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Unsafe Chromium from Cotton Ginneries and Development of An Eco-friendly Alternative

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Abstract: Most of the cotton ginning operations are performed by using double roller (DR) ginning machines which serve an important role in the ginning industries. The rollers used in these industries are made of *Chrome Composite Leather-Clads (CCLC)* covering fixed to a shaft. The CCLC coverings contain about 18,000 to 36,000 mg/kg (ppm) of chromium particles. When the seed-cotton is processed in DR ginning machine, the lint cotton is contaminated with chromium dust of about 140 to 1990 ppm as total chromium which is *carcinogenic substance* as against the safe limits of 0.1 ppm. Due to the constant dust-producing grinding action of CCLC rollers in DR gins, chromium leaks into environment beyond the permissible levels which threat to cotton processing workers and users of cotton garments. During the cotton ginning process due to persistent rubbing of rollers over stationary knife the chromium particles are carried into lint cotton such that the spun yarns contain about 100 to 200 ppm , which according to eco-standards for spun yarns should not be more than 0.1 ppm. The CCLC rollers used in cotton roller ginning machines gets powdered during the ginning process. As chromium is a specific dust, gin and mill workers users of cotton garments are directly exposed to this carcinogenic substance with the *carcinogenic risk* of 2020 chances per million and are vulnerable to health hazards. To offset this problem, pollution-free rubberized cotton fabric (RCF) washers and rollers both for laboratory and commercial studies have been fabricated and experimented. These eco-friendly chrome-less rollers are evaluated for their performances; with a particular reference to techno-commercial and environmental aspects. In this the roller covering is made of multiple layers of fabrics bonded together using a white rubber compounding which has a surface finish conducive to high ginning efficiency. On the basis of the design and development of various rollers with subsequent performance evaluation studies, pollution-free RCF washers and rollers have been demonstrated with a reference to techno-commercial and eco-friendliness in ginneries. These newly developed RCF rollers were successful in their operation. These were found more effective in functioning than CCLC roller ginneries. They have eliminated unsafe chromium related contamination and pollution problems. This cleaner technology is a *source-at-control* preventive measure such that the cotton ginning and textile industries meet the requirements of environmental standards being enforced by many countries and high quality yarns and fabrics meeting the international standards are produced. These ginneries have been tested commercially. This found better in all aspects with reference to cotton technological properties, dye-catch properties, physical and chemical properties. It could be used commercially as an alternative in the cotton roller ginning industries for

the benefit of environment, society, gin and textile mill owners, traders, workers, employees and the government.

Key-Words: - cotton, contamination, carcinogenic, eco-friendly, ginning, pollution, roller

1 Introduction

India is one of the leading cotton growing countries in the world. It has 24% of the world area under cotton cultivation and 11% of the total cotton produced in the world. India ranks first in area with 11.1 million hectares of land under cotton cultivation and third in production. Cotton production has been estimated at 1700 lakh *bales* (each bale weighs 170 kg of lint cotton) during 2004-2005 in the world. Out of total cotton production, 200 lakh *bales* was ginned from 5100 cotton ginning industries in India. The cotton roller ginning process is defined as the mechanical separation of cotton fibres from their seeds by means of one or more rollers to which fibres adhere while the seeds are impeded and struck off or pulled loose . *Roller gins* are of two kinds *viz.,* single roller (SR) gins and double roller (DR) gins. In these gins, spirally grooved leather rollers, pressed against fixed knives, are made to rotate at a definite speed. Crank or eccentric shaft close to leather rollers gives rise to oscillation action of moving knives. When the seed-cotton is fed to the machine, fibres adhere to the rough surface of the rollers and are carried in between the fixed knives and the rollers and the fibres are entangled in the process. The moving knives beat the seeds and separate the fibres, which are gripped, from the seed end. This process is repeated number of times and due to the *'push-and-pull'* action; the fibres are separated from the seeds carried forward on the rollers to be dropped out of the machine. The ginned *cotton seeds* dropped down through the grid slots.

2 Problem Formulation

The roller constitutes an important element of roller gins. Until 1940, only Walrus animal hide was used as roller covering material in USA and UK. Later on due to the non-availability of *Walrus*, these countries did not allow this type of hides to be used and obsolete these roller gins (11). Sheep and Buffalo chrome tanned hides, were used as substitutes in the roller ginning machines, though the *interfibrillary action* was not satisfactory compared to walrus hides. The roller materials *viz.,* ordinary leather, newspaper, corkboard, and coconut coir were also tried, but have not been found suitable. Since 1940, *chrome composite leather-cladding (CCLC)* material has been under use for making rollers of roller gins till now in India and Africa. The CCLC rollers have not been used in USA and UK, since many years. The CCLC roller is made of CCLC washers, which are filled and compressed in a shaft to a high pressure. One of the important property pertains to roller covering material is *interfibrillary action* to be considered in the development of roller ginning process(14).

Since the semi-finished chrome leather washers contains 3 to 4% as total chromium that is around 36,000 ppm (mg/kg) of chromium and are being used by roller ginning industries, attention has been drawn to view the contaminating and polluting aspects during the complete process. The chrome specific dust pollutes the gin-house air and the cotton processing workers suffer from chromium bound diseases and physiological disorders due to the *occupational exposures*. The chromium adsorbed into lint causes allergic symptoms, cancer incidence, brain damage, chronic ulceration and perforation of nasal septums to cotton processing workers. Toxic effects are produced by

prolonged contact with airborne or solid or liquid chromium contamination and pollution even in small quantities. Several CCLC rollers are required in an year due to tremendous wear and tear action arising out of grinding action. This also results in *chrome specific dust (CSD)* production during the process of ginning operation, which is the major unsafe environmental chromium contamination and pollution problems from all 5100 roller ginning industries in the nine cotton growing States of India. The CSD contaminates the lint cotton, spun yarns, woven fabrics and cotton seeds during the cotton roller ginning process (32).

As far as the roller ginning machine construction is concerned, roller is the major component of DR gin. The gin roller length varies from 1025 to 1148 mm with a diameter varying from 178 to 180 mm suitable for operation. The roller consists of 78 to 80 numbers washer disks. Each washer disk is made of dimensions having the diameter 180 mm and thick 1 mm comprising of 18 numbers CCLC flaps stitched and bonded together . Basic Chromium Sulphate (BCS) $Cr\ (OH)\ SO_4\ nH_2O$ and impure chromate having 45-50 % basicity are used during *chrome leather tanning process* for making such CCLC flaps. The various unit operations involved in making washers to final shape of the roller are (i) The washers are filled in a steel shaft having square cross section of 50 mm^2 or hexagonal section of 50 mm E/E to form a roller, (ii) The filled washers are compressed to a pressure of 14 kg/cm^2 by using a conventional pressing machine. The roller is to be pressed on both sides by adding required number of washers on each side, (iii) The pressed roller is turned and finished to diameter 180 mm in a center lathe, (iv) Spiral grooves are made on the surface of the finished rollers. The finished roller is ready for grooving operation by using band saw; initially by marking 'U'-shaped spiral grooves, fixing in the grooving machine and lastly spiral grooves are made on the roller surface by band saw or circular saw cutting machine. The *ginning efficiency* primarily depends upon the surface speed of the roller and number of working strokes on the moving knife. While operation of these rollers in the ginning machines, the rate of ginning goes on declining when the roller diameter is reduced. At the end of cotton season having three months duration, that is after the diameter is reduced to 114 mm, the washers are removed from the shaft. Again the new washers are recovered and cladded in shaft. The worn out and consumed washer disks after considerable period of usage for about three months (27).

Cotton seeds get contaminated with chromium from the source. Present work was aimed initially to identify and study the environmental and health related problems faced with currently used Chrome Composite Leather-Cladding (CCLC) rollers. Some experimental results of chromium analysis and relevant eco-standards, quantity of respirable and suspended particulate matter samples, health survey observations and cotton technological reports of eco-friendly lint and chrome contaminated lint are presented for assessing the hazards of chromium contamination of lint, yarn and fabrics and air pollution problems due to chrome specific dust (CSD). After realizing the hazards of chromium contamination in lint cotton, spun yarns, woven fabrics, cotton seeds, textile effluent and chromium air pollution due to dust-producing grinding CCLC rollers used in ginning environment, there is a need to eliminate this chromium contamination and pollution problem from cotton roller ginning and textile industries.

Hence, the work has been carried out with the following principal objectives:-

To identify and study the environmental related problems existing with the present chrome rollers employed in cotton roller ginning industries**,**

To design and develop eco-friendly chrome-free roller and evaluate its performance with a particular reference to environmental and techno-commercial aspects in ginning industries.

With the author's research background and practical experience in ginning and textile industries, present study is attempted to eliminate this problem, through a suitable design and development of an eco-friendly, chrome-free roller for cotton roller gins. An eco-friendly roller ginning process is developed for replacing conventional CCLC roller ginning process to eliminate the unsafe chromium contamination and pollution from roller ginning industries so as to meet the requirements of the environmental standards while maintaining high quality spun yarns and woven fabrics meeting the international standards (32).

2 Problem Formulation

The objectives of this research are (1) to identify and study the environmental and health related problems existing with the present chrome composite leather clad (CCLC) rollers employed in cotton roller ginning industries and 2) to design and develop an eco-friendly non-chrome rubberized cotton fabric roller and evaluate its performance with a particular reference to commercial and environmental aspects in cotton ginning industries.

With the author's research background and practical experience in ginning and textile industries, present study was attempted to eliminate this problem to the great extent at the source itself, through a suitable design and development of an eco-friendly, pollution-free chrome less roller for cotton roller gins (34). An eco-friendly roller ginning process has been developed for replacing conventional CCLC roller ginning process to eliminate the chromium contamination and pollution from cotton roller ginning industries so as to meet the requirements of environmental standards while maintaining high quality spun yarns and woven fabrics meeting the international standards.

2.1 Environmental Impacts of CCLC Rollers

Environmental impacts of CCLC rollers are assessed from the pollutants *viz., cotton dust* and *chrome specific dust* (CSD) in the mill atmosphere. The *cotton dust* released in the ginning process is a complex and variable mixture of cotton fibres, undeveloped ovules, cotton plant debris including twigs, bract and *pericarp* particles left after the ginning process together with soil particles, bacteria, fungi and residues from pesticides. The visible and invisible dust in the mill atmosphere is known as '*Fly'*. The ambient air particles of about 2.5 μm are classified as cotton dust in ginning environment. *Byssinosis* is a disease due to the inhalation of cotton dust over long period of time (Shirley Vol. II, 1982). It is a permanent disabling lung disease. The symptom is chronic cough ending in chronic bronchitis (respiratory disorder). India has a large number of ginning and textile mills employing 48% of all the factory workers. About 55% of mill workers suffer from *byssinosis* disease (8). As per the rough estimate during field survey/discussions with ginning industry management, presently, there are about 2,13,000 CCLC rollers, which comprise of 1,70,40,000 CCLC washers are used for a cotton season of three months in our country. At present, there are about 7,60,000 people working in 5100 roller ginning

industries and 15,90,000 people working in 6,000 textile industries who are occupationally affected due to the unsafe chromium and pollution problems (19).

3 Problem Solution

The second part of the present study pertains to nullify the unsafe chromium pollution and contamination problems in cotton ginning and textile industries. An exhaustive study is needed for the design and development of eco-friendly chrome less roller, which can be alternatives to the existing CCLC rollers. An exhaustive material studies are done for the suitable material's selection of the gin rollers. These were made of Walrus animal skin, Spider tuck packing, coir-board, rubber packing, metal cylinder, rubber roll, fabric and rubber packing, leather, cotton, rubber and cork, plastics and fluorinated ethylene propylene (11). The peculiar gripping action or adherence of the cotton fibres to the roller surface was considered while designing the rollers. The leather surfaces possess *interfibrillary* action, which enables to adhere the fibre on the surface. This particular property was studied extensively for the different materials and combination of different materials so as to design and fabricate laboratory gin chrome less rollers for gin roller experimentation device (GRED) and prototype eco-friendly chrome less rollers for existing DR gins.

3.1 Materials and Methods

For the present study, roller wearing and compaction rate study were conducted in Roller ginning industries at Belgaum for the cotton seasons 1996-1997 to 1998-2000 and 2001-2002 including 2004-2005. The roller gins are adjusted using spacers as per the standards (10). Grooving is done regularly at the start of each shift as per cotton varieties. To study the heavy metal as total chromium mg/Kg (ppm) in cotton lint samples, seed samples, seed-cotton samples, CCLC roller samples, CCLC roller samples collected during grooving operation, soil samples from the region of investigation is made, root of the plant for bio-availability, fibre, yarn, fabric samples, textile effluent samples, the standard American Public Health Association (APHA) method is followed for chromium (as total and hexavalent) analysis using Atomic Absorption Spectrometer (AAS). Respirable and suspended particulate matter quantity in gin house air is monitored using High Volume Air Sampler (HVAS) cascade impactor with appropriate glass fibre filters. The quantity of pollutants are collected in HVAS as 8 hours basis and analyzed for chromium. The worker dose and exposure time are found using a personal sampler. Cotton technological parameters were tested using High Volume Instrument (HVI) and Scanning Electron Microscope (SEM) for chrome roller ginned lint and eco-friendly roller ginned lint and were confirmed to the international standards (18).
A health study is conducted by the author at Guntur, Bailhongal, Sendwa, Surendranagar, and Tanzania , where maximum number of ginning factories are situated to survey the conditions of health effects and occupational health hazard exposures . In view of the environmental problems existing with the present CCLC rollers employed in ginning industries and subsequent to literature survey made, it was decided to develop environmentally free alternatives (19).
The ginning investigations were carried out at Central Institute for Research on Cotton Technology (CIRCOT), Mumbai. The laboratory rollers for GRED were designed and

fabricated at Calcutta at a local manufacturing firm. Experiments with the designed rollers were conducted at CIRCOT, Mumbai along with the cotton technological parameters. After the initial tests, pilot model rollers were designed and fabricated which were tested in ginning factories at Bailhongal and Sendhwa. Environmental analysis was done in Centre of Mining Environment, Indian School of Mines, Dhanbad, and Eco-Textile laboratory, Mumbai. Mechanical properties were analyzed in various mechanical engineering laboratories.

3.2 Results and Discussions

An experiment was carried to find out the wearing and compactness rate of CCLC rollers used by roller ginning industries for a season lasting three months. At the start of season the diameter of rollers were 180 mm. At the end of season the roller dimensions were noted at left, middle and right positions for all the roller gins in the factory that is 18 ginning machines. Roller side "A" was the front side of the gin. Roller side "B" was the rear side of the DR gin. The results are presented in Table 1. Apart from the wear rate, the table expresses the quantity of pollutants generating during the operation such as, leather powder, cotton dust and chrome specific dust. It was found that the wearing rate was 0.033 mm / hour and the percentage material removed per roller was 43.8%. The final outside diameter at the end of study was nearing to 140mm. Chromium roller compaction rate was 0.050 mm/hour that is 50 μm / hour. Figure 8 depicts a graph of wearing rate of dust-producing grinding of CCLC roller and RCF roller.

Chromium analysis reports of cotton lint samples, seed and seed linter, seed-cotton samples, fiber, yarn and fabric samples were tabulated in Table 2. The CCLC roller contains 18 077 mg/kg (ppm) to 30 780 mg/kg (ppm) as total chromium (3 to 4% as total chromium). This included trivalent and hexavalent chromium. During the ginning operation, lint adsorbs chromium particles, which contains 143 mg/kg (ppm) to 1994 mg/kg (ppm). Chromium concentration in dust samples, SPM and RSPM of different ranges are provided in Table 3. The CCLC roller was grooved at the start of each shift and filing or turning of the roller for leveling was done to get a uniform diameter at the start of each season. At that time, the chromium content in the lint cotton was 1994 mg/kg (ppm). The total weight of chromium removed during a cotton season of 16 hours per day was 450 to 600 grams per gin roller. The chrome specific dust from one ginning machine entered the environment to the level of 143 ppm. The environmental standards for chromium in spun yarn are 2 ppm and Cr (III) for baby clothing and fabric is 0.1 ppm and nil for Cr (VI). The traces found contain hexavalent chromium being adsorbed from contaminated lint, yarn to fabrics and subsequently cannot be removed in fabrics. There is evidence that the toxic effects on humans due to Cr (III) and Cr (VI) of its carcinogenecity and corrosiveness. The analysis shows that traces of Cr (VI) are found in even laboratory grade trivalent chromium compounds and complications do arise due to the reducibility nature of these traces that affect the organic tissues of the body. These regenerating effects occur rapidly and depend on the worker dose and exposure time.

Table 1. Roller wear results for rollers with initial diameters of 180 mm

Machine Number	Outside Diameter of the Rollers After One Cotton Season(mm)*					
	Roller Side 'A' is the Front Side of the Machine			Roller Side 'B' is the Rear Side of the Machine		
	Left	Middle	Right	Left	Middle	Right
1	140	140	140	141	143	142
2	140	140	140	140	142	142
3	145	146	150	150	145	140
4	153	153	153	148	148	148
5	148	147	148	148	148	148
6	146	147	148	146	146	146
7	135	135	135	145	142	140
8	140	140	140	145	142	140
9	150	150	150	148	148	148
10	138	136	136	136	136	136
11	145	145	146	145	145	145
12	136	136	136	136	136	136
13	158	158	158	158	157	157
14	160	160	160	161	160	160
15	154	154	154	155	156	156
16	155	155	156	155	154	154
17	160	160	159	160	160	160
18	160	160	161	160	161	166

**Initial diameter of the rollers = 180 mm .*

Table 2 . Chromium Contamination levels in cotton and its products

Cotton and its Products	Total Chromium	Eco-Standards*
Lint cotton	143-1990 ppm	0.1 ppm
Spun yarns	17- 250 ppm	0.1 ppm
Woven fabrics	17- 45 ppm	0.1 ppm
Cotton seeds	0-312 ppm	2 ppm
Edible oil	0-259 ppm	2 ppm
Oil cake	0-190 ppm	2 ppm
Linter	0-159 ppm	0.1 ppm

*Environmental Standards as per Ministry of Environment and Forests (1996)

Following were the significant findings of chromium in dust samples with relevant eco-standards

Table 3 : Chromium level in dust samples

Sources of Cotton dust	Total chromium	Standards* LD_{50}
Ginning point	51-173 ppm	50 ppm
CCLC grooving point	17-1994 ppm	50 ppm
Respirable Suspended Particulate Matter (RSPM) Below 1 microns	51-190 ppm	50 ppm
RSPM 1 to 3 microns	119-142 ppm	50 ppm
RSPM 3 to 5 microns	103- 295 ppm	50 ppm
RSPM 5 to 7 microns	56-152 ppm	50 ppm
RSPM 7 to 10 microns	52-133 ppm	50 ppm
Suspended Particulate Matter (SPM) in Gin House Air	159 ppm	50 ppm

*U.S. National Institute of Occupational and Safety Hazard Standards (1992)

Hence, CCLC roller contains 18,077 mg/Kg (ppm) to 30,780 mg/Kg (ppm) as total chromium (3 to 4% as total chromium). This included trivalent and hexavalent chromium. During the ginning operation, lint adsorbs chromium particles which contains 143 mg/Kg (ppm) to 1994 mg/Kg (ppm). The CCLC roller is grooved at the start of each shift and filing or turning of the roller for leveling is done to get uniform diameter at start of each season. At that time, the wearing of roller is more and presence of chromium to the extent of 1994 mg/Kg (ppm) with lint. The total weight of chromium removed during a cotton season of 16 hours per day is 450 to 600 grams per gin roller gin. The chrome specific dust from one ginning machine enters in to environment and being adsorbed in lint stage having the level of 143 ppm. The environmental standards for chromium in spun yarn is 2 ppm and Cr (III) for baby clothing and fabric is 0.1 ppm and nil for Cr (VI). The traces found contain hexavalent chromium being adsorbed from contaminated lint, yarn to fabrics and subsequently cannot be removed in fabrics. There is evidence that the toxic effects on humans due to Cr (III) and Cr (VI) of its carcinogenecity and corrosiveness. The analysis show that traces of Cr (VI) are found in even analar grade trivalent chromium compounds and complications do arise due to the reducibility nature of these traces that affect the organic tissues of the body. This regenerating effects occur rapidly and dependent of the worker dose and exposure time.

3.3 Estimation of Cancer Risk due to Occupational Exposure

Estimation of the cancer risk for a 60-*kg* worker who has worked in a ginnery and textile mill exposed to a particular carcinogen under the following circumstances. Exposure time was 6

days *per week*, 30 weeks *per year*, over a period of 20 years. The worker was to breath heavily for 2-hour per workday at the rate of 1.5 m^3/hour and 10 hour per workday at a moderate breathing rate of 1 m^3/hour. The carcinogen has a potency factor of 0.02 *(mg/kg/day)* $^{-1}$ and an absorption factor was estimated at 80% and its average concentration in the air 2.05 mg/m^3 . The data were obtained from chromium concentration in ambient air.

The total amount of air breathed per workday =

∴ Daily intake rate = 1.5 X 2 (m^3 /day) + 1 (m^3 /day) X 10 = 13 m^3 /day.

The total dose = Contaminant concentration X Intake rate X Exposure time X Absorption Factor

13 m^3 /day X 6 days/week X 30 weeks per year X 20 years X 0.8 X 2.05 *(mg/kg/day)* $^{-1}$

= 76752 mg

Using a standard estimate of 70 years for a lifetime, the chronic intake daily (CID) was

$$\text{CDI in mg/kg/day} = \frac{\text{Total dose } (mg)}{\text{Body weight } (kg) \text{ X Lifetime } (days)}$$

$$= \frac{76752}{13 \text{ X } 70 \text{ X } 180 \text{ } days/year}$$

$$= 0.1 \text{ } mg/kg/day$$

$$\text{The cancer risk} = 0.1 \text{ } (mg/kg/day) \text{ X } 0.02 \text{ } (mg/kg/day)^{-1}$$

$$= 2.02 \text{ X } 10^{-3} \text{ } (\textbf{\textit{2020 chances in one million}})$$

3.4 Results of Design and development of eco-friendly technology

The manufacturing technology, design engineering features and assembly drawings show that the conventional fabric and rubber roller gin covering material is selected with the following characteristics, namely,

(1) Hardness of 90 (type DO durometer) ,
(2) 9 to 10 layers of fabrics 20 mm length,
(3) Thickness of fabrics 1.2 mm,
(4) The rubber compounding is resilient and
(5) 0.76 mm of fibre bristles protrude beyond the rubber surface is maintained in spite of wear.

On the basis of the design and development of various rollers with subsequent performance evaluation studies, chrome-free RCF roller has been demonstrated with reference to techno-commercial and eco-friendliness in ginning industries. The newly developed RCF rollers are successful and effective in functioning and in ginning out the seed-cotton. Cost economics study reveals that eco-friendly RCF roller ginnery sounds better in all aspects with reference to environmental, cotton technological and techno-commercial aspects.

4 Conclusion

The CCLC rollers used in ginning industries get powdered during ginning operation and enter the environment as Chrome Specific Dust. It was observed that the chrome specific dust contaminates cotton and its products. Since the semi-finished chrome leather washers contains 3 to 4% as total chromium that is around 36,000 ppm (mg/kg) of chromium and are being used by roller ginning industries, attention has been drawn to

view the contaminating and polluting aspects during the complete process. The chromium adsorbed into lint causes allergic symptoms, cancer incidence, brain damage, chronic ulceration and perforation of nasal septums to cotton processing workers. Toxic effects are produced by prolonged contact with airborne or solid or liquid chromium contamination and pollution even in small quantities. India has a large number of ginning and textile mills employing 48% of all the factory workers. About 55% of mill workers suffer from *byssinosis* disease. As per the rough estimate during field survey/discussions with ginning industry management, presently, there are about 2,13,000 CCLC rollers, which comprise of 1,70,40,000 CCLC washers are used for a cotton season of three months in our country. At present, there are about 7,60,000 people working in 5100 roller ginning industries and 15,90,000 people working in 6,000 textile industries who are occupationally affected due to the unsafe chromium and pollution problems.

The chromium contamination levels for cotton and its products were abnormal for all the samples except that the cotton samples obtained from RCF roller gin rollers *i.e.,* eco-friendly ginning industries. As per the environmental standards , chromium content in cotton and its products not to be more than 0.1 ppm. The samples, namely, lint cotton, yarn, fabrics, seed, linter, edible oil and oil cake were found contaminated and their levels were in the range of 110 to 1990 ppm obtained from the source of dust-producing grinding CCLC rollers sample which contained 18,077 to 30,783 ppm. The ginned lint cotton gets contaminated to an extent of 143 to 1990 mg/kg (ppm) of chromium and the woven fabrics to the tune of 17 to 45 ppm of chromium against the safe limit of 0.1 ppm. Hence, chromium leaks into environment beyond the permissible levels which threat to cotton processing workers and users of cotton garments. The cancer risk of occupational exposures was found to be 2020 chances in all mills. The chromium was not detected from RCF ginned lint cotton as there is no chromium in the source, which confines to the eco-standards. The air pollution due to CSD and cotton dust, which is responsible for synergistic (augmentative) health complications of chromium based diseases and byssinosis diseases on ginning industry workers. Almost most of the mills in India *are not provided* with dust control systems. Nor they provide personal protection devices to the workers. It is mentioned that the ginning industries are located in and around cotton growing areas and employ women in the age group of 21 to 40 years for *menial jobs* and male workers in the age group of 18 to 50 years. The women often come along with their *children* for performing their jobs, like (i) feeding seed-cotton (or *kapas*), (ii) collecting the lint cotton, seed and floor sweeping, (iii) cleaning and grading the seed-cotton and (iv) light activities. The children are exposed directly to CSD. The health effects and reports of the workers have not come out into public, because (i) almost all the workers are not in regular employment, (ii) the cotton ginning industry functions seasonally for 6-8 months in semi-arid zones and 8-10 months in rain fed areas in an year, (iii) the workers are reluctant to go for their medical checkup because of their negligence and fear and (iv) they are economically not sound enough to go for their medical treatments.

On the basis of the design and development of various rollers with subsequent performance evaluation studies, chrome-free RCF roller has been demonstrated with reference to techno-commercial and eco-friendliness in ginning industries. The newly developed RCF rollers are successful and effective in functioning and in ginning out the seed-cotton. Cost economics study reveals that eco-friendly RCF roller ginnery sounds better in all aspects with reference to environmental, cotton technological and techno-

commercial aspects. This improved technology is amenable for commercialization to the industries.

Though the initial cost of the RCF roller is 11 times more than the life of CCLC roller, the high price is compensated, as it is durable up to an estimated life of seven years than more of a few months of CCLC rollers. Besides, it ensures the following advantages.

(1) There is negligible wear and tear and also zero maintenance,

(2) High ginning efficiency and output of about 1.25 times more than the CCLC rollers because the developed roller made up of rubberized cotton fabrics has a surface finish conducive to high ginning efficiency,

(3) 50% reduction in the weight of the rollers consume 25% less in energy consumption that is power saving of three times less compared to CCLC roller ginneries.

(4) It is observed that the noise level in eco-friendly ginneries is reduced to a range of 4 to 7 dB (A) due to inherent properties and cushioning effects,

(5) Eco-friendly cotton and its products can be obtained.

(6) Labour output / hr is 2.4 standard performance rating, that is twice than CCLC ginneries because of cleaner environment.

(7) Medical charges for treating the affected workers decrease manifold.

The newly designed and developed eco-friendly ginneries eliminate chromium contamination and pollution from cotton ginning industries. These give rise to control at-source pollution control, such that the industries meet the requirement of environmental standards being enforced by many countries and high quality yarns and fabrics meeting international standards be produced. The industries will be free from chrome-related contamination and pollution problems, occupational and non-occupational health hazards. The ginneries have been tested commercially and found better in all aspects with reference to cotton technological parameters, dye-catching properties, physical and chemical properties. It could be successfully used commercially as an improved alternative in cotton ginning industries for the cleaner environment with benefits to society, industry owners, traders, workers, employees and the Government.

Recommendations

Most of the cotton ginning operations are done by using DR gins in India, Africa, China, Tanzania and Egypt. Out of the lint cotton obtained from CCLC roller ginneries in these countries, it is quite important to appreciate the fact that the lint cotton so produced is contaminated with chromium heavy metal which produces deleterious effect on the people working in the vicinity. Yarn and seed obtained are also contaminated with chromium. Hence it is imperative that a policy decision must be taken to replace the presently used CCLC rollers with eco-friendly rollers designed and developed in this research project.

2. Industry, Government and Regulators should come forward to subsidize this venture in view of its demonstrated technology.

3. Urgent steps are required to be taken by the National and international Government Regulatory authorities for transfer of this innovative technology to cotton ginning industries and thus save environment from unsafe chromium contamination and pollution.

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