ground level. In some cases, the cut may even be given slightly below the ground level to ensure protection of the exposed tissues against die-back. Recovery from this severe form of pruning is greatly influenced by carbohydrate reserve. By and large, collar pruning is suitable for tea that is characterised by a well marked dormancy period. The main objective is to provide a new fame to the plant by removing old and unproductive branches affected by diseases and pests, particularly in situations where uprooting of unproductive bushes is not possible. Tea recovering from collar pruning also needs special care and management.

In HEAVY PRUNING, which is a variant of collar pruning, the bole is cut at 15 to 45 cm above the ground for frame renewal. But this kind of hard pruning can only be done after serious consideration of plant health and carbohydrate reserve. A debilitated plant exposed to extreme forms of pruning may cause further depletion of food reserve without producing any compensatory maintenance foliage, and in the process the frame formation would suffer.

Medium Pruning : The main objective of medium pruning is to reduce height of the bushes, so that, they do not exceed 80 cm. Continuous picking of shoots on the top of a bush gradually increases the height of the bushes, apart from causing congestion on the top with weak and twiggy branches. This drain in the physiological resources which otherwise could have been utilised for increasing productivity.

Therefore, to bring back the plants to a productive level, stimulate new wood and renew maintenance foliage, medium pruning becomes a useful means. Though relatively less severe than collar or heavy pruning, medium pruning is generally not done below 50 cm, and certainly not lower than what is necessary to remove the knots and congested top.

As with collar pruning, a major determinant for medium pruning is to decide that the plants are ready to take this drastic treatment, that is, whether they have adequate carbohydrate reserves, and whether chances of scorching are minimal. In north-east India, this operation is ideally carried out during end December to end January, but before this operation is carried out, plants must be rested for six to eight weeks.

Top or Light Pruning : This is the standard method of recurring pruning in Assam and the Dooars. The main objective of this pruning is to renew the leaf bearing branches, apart from cleaning out the bush. Normally top pruning is done 2 to 3 cm above the last prune; in effect this system of pruning leaves a considerable amount of foliage on the plants though much of it defoliates naturally; but under certain conditions of growing this foliage may even remain infact and carry on normal physiological functions. The technique of light pruning therefore essentially involves a uniform cut-across followed by a cleaning out operation to remove thin unproductive branches and dormant shoots. Sometimes only a cut-across, that is, removal of top part of light pruned tea is practiced to invigorate growth without undue removal of foliage.

Lung Pruning : The essence of lung pruning is to prune selectively, so that, all leaves below the level plucking are left and the peripheral branches are not cut. These left out branches have turned lungs though in no way are they connected with respiration per se. This system of pruning ensures that sufficient amount of actively synthesising foliage is left on the bush so that a carbohydrate balance is maintained to enable optimal growth of the plants. The use of this system of pruning is rather restricted, and leaving a few (ideally tow) `breathers' at the time of medium pruning have generally been beneficial for stimulating growth.

5.5.2 Skiffing

Skiffing is the lightest form of pruning involving as it does removal of certain amount of growth above the previous pruning level. It essentially is the levelling of the foliage either by giving a cut in the green stem in the lighter forms of skiffing, or, into the red wood in harder forms of skiffing. The object of skiffing is not only to have an early start of crop production but also to achieve more of the high quality first flush and total crop as well. Skiffing helps in thickening the pruning wood and improving the general health of the bushes.

5.5.3 Tipping

Immediately after pruning, the plants enter into a phase of unrestricted growth and if this unrestricted growth is allowed, most of the shoots would mature as branches. To prevent this, the new growth has to be controlled, so that a uniform plucking table is formed. Tipping therefore is an operation aimed at forming a level and a flat plucking surface, and filling it by quick production of secondary branches.

5.6 Plucking Green Tea

Plucking or picking denotes harvesting of tea crop. Plucking of young shoots, the two leaves and buds, is an complex art consuming about 15 percent of the total cost of production of tea and much of the quantity and quality of harvested crop depends on the standard of plucking. It involves removal of young growing shoots comprising the apical bud, the internodes and two or three leaves below it, which together constitute the crop. The tender shoots removed are the sinks as they cannot support their normal growth. They are harvested at regular intervals to stimulate successions of a new crop of shoots. The growing shoots in turn are dependent on the assimilates from the mature foliage where they are produced, that is, the source. Consequently, an ideal plucking system must take cognizance of the intricate relationship between the sink and the source. In practical terms, the amount of maintenance foliage to be retained is of prime consideration in determining the system of plucking to be adopted as it is the maintenance foliage that provides the assimilates for the production of shoots.

Photograph - 5.2 : Basket carrying green tea leaves for further processing to black tea. System of transportation observed with small gardens. Eco-friendly transport system.

The growing bud exerts maximum pulling force for metabolites from the maintenance foliage; the relative sink capacity of a shoot of one leaf and a bud and two leaves and a bud being 75 and 35 percent, respectively. Therefore, indiscriminate removal of large buds and one leaf and a bud would adversely affect the health of bushes.

The initial growth of leaves following pruning occurs at the expense of carbohydrates formed during the previous growth and stored in roots and older wood. These new shoots develop from the dormant buds on the stubs that are left on the plant during pruning. As explained earlier, these crops of new shoots are the primaries and the two covers on the dormant buds are known as the scale leaves or cataphylls or janams. The emerging leaves are arranged in spirals around the stem in such a manner that the first five leaves form a series which encircle the stem twice, while the sixth leaf appears above the first of the previous series.

5.7 Plucking Standard

The standard of plucking is unequivocally important as more than anything else, it determines the quality potential of the processed leaf. It is generally accepted that fine plucking makes the best quality tea as this form of plucking consists picking of only tow leaves and a bud and plucking of these flushes is regarded as fine plucking. In a broader sense, fineness of plucking may also involve harvesting all one and a bud, two and a bud and single banjhis over the janam, apart from the fact that fine plucking also calls for plucking at short intervals usually at seven days intervals. If still shorter rounds of plucking are practiced to get leaves with attributes for high quality, then it may cause severe depletion of `sinks' on plucking surface as the shoot will not have opportunities for optimal growth so necessary before plucking. Consequently, over a period of time total yield may decline but quality of tea will certainly improve.

At the other extreme of fine plucking are the medium, coarse or very coarse plucking. These three systems of plucking greatly increase the quantity of harvested crop, but only at the cost of quality. Medium plucking, for example, involves harvesting of large shoots with two leaves and a bud, three leaves and a bud plus the single banjhis or dormant leaves. Coarse plucking involves removal of all shoots with two leaves and a bud, three leaves and a bud, four leaves and a bud and double banjhis. Very coarse plucking removes all shoots with three leaves and a bud and even shoots with four leaves and a bud. Coarse plucking can be done at 8 to 10 or even 12 days intervals, and because of the increase in the size of shoots, the weights of harvest also increase proportionately with the length of the shoots harvested. Indeed, a linear relationship, exists between the size of shoots with different combinations of leaves and a bud and their weights.

In terms of `sink' capacity of pluckable shoots, shoots with one leaf and a bud have the highest sink capacity (75 percent) - therefore, their indiscriminate removal along with larger buds may adversely affect the physiological balance causing a decline in the production of subsequent flushes. From this point of view at least standard plucking would appear to be ideal.

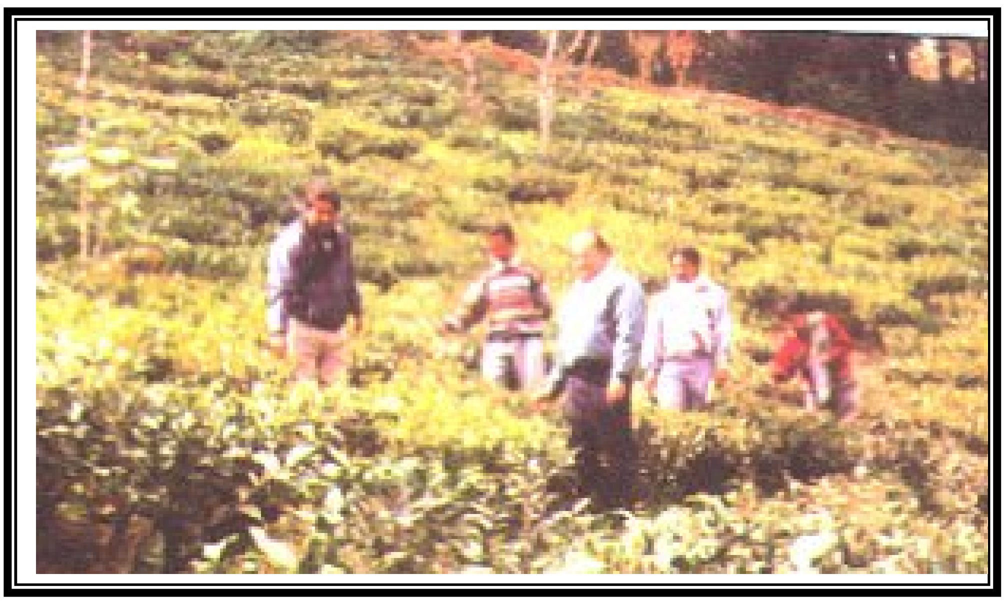
5.8 Plucking Interval

For efficient harvesting of shoots plucking interval is most crucial. The interval is ideally determined by the rate of a leaf unfolding. In north-east India, the general practise is to harvest shoots at 7 days intervals on the assumption that by this time the levels of various biochemical constituents necessary to make tea of quality would reach their optima. Any increase or decrease in plucking interval could significantly influence the dynamic metabolic system, even leading to alterations in leaf physiology. Therefore, plucking rounds at shorter intervals with fine plucking can reasonably assure a better quality of made tea than teas plucked at longer intervals. Thus, 5 days plucking rounds can give good quality of made tea because of a lower content of ash and fibre, though black teas made from 7 days pluckings would have a balance of VFC (volatile flavour constituents), ash, soluble solids and caffeine and therefore would have an optimum quality. Teas manufactured from 9 to 11 days pluckings are generally of low quality possibly because of a decrease in soluble solids, with a significant increase in crude fibre. It is equally important that theaflavin (TF) and thearubigin (TR) also vary with the maturity of leaves at 5 to 11 days plucking intervals.

Apart from quality, plucking interval also affects overall quantum of harvestable shoots. Generally, as the plucking interval or length is increased, there is a corresponding increase in yield of both light pruned and unpruned tea, but quality deteriorates. This happens because longer rounds increase the quantum of coarser leaf and banjhi leaves, and both have a negative effect on quality. This drawback notwithstanding, plucking interval is often extended to 8 to 10 days in early spring or later autumn, or shortened to 5 to 6 days, depending on the growth of shoots, or on purely mundane consideration like the requirements of quantity or quality of tea at a point of time. What therefore is an ideal plucking round is difficult to generalise, because as stated earlier, very many interacting phenomena are involved here. But where standard plucking is the practice, the shortest possible round could be 5 days during the monsoon (if growth is rapid), the longest being 7 days. With fine plucking the corresponding period should be 6 and 9 days respectively.

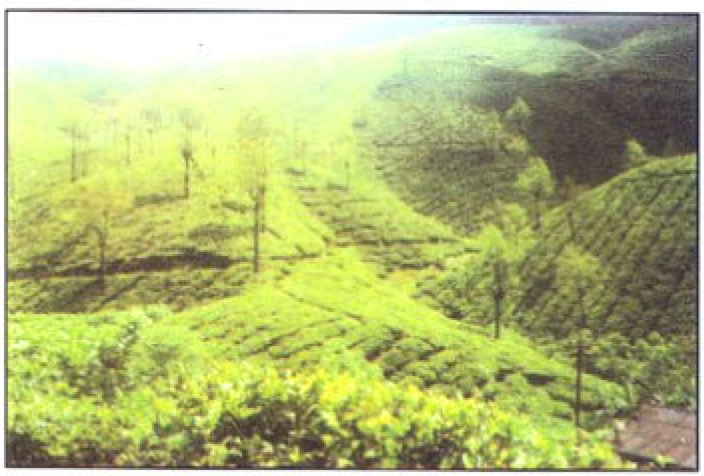
Photograph-5.3 : View of plantation in Darjeeling. Portion has already been plucked.

Photograph – 5.4 : Solid waste from tea garden after deep pruning. This solid waste acts as a fuel in rural area.



Photograph – 5.5 : Makai Bari Tea Gardens. Produces 100% bio-dynamic tea. No chemical/pesticides used here. 100% EUU.

Photograph 5.6 : Full grown tea plants in South India just before the time of plucking, with shade trees at intervals.



Photograph - 5.7: View of Plantation in South India covering a large area

Photograph 5.8: Female Workers busy in plucking green tea leaves in South India

Photograph - 5.9 : Interaction with Tea Garden Manager during in -depth study period in South India.

5.9 Black Tea Processing

5.9.1 Overall Steps

Black tea manufacturing technology involves disruption of the cellular integrity of tea shoots; in doing so, the mixing of substrates, polyphenols and the enzymes, polyphenols oxidase is facilitated. This results in the initiation of a series of biochemical and chemical reactions with the uptake of atmospheric oxygen and formation of pigmented hot water soluble polyphenolic compounds, characteristic of black tea.

Black tea processing consists of the following unit operations:

- Withering (partial removal of moisture)
- Rolling/disruption (size reduction)
- Oxidation/Fermentation (biochemical reactions in the presence of oxygen)
- Drying (completion of moisture removal)
- Sorting (fibre removal; grading based on size)

Of these, chemical changes occur primarily during withering, fermentation and drying.

5.9.2 Withering

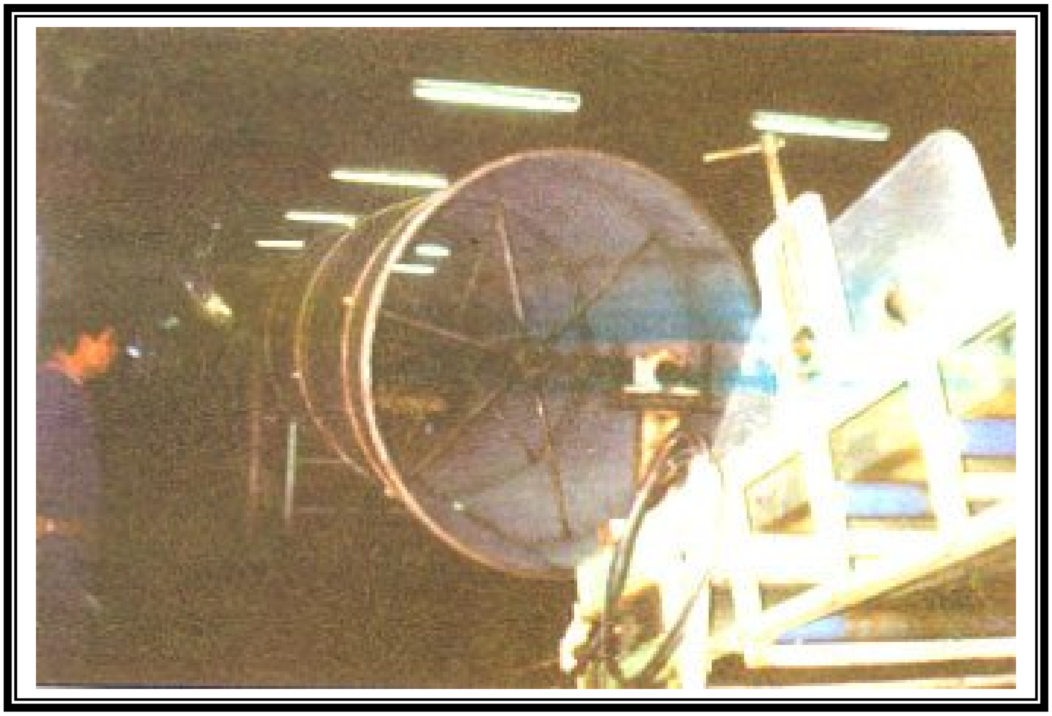
Withering is carried out to prepare the green tea shoots bio-chemically and physically for subsequent manufacturing operations. Withering essentially consists of storage of green shoots for about 12 to 20 hours with the partial removal of moisture (known as physical wither) from the leaf. Withering is accompanied by certain chemical changes (known as chemical wither) which may affect fermentation and thereby, the quality of the final product. Chemical wither is essentially a time-temperature dependent process. Some of these changes are dependent on moisture loss while others are independent.

The major physical change during withering is the increase in cell membrane permeability and consequently, the leaf becomes flaccid. The increased permeability of the membrane has a great effect on the mixing of substrates and enzymes during fermentation.

Withering is also accompanied by the activation of oxidative, hydrolytic and proteolytic enzymes, causing significant changes in the chemical composition of tea shoot, as a result the levels of soluble protein, free amino acids and simple sugars increase in the withered leaf. Amino acids increase due to the breakdown of proteins by the enzyme pepsidase. Amino acids are primarily the precursors of the aromatic compounds.

Caffeine content increases with withering. The increase in caffeine content is greater if the withering is accompanied by loss of moisture. Caffeine forms a complex with theaflavins thearubigins and “Creams” down from the liquor; this creaming down is a desirable cup character for black tea.

The Chemical wither also increases the level of organic acids and improves polyphenol oxidase (PPO) activity. The increase in organic acids will have an obvious effect of reducing pH and TF formation is increased as pH tends towards 5.0. The effect of increased PPO activity is beneficial for more TF formation provided oxygen availability is not limited during catechin oxidation. Volatile compounds essentially impart aroma to the finished product. Volatile compounds present in the tea are classified into two groups : Group-I compounds, which are deleterious to the tea quality and Group-II compounds, which impart sweet flowery aroma to tea and its presence is highly desirable. The ratio of Group-II compounds to Group-I compounds is known as the flavour index and it is a semi-quantitative method of describing the aroma quality of tea. Tea with higher values of flavour index normally have better aroma quality. Withering improves flavour index and thereby, sweet aroma.

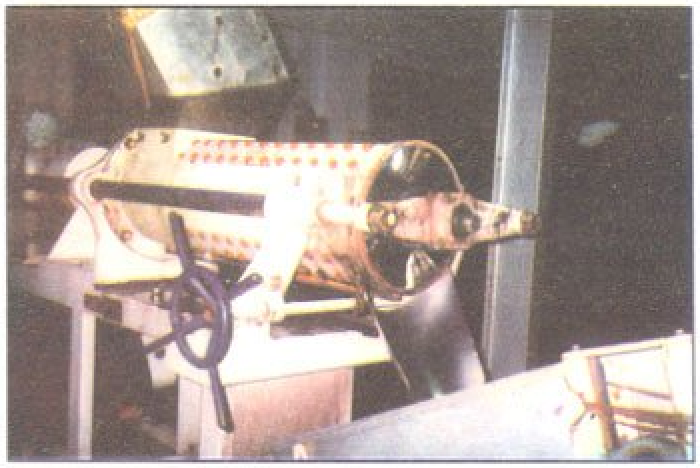


Photograph – 5.10: Weathering machine. Plucked green leaves are weathered properly to reduce moisture and to condition the plant for onward action.

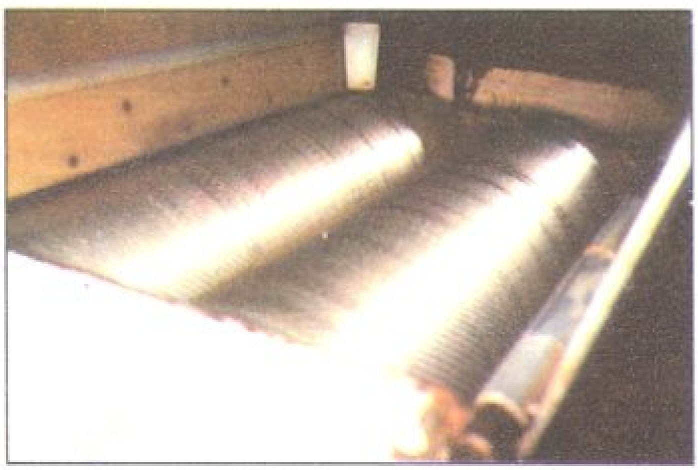
5.9.3 Leaf Disruption

This stage in processing is described in a number of ways, e.g. rolling, cutting, crushing, tearing, but the basic requirements are size reduction with a degree of cell disruption to allow the exposure of the new surfaces to air in the subsequent fermentation stage.

The LTP machine consists of a central rotor with a number of knives and beaters, where the leaf is bruised and cut by the rotating knives and beaters. The leaf next enter into the rolling section. The rolling is done either by orthodox rollers or by a combination of orthodox rolling and the CTC machines. The surface of each roller is made up of a number of segments made of stainless steel. The withered leaf passes through a battery of three to five such CTC machines which cause the leaf to get crushed, torn and curled.

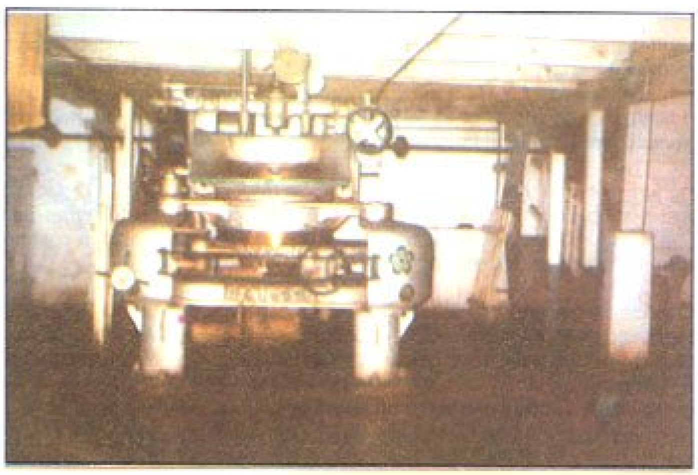


Photograph -5.11 Rotorvane machine. Partial cutting, turning and curling operation take place in this machine (CTC).



Photograph 5.12 : CTC roller. Complete cutting, turning and curling operation takesplace in CTC roller after rotorvane operation.

Photograph –5.13 Gugi machine make CTC tea of different formula size



Photograph 5.14 : Orthodox roller rolls the weathered leaf continuously in the annular space.

5.9.4 Fermentation

Tea fermentation is essentially the oxidation of simple substrates into complex characteristic substances by endogenous enzymes present in the tea leaf. This distinguishes tea manufacture from other food processes in which exogenous fermentation inducing agents are added to the raw material.

Fermentation is not confined only to the period during which the leaf lies in the fermenting drums, racks or floors. It commences from the time the cells are bruised and extends until the enzymes are deactivated in the drier. As a first step during fermentation, the catechins are oxidized to highly reactive transient orthoquinones by polyphenol oxidase. The quinones in turn dimerize to produce theaflavins (TF), which are orange red substances that contribute significantly to astringency, briskness, brightness and the colour of tea beverage. Theaflavins comprise 0.3 to 2.0 percent of the dry weight of black tea.

Further transformations of dicatechins and theaflavins yield compounds which are known as thearubigins, comprising about 9 to 19 percent of black tea, are red brown in colour and contribute to colour, strength and mouth feel of liquor.

While theaflavin content of tea increases during fermentation and starts declining after reaching a peak thearubigin content continually increases throughout the fermentation. In actual practices, the completion of fermentation is judged by the change in colour (green to coppery) and the pleasant aroma that develops. However, chemically optimum fermentation may be assessed by monitoring the profile of TF content and taking the time required for the production of maximum. TF Proper balance between theaflavins and thearubigins is also essential for a good cup of tea.

Like any other enzymic reaction, the rate of fermentation primarily depends upon the concentration and relative proportion of individual substrates, availability of oxygen, the activity of enzyme, pH and the temperature. Since it is not a homogeneous system, the degree of contact between the enzyme and substrate will be important. In addition, mass transfer of air to the reaction side is crucial in controlling the rate and product profile of fermentation.

During fermentation, the PPO activity is known to decrease due to the formation of insoluble complexes of polyphenol oxidation products with the enzyme protein by feed back action. This precipitation process increases as fermentation continues and the temperature of the fermentation leaf increases.

Both reaction rate and the ultimate concentration of products are affected by the concentration of oxygen. Theaflavin production will be inhibited if the concentration of the oxygen in the air falls below normal, which can occur in dead spots' in a forced-air fermentation system. By increasing the oxygen concentration of the air in a fermentation unit, it is possible to achieve higher theaflavin levels.

Temperature is one of the most important factors influencing the complex series of enzymic and chemical reactions during fermentation. Temperature not only affects the rate of fermentation but also the ultimate level of theaflavin in tea. As a rule of thumb for altering the fermentation times to suit ambient temperature conditions, the rate of fermentation at any temperature will be taken as 1.7 to 1.8 times as fast as that a 10°C cooler. Though, increase in temperature accelerates the fermentation rate, maximum theaflavin occurs, when fermented at low temperature for a long time. This happens because as the temperature increases, the break-downs reactions become more rapid than the theaflavin formation reaction, and ultimately less theaflavin is produced. Another advantage of low temperature fermentation is that the peak of TF production is maintained for a longer period. Even a delay in firing results in a detectable difference in quality.

Photograph – 5.15 : Orthodox tea fermentation section (Makai Bari)

5.9.5 Drying

The drying of fermented tea has three major objectives; to terminate the biochemical functions by heat denaturation of the enzyme; to reduce the moisture to increase the shelf stability of black tea and finally, to enhance chemical reactions responsible for black tea character and flavour.

The polyphenol oxidase enzymes which convert catechins into theaflavin are not inactivated as soon as the leaf enters the drier. In fact the fermentation process is actually accelerated and continues at a faster rate till the temperature of leaf reaches 55°C at which the enzyme is completely inactivated. Hence, any unoxidised catechin will continue to be converted into theaflavin until oxidase enzyme has been inactivated. It has been reported that 10 to 15 percent of theaflavin content in black tea is formed during the first 10 minutes of drying.

A noticeable effect of drying is the change in colour of dried leaf brought about by the transformation of chlorophyll into pheophytin, which imparts the desired black colour. During drying, the reduction in stringency of fermented tea occurs due to the combination of polyphenols with tea leaf proteins at the elevated drying temperature. Drying causes an overall reduction in the quantity of volatile compounds, although certain aromatic compounds continue to be formed. Relative distribution of chemical compounds in the tea bush is presented in Table-5.1

The fermented Tea leaf is dried by exposing to a draft of hot air; the process takes about 30 (thirty) minutes. Some of the flavour characteristic of the final product are developed as the leaf heats up during the drying process, and eventually the leaf temperature and moisture levels bring about the enzyme destruction or inactivation necessary for preservation of the product. The conventional tea dryer is basically a rectangular chamber. The tea to be dried is spread on perforated trays. These dryers are driven by trays-carrying chains and sprockets running on angle iron runners. The movement of the trays with the leaf is counter-current to the draft of hot air. Recently the technology of fluid-bed drying at 125°C for 20 minutes is being followed in many cases. Normally the leaf enters the driyer with 60-72% moisture, depending on the cutting process used, and is dried down to 2.5-3.5% moisture.

Table – 5.1

Relative distribution of chemical compounds in the tea bush

Compound	Flush	Mature Leaf	Green Stem	Mature Stem	Root	Seed
Polyphenols	++	+	+	+	+	-
Amino acids	++	+	+	+	++	+
Nucleotides	+	+	+	+	+	+
Phosphate Ester	+	+	ND	ND	ND	ND
Caffeine,	++	+	+	+	+	-
Theobromine	+	+	+	+	+	+
Carbodase	+	+	+	ND	ND	+
Lipids	+	+	+	+	+	+
Organic Acids	+	+	+	+	-	-
Chlorophyll	+	++	+	+	-	ND
Carotenoids	+	+	+	+	+	+
Unsaponifiables	+	+	+	+	+++	+++
Saponin	+	+	+	+	+	+
Minerals	+	+	+	+	+	+
Volatile Compound						

Note: ND denotes not determined & Signs denote relative distribution of each compound.

Photograph – 5.16 : Picture shows diesel fired burner attached with the drier. Fermented tea is dried at 110°C – 130°C.

5.9.6 Cooling , Sorting And Grading

The hot dried tea is cooled on the factory floor before it is sent for sorting and grading. Sorting is the operation in which tea particles of the bulk are separated into various grades of different sizes and forms confirming to trade requirements. In other words, it basically converts the bulk into finished products. The process of sorting has two objectives (i) to enhance the value (ii) to impart quality.

Sorting enhances the appearance and quality of liquor; at the same time it can also deteriorate the quality. The presence of fibre or flakes of coarse leaf in a primary grade causes harshness and their removal makes the liquor mellow. The cleaning of fibre also improves the black appearance of tea which is desirable. Bloom is indicative of liquor character; over sorting and over cleaning can result in loss of bloom. Usually a tea which has not been well fired, loses bloom more quickly. If tea absorbs moisture during the cleaning process, liquors can deteriorate and its keeping quality reduces. Sorting of bulk has to be done in three stages – (1) Cleaning of fibre (2) Grading and (3) Winnowing.

The initial separation of leaf and dust can be carried out on a Middleton fitted with a sieve on No.24 mesh on the top and No.10 mesh on the bottom. Tea particles which pass through mesh No.24 are collected separately and graded further in the dust grade sorter. Similarly, particles which are retained on No. 24 mesh and pass through mesh No.10 are graded separately in the leaf grade sorter. Particles retained over 10 are generally taken for reconditioning.

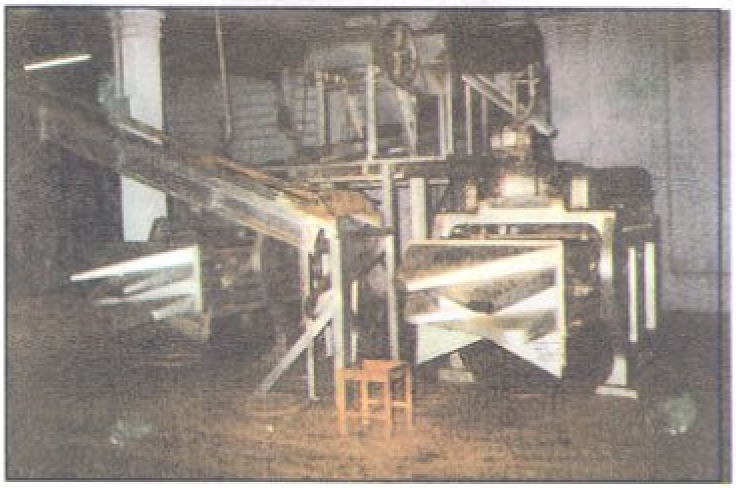
Both leaf and dust grades are further fractionated either in Trinic sorters or vibro sorters. The recommended standard mesh sizes are opening for different CTC grades is presented in Table-5.2.

After sifting, each grade is finally cleaned by winnowing during which fibres and flaky teas are removed. Generally, Super Fine Dust (SFD) and Fine Dust (FD) grades are cleaned separately in the fibrex after winnowing.

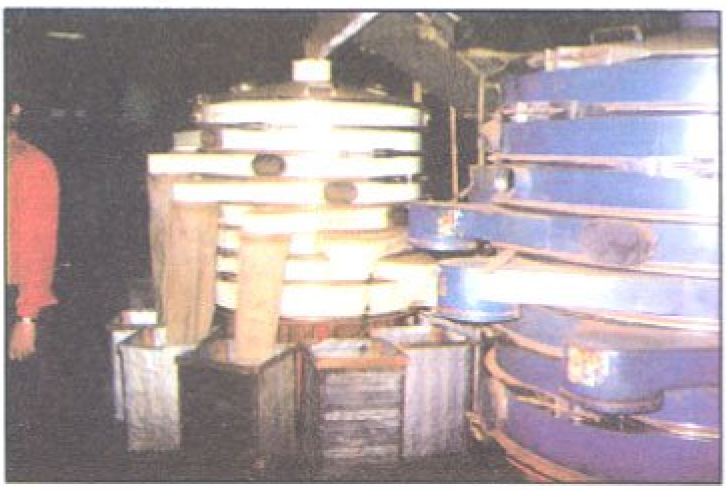
Table-5.2

Description & Characteristics of CTC Tea

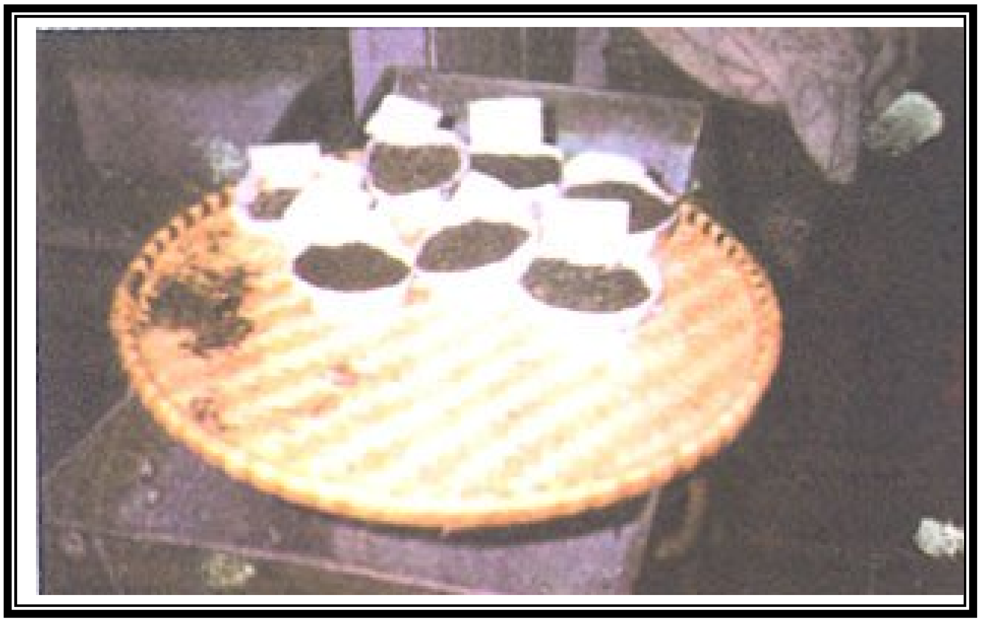
Category	**Size**	**Grade Name**	**Appearance**	**Liquor**
CTC Leaf Grade	Over Mesh 10	Flower Pekoe (FP)	Biggest granular size tea with embedded fibre or clean appearance	Thin and plain, 150-200 cups/Kg.
	Over Mesh 12	Pekoe (PEK)	Bolder grade with granulation and black and clean appearance	Colour with medium strength 170-200 cups/Kgs.
	Over Mesh 16	Broken Orange Pekoe (BOP)	Medium sized and granular clean teas	Very coloury and strong with brightness and briskness, 250-300 cups/Kg.
	Over Mesh 16	Broken Pekoe (BP)	Medium granulation with a little flaky particles	Very coloury and strong with brightness and briskness, 300-350 cups/Kg.
	Over Mesh 24	Pekoe Fannings (PF)	Small sized and granular shape with a little flackiness	Very strong and coloury with some brightness and briskness, 300-350 cups/Kg.
	Over Mesh 24	Pekoe Fannings one (PF1)	--	--
CTC Dust Grade	Through Mesh 24	Pekoe Dust one (PD1)	Granular finer particles with clean appearances	Very coloury and strong, 300 -350 cups/Kg.
	Over Mesh 30	Pekoe Dust (PD)	--	--
	Over Mesh 40	Red Dust (RD)	Finer particles of dust with clan appearance smaller than PD	Colour and strong with some brightness and briskness, 300 –350 cps/Kg.
	Over Mesh 50	Super Red Dust (SRD)	Black and clean powdery appearance smaller than RD	Good colour with more strength and brightness, 350-400 cup/Kg.
	Through Mesh 50	Super Fine Dust (SFD)	Black clean very fine particles with heavy density	Colour and more strength and some brightness, 450-500 cup/Kg.
	Through Mesh 50	Fine Dust (FD)	Finer powdery dust clean fibre	Coloury with some strength, brightness and briskness, 450-500 cups/Kgs.



Photograph-5.17 : Penual machine of capacity 400-kg/hr used for getting eight (8) types of final CTC product through vibroscreening process.



Photograph –5.18 : Screening and separator machine (Makai Bari).



Photograph – 5.19 : Grading of Orthodox Tea (Makai Bari).

5.9.7 Packing

Sorted and graded black tea is normally packed in a ply wood tea chest. The chests are assembled using various components, like the plywood shooks, battens, metal fittings, iron nails and aluminium foil with tissue paper lining. Recently attention has been drawn to the use of non-conventional materials like paper, multiwall paper sacks and polythene lined jute bags.

Flow sheets of conventional process of CTC, Orthodox & Green Tea are furnished in Fig.-5.1, 5.2 & 5.3 respectively.

5.10 Fuel and Power Requirements

Factories require a power source for driving machinery and a fuel source for heat generation. The nature and combination of fuel and power sources varies considerably depending on the natural resources of the tea growing area concerned, and on the economics applying to possible alternatives. The efficiency of the drying system and local meteorological conditions will also effect the fuel consumption. An indicative energy consumption pattern of different sources of energy is presented in Table- 5.3.

Table- 5.3

Thermal Energy Consumption of Different Energy Sources

Fuel	Average **calorific value**	**Amount of fuel consumption per kg. of made tea**	**Average energy consumed (KWhr/kg. made tea)**
Coal	5830 Kcal/kg	1.125 kg	7.62
Leco	6900 Kcal/kg	0.625 kg	5.01
Wood	3500 Kcal/kg.	2.000 kg	8.13
Natural Gas	9000 Kcal/Nm3	0.62500 Nm3	6.53
TD Oil Direct	10500 Kcal/kg.	0.300 kg	3.65
TD Oil Indirect	-	0.500 kg	6.10

The summary of section wise energy consumption in typical CTC production unit is presented in Table- 5.4.

Table- 5.4

Section-wise energy Consumption in Typical CTC Factory

Sections	**Electricity**		**Wood**			**Total energy**	
	Unit/kg	%	Kg/kg	Unit/kg	%	Unit/kg	%
Withering	0.104	15.71	0.03	0.125	2.75	0.229	4.35
CTC	0.300	45.32	-	-	-	0.300	5.70
Drying	0.235	35.50	1.07	4.473	97.28	4.708	89.51
Sifting	0.023	3.47	-	-	-	0.023	0.44
Total	0.662	100.00	1.10	4.598	100.00	5.26	100.00
%	12.60			87.40		100.00	

Electrical Power Source

The simplest source of power is in areas where a national supply and distribution network is available. However tea estates often install their own generation facilities for running the plant and other facilities during power shutdown period. Nowadays most standby generators are driven by diesel engines, producing about 3 kWh per litre of fuel consumed. To produce one tonne of tea normally requires between 430 and 490 kWh.

Photograph – 5.20 : View of a CTC tea manufacturing unit. The factory produce green tea in very small amount.

Photograph – 5.21 : Detail process study site in Jalpaiguri.

Figure-5.1

CTC TEA MANUFACTURING - PROCESS FLOW DIAGRAM

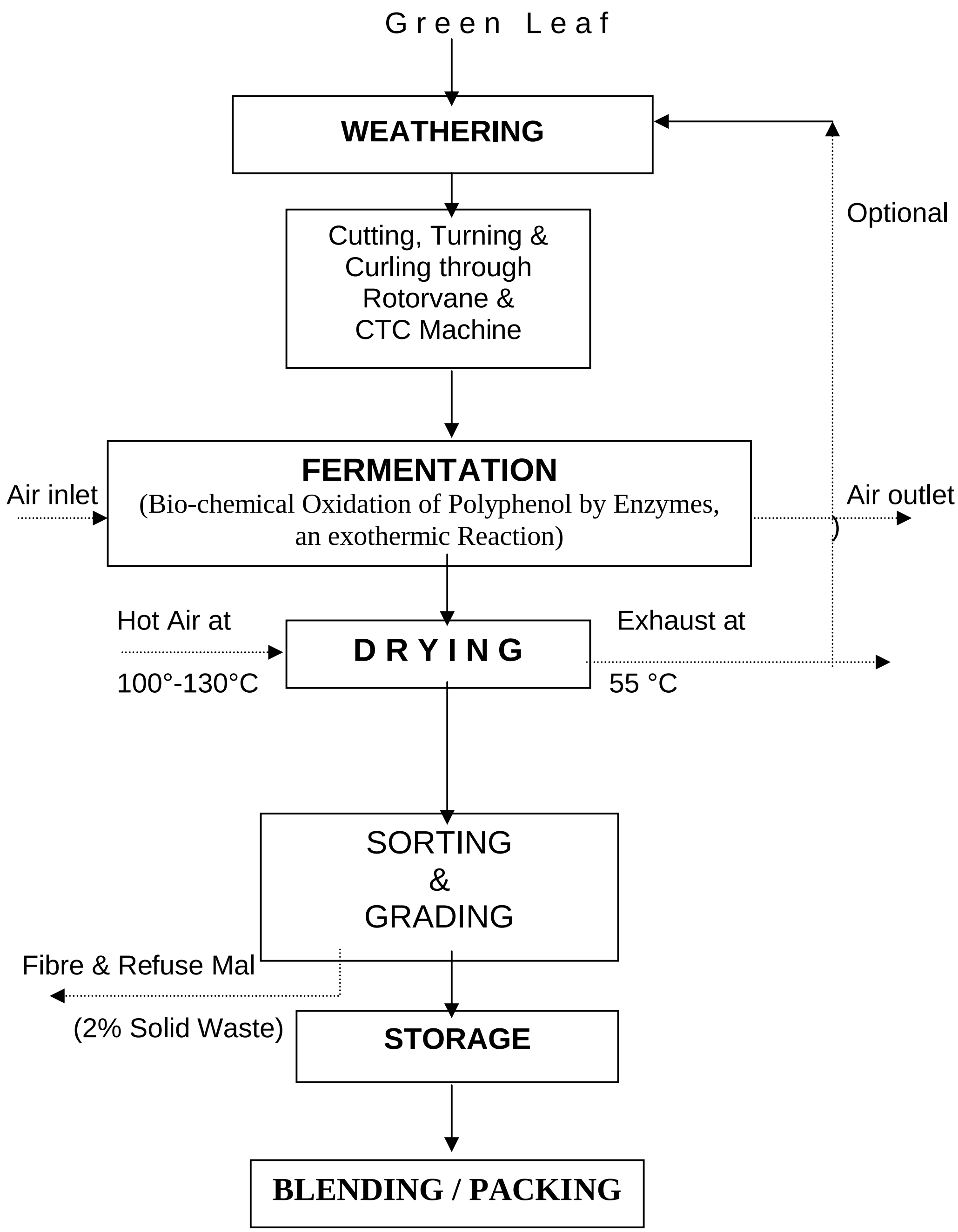


Figure-5.2

ORTHODOX TEA MANUFACTURING - PROCESS FLOW DIAGRAM

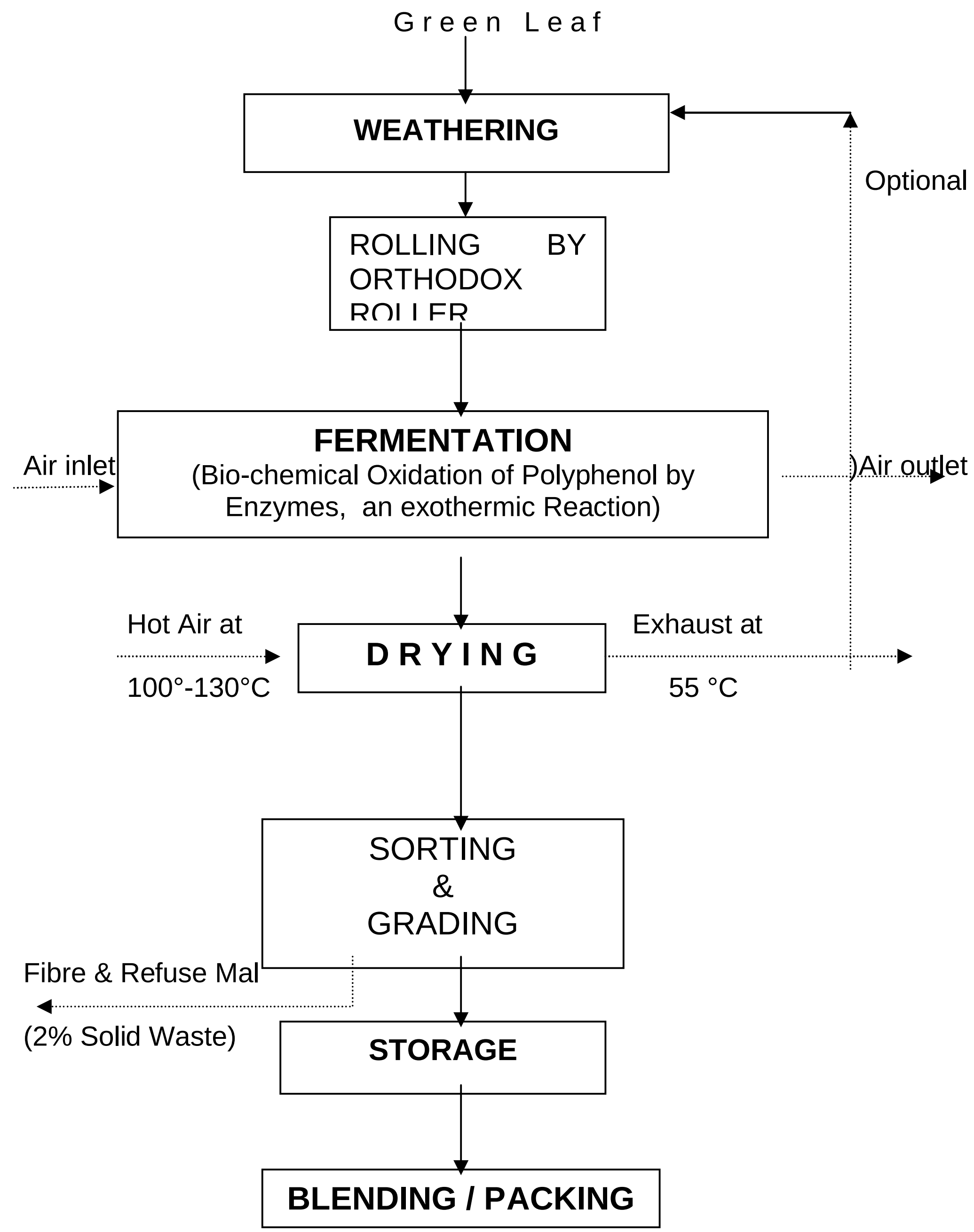
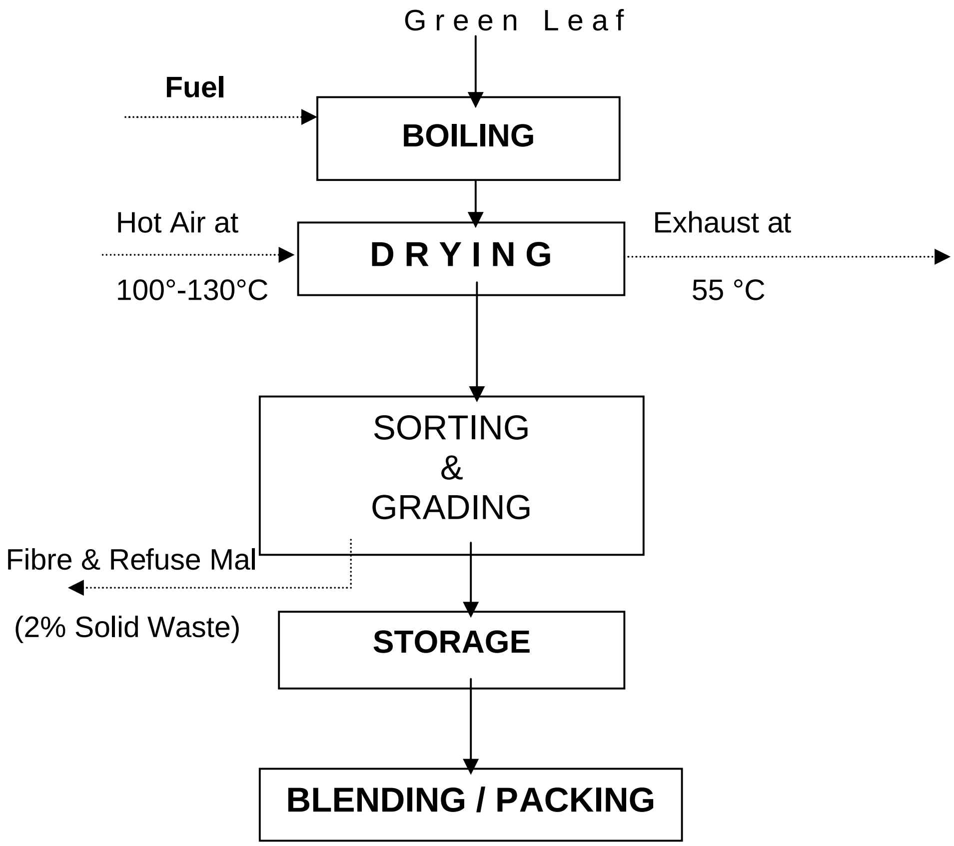
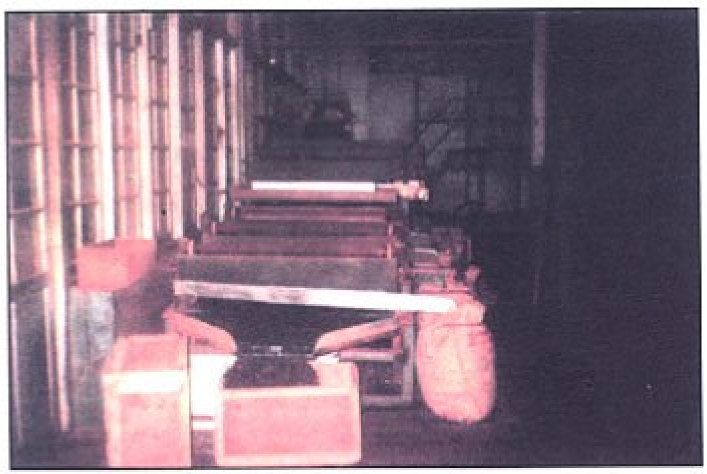


Figure-5.3

GREEN TEA TEA MANUFACTURING - PROCESS FLOW DIAGRAM



Photograph 5.22 : Machinery Setup inside a CTC Tea Production Unit in a South Indian Tea Factory



Photograph –5.23 : Sorting Section at a CTC Tea Production Unit in South India

6.0 Pest Attack and Crop Losses

Tea provides a stable microclimate and a continuous supply of food for rapid build up of phytophagous species that include insect, mites and eelworms. More than 300 species of insects, mites and eelworms are active in tea areas, though not all at the same time. The simultaneous presence of different species of mites and insects, each with their characteristic mode of feeding, and diverse habitat and seasonal cycles, calls for optimal management of the pests which should be both ecologically and economically sound. A major aspect of tea pest management is the practice of simultaneous application of species specific acaricides and insecticides against pests with diverse temporal distribution with the plant itself. It is essential that these pesticides do not leave any residue in tea to avoid consumer hazards.

A loss of 10 percent due to overall pest attack is a generally accepted figure though it could be 40 per cent in devastating attacks by defoliators. The different types of pests that are found to be associated with the Roots, Stems and Leaves of the tea plants are given in table 6.1. The sequence of the appearance of different pests on tea plants is given in table 6.2.

Table-6.1

PESTS OF TEA

Root associated Pests	Stem associated Pests	Leaf associated Pests
Nematodes (Eelworms)	Shot – hole borer	Chewing and biting
While/Cockchafer grubs	Large hepialid borer	Caterpillars
Root mealy bug	Red coffee borer	Sucking
		Aphid
		Tea mosquito
		Scales
		Mealy bug
		Tea jassid
		Sucking and scraping
		Mites
		Thrips

Table-6.2

Sequence in the Appearance of Different Kinds of Arthropod Pests on Tea

Phase/growth	Period	Major pests
Appearance of new flush of leaves	Feb-April	Tetranychid (Oligonychus coffeae) and Eriophyid mites (Acaphylla theae)
Rapid growth of flush, i.e. young leaves and buds on the upper end	May-July	Sap imbibers, thrips, Jassids, mosquito bugs
Growth of maintenance foliage on the lower side of the plants	July-Sept	Leaf eating beetles and defoliating caterpillars
Appearance of dormancy: slow growth of flush: only maintenance foilage	Oct-Jan	Eriophyid (Calacarus carinatus) and Tenui-palpid (Brevipalpus phoenicis)

7.0 Pesticide Applications and their Environmental Aspects

7.1 Pesticides Application in Tea Plantation

7.1.1 Pesticides types used

To target pests both organic and inorganic pesticides are applied depending upon the type of pest. The classification of pesticides based on pest category is given Table 7.1. The details of organic and inorganic pesticides used are given in Table 7.2

Table – 7.1

Classification of Pesticides based on Target Pests

Acaricides	**Insecticides**	**Insecto-Acaricides**
Control mites Dicofol Sulphur	Control insects Deltamethrin Endosulfan	Control insects and mites Ethion Quinalphos

Table-7.2

Some details of Available Organic and Inorganic Pesticides

Organic Pesticides:			
Chlorinated hydrocarbons	**Organo-phosphates**	**Carbamates**	**Synthetic pyrethroids**
Dicofol Endosulfan	Ethion Phosalone Monocrotophos Quinalphos	Carbaryl Aldicarb Carbofuran	Cypermethrin Deltamethrin Fenvalerate
Inorganic pesticides : Eg. Sulphur			

7.1.2 Recommended Doses

The doses of pesticides usually applied per hectare of land are given in Table – 7.3

7.1.3 Steps for Effective Pest Control

The tea processors should take following corrective measures during pesticides applications:

1] When infested by mites occuring normally from foci, chemicals are applied and such infestation are identified in the field & properly marked.
2] Chemicals of approved grade as laid down in guidelines by Tea Research Institute are only used, within the expiry date.
3] Application methods normally follow the recommendation on the dosage & the recommended safety measures.
4] Spray are made always after a plucking. Spraying are not overdue between the plucking intervals as more sprays often cause building-up of residue. Functional sprayers with proper functional nozzles are normally used.
5] Chemicals are used on a rotational basis. Chemicals are normally not repeated more than two consecutive rounds.
6] CDA (Controlled Droplet Application) applicators are normally not used.
7] Correct spraying intervals are normally followed.
8] For effective control of pests the measures to be taken are given in the following Table -7.4.

Table – 7.3

Pesticides and their Recommended Dosage *

Chemicals	Target Pests	**Dosage / ha**	
		New clearing 1 year fields	**Other fields**
Dicofol 18.5 E.C.	All mites	1 lt (HS 22 ml)	1 lt (PS 29 ml)
Sulphur 40% a.i.	All mites	1.5 kg (HS 44 g)	2 kg (PS 57 g)
Sulphur 80% a.i.	All mites	750 g (HS 22 g)	1 kg (PS 29 g)
Ethion 50 EC	All mites and thrips	750 ml (HS 16.6 ml)	750 ml (PS 22 ml)
Phosalone 35 EC	Thrips, Caterpillars, All mites	750 ml (HS 22 ml)	1 lt (PS 29 ml)
Endosulfan 35 EC	Thrips, Caterpillars, Aphids Helopeltis, Scale insects, Mealy bugs	750 ml (HS 22 ml)	1 lt (PS 29 ml)
Quinalphos 25 EC	Caterpilars, Thrips, Scales Insects, All mites	500 ml (HS 16.5 ml)	750 ml (PS 2 ml)
Monocrotophos 36 SL	Thrips, Caterpillars, All mites (except Scarlet)	300 ml (HS 8.0 ml)	350 ml (PS 10 ml)
Dimethoate 30 EC	Aphids Caterpillars, Mealy bugs, Thrips, Scale insects, Helopeltis	500 ml (HS 16.5 ml)	750 ml (PS 22 ml)
Phenthoate 50 EC	Scale insects, Thrips, Mealy bugs, Helopeltis, Caterpillars, Aphids	750 ml (HS 22 ml)	1 lt (PS 29 ml)
Fenthion1000 EC	Aphids, Mealy bugs,	150 ml	200 ml
Pesticide Mixtures	Scale insects	(HS 4 ml)	(PS 6 ml)
Dicofol + Ethion	All Mites	400 ml + 400 ml (HS 11 ml + 11 ml)	500 ml + 500 ml (PS 14.5 ml+14.5 ml)
Dicofol+Quinalphos	All Mites	400 ml + 300 ml (HS 11 ml + 7.7 ml)	500 ml + 350 ml (PS 14.5 ml + 10 ml)
Deltamethrin + Phosphamidon	Tea Mosquito Bug	80 ml + 120 ml (HS 2.2 ml+3.3 ml)	100 ml + 150 ml (PS 8 ml + 4.3 ml)
Cypermethrin 25 EC + Monocrotophos	Tea Mosquito bug	50 ml + 300 ml (HS 1.3 ml+7.7 ml)	60 ml + 350 ml (PS 1.7 ml+10 ml)
Quinalphos 25 EC + Dichlorvos	Tea Mosquito bug	500 ml + 190 ml (HS 16.6 ml+5.5 ml)	750 ml + 250 ml (PS 22 ml+7.3 ml

PS : Power Spray HS : Hand Spray

Quantity required for every 10 litres of water.

** Ref : Guidelines on Tea Culture in South India*

Table-7.4

Steps for Effective Control of Pests

Sr.No.	**STEPS**
1.	Right timing of spraying
2.	Right choice of chemicals
3.	Good quality chemicals
4.	Correct dosage
5.	Sufficient spray volume
6.	Correct spraying technique
7.	Correct spraying interval
8.	Adequate rounds
9.	Maintenance of sprayers
10.	Reasonable task

7.1.4 Safety Precautions

While applying the pesticides on tea plants following precautions needs to be taken are given in Table – 7.5

Table – 7.5

Safety Precautions Needed for Application of Pesticides

Sl. **No**	Safety Precautions
1	Careful reading of the label on pesticide containers.
2	Use of pesticides only when it is essential.
3	Use of only recommended pesticides.
4	Application of correct dosage by recommended method.
5	Periodic medical check-up of operators.
6	Use of protective clothing.
7	Contaminated clothes with pesticides should be discarded.
8	Care should be taken so that children, sick persons and pregnant and nursing mothers are kept away from pesticides.
9	During the time of handling of pesticides eating, drinking, smoking should be avoided.
10	Never to blow out clogged nozzles with mouth.
11	While mixing chemicals/pesticides care should be taken to avoid contact with skin, mouth and eyes.
12	Attention should be given not to leave pesticide/containers unattended in the fields.
13	Operators should wash hands with soap-solution after pesticide handling.
14	Regular cleaning of protective cloth.
15	Pesticides should be kept in locked store room and out of reach of children and other unauthorized persons.
16	Pesticides should be kept in their original labeled containers.
17	Decantation of pesticides into unlabeled containers should be avoided except for immediate use.
18	Dispose empty containers after thorough washing.
19	Never reuse the container for any other purpose. It is very difficult to make the containers completely free from pesticides after washing.
20	It is to be assured that the operators who handle and apply pesticides understand and follow safety precautions.

7.2 Environmental Aspects

The problem of pesticide residues on made tea is receiving attention. The pesticides on tea are generally used after plucking. If the sprays are done between pluckings the residues can be high. As spraying is done after plucking the deposits are left on the mature leaves and on shoots and leaves which are in different stages of growth. The weight of these immature shoots increases over a period of 7-14 days depending on the plucking intervals. Therefore, the pesticides undergo what is called a growth dilution, which should not be mistaken for the pesticide degradation. By the time immature buds attain the size of pluckable shoots (Three leaves and a bud) the residues of the pesticide on them will be very low. It is estimated that the weight of all shoots increases approximately 13 times in a week and 80 times in two weeks.

Pesticides applied on tea are degraded and also further diluted by rain and dew, photolysis through sunlight and biodegradation. Compounds like dimethoate, fenitrothion, and quinalphos have all half-life below two days, though for ethion the value is 3.4 days. Dicofol has a half-life of nearly four days.

Sensitivity of pesticides to light is an important factor which determines their residues on tea. The mechanism for most photochemical reactions involves the photolytic cleavage of covalent bonds. Since these reactions are based on functional groups, it makes no difference whether a pesticide is an insecticide, fungicide, or herbicide. Under experimental conditions the photodegradation of some of the commonly used pesticides is as follows:

Quinalphos > Malathion > Chlorpyriphos > Fenthion > Fenitrothion >Dimethoate > Phosalone > Ethion > Aldrin > Dicofol > Deltamethrin >Fenvalerate > Cis-permethrin > Cis-cypermethrin.

Considerable amount of pesticide on the leaves is lost during the process of manufacture. The loss may be 30-60 per cent. Degradation in this stage may be due to evaporation and thermal decomposition. Compounds with higher vapour pressure are likely to leave less residues than those with lower vapour pressure. Processed tea when infused with boiling water will extract small quantities of residues in tea liquor. Most of the pesticides used in tea have very negligible solubility in water. In fact, it is the liquor which is consumed and not the tea as such.

Based on the degradation rates of the chemicals that are used in tea, the safety intervals can be classified as follows :

1] Pesticides with rapid degradation rate. In these cases the safety interval is set at five days. Dichlorvos (DDVP) and the pyrethroids.
2] With moderate degradation rates, the safety interval is set at 6-10 days; Malathion, Fenitrothion, Quinalphos, Dimethoate, Phosphamidon, Phosalone.
3] Pesticides with slow degradation rate where the safety interval should be more than 10 days: Ethio, parathion, Methyl parathion, Demeton, Tetradifon, Dicofol, Chlordimefom.

Photograph –7.1 : Store House of tea planter near tea garden for fertilisers/ Pesticides chemicals etc. It has been observed that there has been use of chemical pesticides and fertilisers in tea cultivation.

Photograph 7.2 : Project Team accompanied by UPSAI Scientist

Photograph 7.3 : Laboratory Facilities at UPASI Tea Research Foundation

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8.0 Data Collection

8.1 Study Details and Overall approach

Questionnaire survey was carried out for collecting basic information about the tea processing industry and their capacity in the country. The data received from the tea processing industries were complied and tea industries were selected for indepth studies. However, before finalization of an industry the basic information from the industry was analysed for its suitability for detailed study.

In-depth study in selected tea gardens were done which included entire process operations and collected samples of water, soil and tea leaf to obtain a clear picture of the environmental pollution by analysis

8.2 Questionnaire Survey

Questionnaire format was specially designed for the purpose of gathering information about different aspects of the tea processing industries including work force, tea processing, environmental management etc. The preformatted questionnaires were sent to different tea gardens/factories in the country and finally 49 questionnaires have been received from the industries. State-wise responded tea industries with their names are presented in Table-8.1.

Some of the main areas covered in the questionnaire are as follows :

(i) General information

The garden was requested to furnish the basic information like name, location, area, population and quality and brand of tea produce, etc.

(ii) Work Force

Category-wise description of manpower involvement, working hours, ailments of the workers, arrangement of medical checkup and general education level.

(iii) Tea Plantation

Information regarding tea leaf plucking, soil treatment, existing irrigation facility, chemical application, average annual input, appropriate moisture content in green leaf, method of collection and dispatch facility and ratio of production of finished tea.

(iv) Tea Processing

Process of conversion of green tea to finished tea, composition of finished tea, name and approximate daily consumption/use of different process in input and production of different process output, production of bye-products and waste per ton of plucked, energy require to produce one ton of finished tea, fermentation process, name and approximate daily generation of un-useable/waste materials from operation and tea processing, source and consumption of water, presence of water purification method, disposal and treatment of waste water, solid waste generation and disposal, emission of air pollutant from processing unit, measures to control air pollution.

(v) Environmental Management and Safety

Whether there is a separate department for environment management and safety, any environmental policy, ISO 9000 certificated, quality control arrangement etc.

(vi) Financial

Approximate valuation of tea garden and factory, annual expenditure and annual turnover. However, data provided in the questioner survey was used for highlighting annual production, daily manpower and solid waste generation by the process is presented in Table-8.2. Daily water consumption in the tea plantation/process unit and wastewater generation by the process unit scenarios is depicted in Table-8.3. Comparison of actual domestic water consumption with the theoretical water demand is presented in Table-8.4.

Table-8.1
Tea Estates who responded to the Questionnaire Survey

Region/State	**Name of the Tea Estate**	Code	Region/ State	**Name of the Tea Estate**	Code
West Bengal	Pahargoomiah	WB-1	Assam	Rungagora	AS-16
	Namring	WB-2		Borsopori	AS-17
	Tukvar	WB-3		Langharjan	AS-18
	Risheeaat	WB-4		Nagrijuli	AS-19
	Karballa	WB-5		Borahi	AS-20
	Choonabhutti	WB-6		Nokwroy	AS-21
	Banarhat	WB-7		Dikon	AS-22
	New Dooars	WB-8	**Himachal Pradesh**	The Sidhbari Co-operative Tea Factory Limited	HP-1
Assam	Burtoll	AS-1		Kausami	HP-2
	Labac	AS-2	South India	Strathern	SI-1
	Dewan	AS-3		Tatamala	SI-2
	Kalline	AS-4		Talapoya	SI-3
	Jellalpore	AS-5		Cherakara	SI-4
	Towkok	AS-6		Wallardie	SI-5
	Manjushree	AS-7		Moonglaar	SI-6
	Nahorhabi	AS-8		Ackoor	SI-7
	Meleng	AS-9		Upper Surianalle	SI-8
	Jamguri	AS-10		Pattumallay	SI-9
	Murphulani	AS-11		Arrapetta	SI-10
	Tinkong	AS-12		Sholeyar	SI-11
	Desam	AS-13		Kallyar	SI-12
	Basmatia	AS-14		Merchision	SI-13
	Numalighur	AS-15		Bappunji	SI-14

Table-8.2

Annual Production, Manpower & Solid Waste Generation by the Tea Industries

Tea Estate Code	Production of Green Leaf (ton) per Ha. per annum	Production of Black Tea (ton) per Ha. per annum	Ratio of Black Tea to Green Leaf	Daily Manpower in Plantation per ton of Green Leaf Production	Daily Manpower in Factory per ton of Black Tea Production
WB-1	8.30	1.95	0.23	75.93	1.03
WB-2	2.39	0.53	0.22	338.75	93.24
WB-3	2.69	0.59	0.22	387.17	79.46
WB-4	3.17	0.70	0.22	346.11	53.93
WB-5	7.88	1.75	0.22	75.16	27.65
WB-6	7.58	1.60	0.21	101.74	20.60
WB-7	7.46	1.65	0.22	78.83	21.72
WB-8	7.16	1.57	0.22	74.95	15.78
AS-1	12.47	2.59	0.21	53.15	27.85
AS-2	14.15	3.11	0.22	49.46	29.33
AS-3	14.03	3.09	0.22	44.18	51.70
AS-4	11.23	2.58	0.23	44.93	22.68
AS-5	8.23	2.01	0.24	115.98	29.08
AS-6	7.48	1.63	0.22	67.85	26.37
AS-7	-	2.53	-	-	-
AS-8	8.91	1.96	0.22	69.35	43.06
AS-9	6.90	1.47	0.21	83.75	35.58
AS-10	4.59	1.09	0.22	-	32.36
AS-11	6.09	1.48	0.24	59.55	13.45
AS-12	8.86	1.84	0.21	74.04	49.86
AS-13	-	2.02	-	-	27.18
AS-14	11.21	2.41	0.21	78.00	34.59
AS-15	6.10	1.41	0.23	78.90	2.10
AS-16	7.56	1.84	0.24	87.70	3.53
AS-17	5.96	1.41	0.24	71.16	2.44
AS-18	11.15	2.49	0.22	77.27	2.51
AS-19	9.18	2.18	0.24	84.95	43.11
AS-20	5.04	1.09	0.22	181.74	63.08
AS-21	10.98	2.42	0.22	44.87	33.72
AS-22	10.23	2.23	0.22	54.21	26.77
HP-1	-	-	-	-	33.54
HP-2	12.37	3.05	0.25	66.92	1.44
SI-1	26.05	6.29	0.24	32.05	23.11
SI-2	8.36	2.05	0.24	51.62	-
SI-3	20.84	5.07	0.24	18.95	9.12
SI-4	0.07	0.02	0.28	5833.69	3233.23
SI-5	9.74	2.31	0.24	54.58	8.79
SI-6	12.27	2.73	0.22	44.72	5.20
SI-7	0.64	0.16	0.25	1407.17	567.09
SI-8	14.18	3.48	0.24	37.66	15.19
SI-9	7.98	1.98	0.25	585.72	14.11
SI-10	14.79	3.56	0.24	42.02	8.08
SI-11	16.28	3.97	0.24	36.54	18.14
SI-12	16.41	4.03	0.25	37.00	15.84
SI-13	6.59	1.62	0.24	94.42	13.90
SI-14	23.59	5.15	0.22	26.24	10.50

Table-8.3

Daily Water Consumption & Wastewater Generation Details

Code	Daily Water Consumption (in Litres)		Daily Wastewater Generation (in Litres)
	For Plantation per ton of Black Tea Production	**For Misc. Services per ton of Black Tea Production**	**From Misc. Services per ton of Black Tea Production**
WB-1	2932394.0	257.50	257.50
WB-2	-	-	420.00
WB-3	8543.70	-	-
WB-4	10786.50	-	-
WB-5	-	674.30	539.50
WB-6	12119.30	807.90	888.70
WB-7	-	144.80	115.80
WB-8	74805.20	467.50	92.50
AS-1	169.80	509.40	-
AS-2	202.30	606.8	-
AS-3	196.30	588.90	-
AS-4	3819.20	2386.90	-
AS-5	3101.60	1938.50	1938.50
AS-6	890.90	178.20	-
AS-7	1538.00	192.20	-
AS-8	3444.90	-	645.90
AS-9	5390.70	-	-
AS-10	202.25	252.80	252.80
AS-11	-	-	1345.60
AS-12	-	-	-
AS-13	4530.30	4530.30	3850.70
AS-14	728.30	910.40	-
AS-15	-	-	150.20
AS-16	-	-	195.90
AS-17	-	-	110.70
AS-18	-	-	358.40
AS-19	-	-	-
AS-20	1837.50	2450.00	2450.00
AS-21	1124.00	374.60	374.60
AS-22	257.60	309.50	232.10
HP-1	-	-	-
HP-2	480.30	12.01	-
SI-1	-	-	-
SI-2	-	-	-
SI-3	-	165.80	165.80
SI-4	-	-	-
SI-5	3768.80	-	-
SI-6	140.03	-	-
SI-7	-	-	-
SI-8	-	-	205.30
SI-9	3024.50	-	672.10
SI-10	346.20	69.20	-
SI-11	-	954.80	381.90
SI-12	-	1005.80	502.90
SI-13	-	1853.60	926.80
SI-14	-	-	-

Table – 8.4

Comparison of Theoretical & Actual Water Consumption

Code	Daily per Hectare Water consumption in Plantation (in Litre)	Daily Total domestic water consumption in the factory (in Litre)	Total Manpower in Tea Processing Factory	Theoretically Daily Total domestic water consumption in the factory (in Lt.) **
WB-1	19149.20	1000	4	120
WB-2	-	-	111	3330
WB-3	22.89	-	93	2790
WB-4	-	3000	40	1200
WB-5	-	3000	123	3690
WB-6	74.66	2000	51	1530
WB-7	-	500	75	2250
WB-8	488.65	2400	81	2430
AS-1	1.50	3000	164	4920
AS-2	2.12	3000	145	4350
AS-3	2.07	4500	395	11850
AS-4	34.09	10000	95	2850
AS-5	21.59	5000	75	2250
AS-6	6.32	1000	148	4440
AS-7	16.22	1000	N.G.	-
AS-8	23.44	-	200	6000
AS-9	30.06	-	165	4950
AS-10	0.86	500	64	1920
AS-11	-	Nil	30	900
AS-12	-	N.A.	215	6450
AS-13	30.67	10000	60	1800
AS-14	7.23	2500	95	2850
AS-15	-	N.A.	7	210
AS-16	-	N.A.	9	270
AS-17	-	N.A.	11	330
AS-18	-	N.A.	7	210
AS-19	-	N.A.	221	6630
AS-20	8.34	4000	103	3090
AS-21	8.12	1000	90	2700
AS-22	2.61	2000	173	5190
HP-1	-	N.A.	27	810
HP-2	6.67	25	3	90
SI-1	-	N.A.	158	4740
SI-2	-	N.A.	N.A.	-
SI-3	-	N.G.	55	1650
SI-4	-	1000	61	1830
SI-5	28.95	-	35	1050
SI-6	2.03	Nil	165	4950
SI-7	-	N.G.	193	5790
SI-8	-	-	111	3330
SI-9	19.98	N.G.	21	630
SI-10	4.11	600	70	2100
SI-11	-	5000	95	2850
SI-12	-	4000	63	1890
SI-13	-	2000	15	450
SI-14	-	N.G.	34	1020

** Considering, Per Capita Domestic Water Consumption in Factory = 30 lpcd

8.3 In-depth studies in Selected Tea Gardens

8.3.1 Selected Tea Gardens and their locations

In-depth were conducted in 19 selected tea gardens whose details are presented in Table- 8.5.

Table-8.5

Tea Estates Visited

Name of the Tea Estate / Garden	Location	Name of the Tea **Estate / Garden**	Location
Sabujion Tea Garden	Jalpaiguri	Castleton Tea Garden	Kursheong
Vayapara Tea Garden	Jalpaiguri	Singeel Tea Estate	Kursheong
Nepati Valley Tea Estate	Jalpaiguri	Aibheel Tea Garden , Chalsa	Dooars
Nepati Valley Tea Estate Nursery	Jalpaiguri	Green way Agriculture (P) Ltd.	Dooars
Sonegaria Tea Garden	Jalpaiguri	Good Way Agriculture (P) Ltd.	Dooars
Jaipur Tea Estate	Jalpaiguri	Valley View Tea Estate, Ooty	Tamil Nadu
Bardihi Tea Garden	Jalpaiguri	Waterfall West (Kothari Tea Estate), Bhelparai	Tamil Nadu
Happy Valley Tea Garden	Darjeeling	Harrison Malayalam Tea Estate, Wyanad	Kerala
Margarette Hope Tea Garden	Darjeeling	Devon Tea Estate , Shimoga	Karnataka
Makaibari Tea Estate	Darjeeling		

The detailed study of the manufacturing process of Tea was carried out in all the above mentioned Tea Gardens/Estates. The main study was focused on sources of water for irrigation and soil characteristics which are of main concerned for tea processing industry. The details and analysis of surface water and soil are given as under:

8.3.2 Surface water

During in-depth study, several surface water sources (mainly river and cannel) have been identified which are being used for irrigation purpose in tea plantation areas. Surface water samples were drawn from 11 sources and were taken for laboratory analysis. Samples were examined for 12 parameters covering the major physical and chemical characteristics expected in the surface water. Water quality monitoring results are presented in Table- 8.6.

pH values (6.97 – 7.75) are generally very close to the neutral mark and are within the tolerance limit of 6.5 – 8.5. Toxic constituents like pesticides are absent in all the samples. However heavy metals like Cr, Cu, Pb, Cd, Hg, Ni and Co have been detected. The variation of Cu, Pb, Cd, Hg, Ni and Co concentration are 0.011 – 1.43 mg/l, 0.017 – 1.4 mg/l, 0.021 – 1.66 mg/l, 0.0007 – 0.032 mg/l, 0.397 – 0.85 mg/l and 0.0056 – 0.121 mg/l respectively. Concentrations of Cr, in two samples are found to be 5.536 mg/l & 6.051 mg/l which are quite alarming.

However, the Cr concentration in other nine samples varies between 0.07 and 1.08 mg/l. Generally, it can be inferred from the review of the water analysis results that the river/cannel water is fairly good and fully support the irrigation in tea plantation areas. The health of tea plantation workers who are exposed to this surface water for irrigating the tea plantation area were found to be sound and does not indicate any special ailment which could be attributed to the quality of the surface water.

Table: 8.6
Analysis of Surface Water

SL. No.	pH	Turbidity (NTU)	Colour	Iron (mg/L)	Pesticide (mg/L)	Total Cr (mg/l)	Cu (mg/l)	Pb (mg/l)	Cd (mg/l)	Hg (mg/l)	Ni (mg/l)	Co (mg/l)
SW1	7.75	0	0.1	-	ND	5.536	0.1072	ND	ND	0.0091	0.802	ND
SW2	7.69	1	0.1	-	ND	1.08	1.43	1.41	1.66	0.0012	0.7738	0.0095
SW3	7.17	0	0.01	0.082	ND	6.051	0.255	ND	ND	0.0007	0.778	0.0056
SW4	7.12	1	0.02	-	ND	0.148	0.141	0.017	0.022	0.002	0.801	0.025
SW5	7.09	0	0.1	-	ND	ND	0.043	ND	0.021	0.032	0.83	0.044
SW6	7.45	0	0	-	ND	ND	0.049	0.024	ND	0.0091	0.85	0.07
SW7	7.38	1	0.01	-	ND	ND	0.039	0.035	ND	0.0009	0.793	0.0286
SW8	6.97	1	0		ND	0.257	0.478	1.21	0.018	ND	0.397	0.0114
SW9	7.48	0	0.1	-	ND	0.35	0.011	0.757	0.0842	ND	0.398	0.0145
SW10	7.40	0	0	-	ND	0.079	0.163	0.155	0.919	ND	0.6009	0.0217
SW11	7.63	0	0	-	ND	0.07	0.178	0.252	0.915	ND	0.595	0.121

8.3.3 Soil

To examine the impacts of chemicals/fertilisers/pesticide on the soil in the tea plantation area, the physico-chemical characteristics of soil have been examined by analysing soil samples collected from selected points inside the tea gardens. For the said purpose ten soil samples were collected during in-depth study from the different tea plantation areas. Soil analysis results are presented in Table- 8.7.

The soil is generally acidic in nature with pH range 3.25 – 4.45. Moisture content of the soil varies between 4.5 – 33.18% with average moisture content being about 17.15%.

Organic matter content of the samples varies between 1.31 – 3.53% with an average value of 2.18%. Pesticides are absent in all the samples. Levels of Cr, Cu & Hg are observed to vary between 29.15 and 39.59 mg/l, 50.69 and 269.6 mg/l & 50.69 and 405.2 mg/l respectively.

In general the soil analysis results reveal that there is no indication of soil contamination due to tea plantation activities irrespective of the location of the tea growing areas. The soil analysis also indicates that the soil in general have fairly good agricultural potential.

Table-8.7
Analysis of Soils

SL. No.	PH	Moisture (%)	Ash (%)	Organic Carbon (%)	Pesticide (mg/l)	TotalCr (mg/l)	Cu (mg/l)	Pb (mg/l)	Cd (mg/l)	Hg (mg/l)	Ni (mg/l)	Co (mg/l)
S1	3.25	33.18	60.74	2.256	ND	32.65	269.6	405	252	405.2	65.5	141.5
S2	3.62	10.42	92.76	1.913	ND	39.59	208	423	259	130.4	105.5	149
S3	4.29	4.5	66.0	3.53	ND	26.13	124.9	435	251	124.9	87.13	146.3
S4	3.34	26.6	92.63	1.158	ND	31.19	50.69	410	262	50.69	70.23	141.7
S5	3.99	6.05	88.29	2.514	ND	29.15	141.5	418	256	141.5	95.16	143.9
S6	3.84	9.75	89.45	2.03	ND	26.15	150.2	406	254	60.5	67.7	142.8
S7	3.33	6.54	94.7	1.31	ND	27.13	135.5	411	251	112.6	71.32	141.8
S8	3.37	15.58	89.95	2.48	ND	26.22	130.4	421	256	167.1	97.41	145.2
S9	4.45	30.58	86.92	2.53	ND	28.05	143.7	430	260	80.2	84.23	143.2
S10	4.13	28.29	89.87	2.06	ND	28.10	182.3	409	255	123.7	76.5	146.1

Table : 8.8
Analysis of tea leaf

SL. No.	pH	Moisture (%)	Ash (%)	Pesticide (ppm)	Total Cr (ppm)	Cu (ppm)	Pb (ppm)	Cd (ppm)	Co (ppm)	Ni (ppm)	PCP (ppm)
L1	6.35	16..22	5.31	NIL	0.0062	3.763	0.0702	0.096	0.0067	0.277	0.018
L2	8.48	53.91	5.36	NIL	0	0.453	0.0772	0.030	0.0123	0.472	0.059
L3	6.00	9.98	5.61	NIL	0.0053	3.021	0.3310	0.343	0.014	0.196	0.034
L4	7.43	56.59	7.79	NIL	0	0.511	0.6210	0.360	0.013	0.385	0.042
L5	6.88	14.19	8.40	NIL	0.0015	0.173	0.2850	0.160	0.0046	0.152	0.025
L6	6.78	24.51	6.50	NIL	0.0051	3.040	0.340	0.345	0.0139	0.195	0.034

8.4 Desk Research

The Consultants have made extensive desk research on different aspects of tea plantation and Black tea production. Relevant details of the said research have already been presented in the earlier sections of this report.

8.5 Production verses Plantation – Important Data

The indepth study in selected tea processing industry has generated the following information:

(i) It has been observed that per 10,000 m^2 of land 1700 tea bush are planted.
(ii) One kg of green tea per year is available from one tea bush.
(iii) To manufacture one kg black tea on an average 4.5 – 5.0 kg of green tea is required. Alternately, it may be mentioned that 1 kg of green tea produces nearly 0.22 kg black tea.

(iv) The total solid waste which can no more be reused in the process is 2.0% of the black tea produced. 0.3% of this waste is recycled using some special technique. Thus, 1.7% solid waste has no use value to the black tea producers but this 1.7% waste material is not really a waste. This is normally sold to select reprocessing units where some chemicals by product are recovered from this waste. The process of recovery involves some chemical waste. For example, during detail study it was observed that a plant producing 800 tonnes of CTC tea annually generates solid waste to the extent of 16 tonnes.

(v) The solid waste, which is generated in tea agriculture during pruning/skiffing operation, is used as a fuel. Thus prima-facie it may be opined that neither tea agriculture nor black tea production really generate any solid waste of significance.

(vi) During tea agriculture it appear that there is very little emission to air or to water body.

(vii) Low energy is required during green leaf production.

(viii) The fertilizers, which are normally used during tea cultivation, have minimum if not nil effect on the environment.

(ix) Pesticides are used to combat some diseases of the tea plants. But these are ultimately washed away by the rainwater as a result pesticide presence in the tea leaves could not be detected.

(x) Plant hormones are also used in the tea gardens with an aim to influence the physiological processes of growth and development in tea plants. A few growth promoters that are used in the tea gardens are as follows:

- Triancontanol : A growth promoter is a long chain of fatty acid alcohol derivatives helpful in increasing photosynthetic activity, reducing rate of photorespiration, maintaining cells turgidity, uptake of nutrients etc.

- Antitranspirants : Another growth promoter which is helpful in regulating the stomata, preventing transpiration losses, serving as an osmoticum etc.

(xi) Organic Tea also can be grown with no input of chemical fertilizer/pesticides, such tea processing companies producing tea, which is 100% natural in character. Organic tea is very costly & production only can be boosted provided appropriate market is there.

(xii) Limited chemical study of the leaves, soil & the water used in the system have indicted that the tea leaves, soil & water are all by and large free of pesticide residues.

(xiii) Right now the productivity of CTC tea is very high & the cost of leaves, vis-à-vis cost of Black Tea are not matching as a result tea producers are not getting much encouragement in terms of revenue generation. It has also been seen that tea plantation is more lucrative than rice cultivation. So, many paddy fields are bring converted forcibly to grow CTC tea.

(xiv) Tea processing that is the factory operation is more or less a dry process and as such does not generate any liquid effluent.

(xv) Odour generated during tea processing that is inside the tea factory is of tea only.

(xvi) The solid waste, which is generated as a byproduct of the industry is also chemically processed in another industry to manufacture certain potential chemicals, which are really in demand.

(xvii) So far as the Environment Management is concerned, tea producing units, whether it produces organic or orthodox or CTC tea, all Companies are environmentally friendly. So far as the generation of pollutants is concerned.

All the above facts directly indicates that tea industry including tea cultivation does not pose any threat to the environment rather tea making could be broadly termed as an Eco friendly industry.

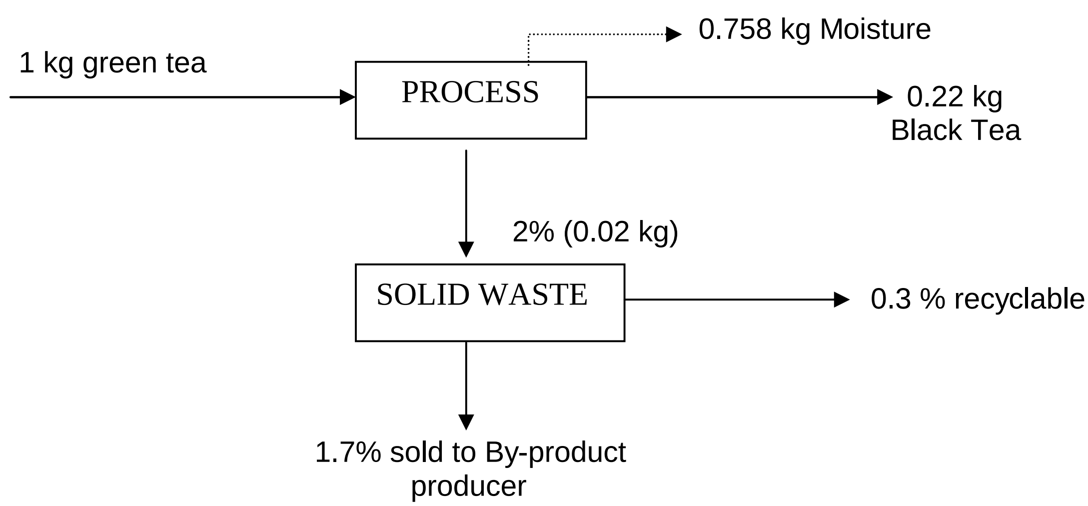
8.6 Mass Balance

It appears that the raw material is merely fresh green leaf, and the product is dried tea.. Fresh green leaf contains a proportion of fiber and stalk, the percentage of which depends on whether the plucking is fine or coarse. Fig 8.1, presents the flow diagram of the mass balance.

Air is used in large quantities, under controlled conditions of temperature and humidity. Other raw materials are fuel, wood, Coal, Oil, gas.

1 tonne of dried tea requires approximately:
4.5 tonnes green leaves.
450 KW electricity.
500 liters oil (or other fuel), depending on the process used.
250 man hours of work.
23 tea chests (or alternative packaging).
3 kg nails (if tea chests are used).
2000 tonnes of air.

Fig 8.1
Flow Diagram of the Mass Balance



9.0 Environmental Management Plan

As stated earlier the tea industry does not pose any threat to the environment. The industry does not generate much waste. It has been seen that a significant portion of the waste are being re-used in some way or the other. However, the industry should take up certain measures/actions, which may be useful in improving & maintain the environmental performance of the industry.

9.1 Air Pollution Control

Source of air emission in the tea industry is basically the D.G. set, which is operated only during the power shutdown period.

The following efforts are needed from the management towards controlling the air emission.

- Use of low sulphur fuel for combustion purpose in D.G. sets.
- Use of tall stack.
- Avoiding frequent start-up and shutdown of D.G. sets.

9.2 Wastewater Management

Source of wastewater in the tea industry is the domestic sector since the industrial process is basically dry in nature. Hence it is recommended that the domestic waste thus generated be treated in simple treatment system prior to its final disposal. Infact, the wastewater so generated may be treated in Septic Tank. Partially treated effluent from the septic tank should either be disposed off in soak pits or to be further treated in up-flow anaerobic filter (UFAF).

Soak pits are cheap to construct and easy to operate. These pits need no media when lined or filled with rubble or brickbats. When water table is sufficiently below ground level, soak pits should be preferred only when land is limited or when a porous layer underlies an impervious layer at the top, which permits easier vertical downward flow than horizontal spread out. Minimum horizontal dimension of soak pit should be 1 m. The pits should be covered and the top raised above the adjacent ground to prevent damage by flooding.

In such case where suitable conditions do not exist for adoption of soil absorption system, the partially treated effluent from the septic tank should be treated in up-flow anaerobic filter (UFAF).

The up-flow filter can be successfully used for secondary treatment of septic tank effluent in areas where dense soil conditions, high water table and limited availability of land preclude soil absorption or the leaching system for effluent disposal. It is a submerged filter with stone media. The septic tank effluent is introduced from the bottom. The microbial growth is retained on the stone media making possible higher loading rates and efficient digestion. BOD removals of 70% can be expected. The effluent is clear and free from odour. This unit has several advantages viz. (a) a high degree of stabilization; (b) little sludge production; (c) low capital and operating cost; and (d) low loss of head in the filter (10 to 15 cms) in normal operation. The up-flow anaerobic filter can either be a separate unit or constructed as an extended part of septic tanks.

The treated effluent from the UFAF could be discharged into any inland surface water or can be used for gardening purpose.

Apart from such treatment the management should also practice the following :

- Reduce wastage of water.
- Reduce volume of water use.
- Use of treated water for gardening purpose.

9.3 Solid Waste Management

The tea plants provide some green manure from leaf-fall; where shade trees are planted their leaves also form green manure.

The waste from factories amounts to about 2% of total production. Currently it is either returned to the field as fertilizer or sold at a very low price.

Products which can be produced from tea waste are shown below :

- Caffeine
- Polyphenols (valuable anti-oxident)
- Pigments (Edible colours)
- Polymers (tea polyphenols can be used to replace some of the phenol in phenol formaldehyde resins)
- Animal feeds (under investigation)
- Foaming agent
- Vinegar
- Tea seed oil (alternative to groundnut and olive oils for cooking, cosmetics and pharmaceuticals)
- Furfural.

9.4 Overall Management

The overall measures/actions that the industry may take up with an aim to improve the environmental performance of the industry are as follows:

- Practice Good House Keeping.
- Maximum re-circulation / re-use of the wastes.
- Conservation of domestic water.
- Quality control laboratory should monitor the residence of pesticides in finished tea.
- Generally finished tea is packed in poly-bags and these poly-bags are placed in jute bags for final delivery. It is suggested that the plastics used for such packaging should be of food grade in nature.
- Tea industries may try to use food grade jute bags instead of odourless jute bags as are currently being used.
- Attempts should be made to use organic fertilizers and pesticides in place of chemical fertilizers and pesticides.
- Attempt should also be made to optimize the use fertilizers and pesticides during tea production.

- Periodic (once in six months) monitoring of a few selected water sources around the tea garden should be made.
- Periodic monitoring of health condition of workers both in garden and factory should be made.

10.0 Minimal National Standards (MINAS)

The prime concern today is to prevent pollution of the physical environment of air, water and land such that the entire living system including the plant is not adversely affected. Indiscriminate pollution of the environment in the past has seriously affected the plant kingdom, animals and birds. Human beings are the worst victim, who are directly affected by the pollutants as well as by the loss of animals, birds and plants.

There is an urgency for the abatement of pollution and it is essential that no further damage is done to the environment. Industries are one of the major contributors to the pollution. It is therefore, necessary that Rules & Regulations are laid down to avoid further deterioration of the environment. The Central Pollution Control Board (CPCB) has been entrusted to frame and implement Rules & Regulations in the country to prevent any further pollution as also control such pollution which are already being contributed by the industries.

The Central Board operates through similar Boards at the State level who have the statutory powers to lay down the Rules & Regulations to control the indiscriminate pollution of the environment in their respective states.

Pollutants which are being discharged by the industries differ in their characteristics. It is therefore, necessary that standards be laid down industry-wise for the permissible levels of pollutants that can be let out by them to the environment. Such standards are available now for most of the major industries of the country. The Tea Processing Industry however is one of the exceptions in this respect.

It is in this context that the CPCB desires to formulate 'Minimal National Standards' (MINAS) in respect of the liquid wastes and emissions for the Tea Processing Industry.

It has been observed that the tea industry is a dry industry. However, liquid **waste of domestic nature** is generated in the township and labour lines of the gardens. A small amount of liquid waste is also generated from the domestic sector in the industry.

There is **no source of air pollution** in the tea processing. However D.G. sets are installed in a few gardens which are operated only during the power shut-down period.

The **solid waste from a tea industry is either used as fertilizer** or used for making other by products.

Considering the above the following standards are recommended for the consideration of CPCB.

10.1 Air Emission Standards

Diesel with low sulphur content shall be used to operate the D.G. sets.

The minimum height of stack to be attached with the D.G. set shall be calculated using the following formulae and the formula that gives higher value shall be applicable.

Formula No.1

$H = h + 0.2 \sqrt{KVA}$; where
H = Total height of stack in m.
h = Height of the building or nearest building
KVA = Generator Capacity

Formula No.2

$H = 14 Q^{0.3}$; where
H = Total height of stack in m from ground level.
Q = Emission rate of SO_2 in kg/hour from the DG Set.

In any case the stack height shall not be less than 11 m. SO_2 emissions shall not be more than 400 mg / NM^3 . The exhaust of DG set should be free from any visible smoke.

The management should ensure that the DG set purchased, should be of standard quality and make. Regular maintenance of the DG sets for achieving better combustion efficiency (preferably above 90%) should be undertaken.

10.2 Wastewater Discharge Standards

pH	= 6.0 – 8.0
Total suspended solids	= 100 mg/l.
Oil & Grease	= 10 mg/l.
BOD	= 30 mg/l

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