



Case studies on the risk assessment of hazardous effect of photocopier machine in Guwahati city, India

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Abstract

In the present scenario, photo-imaging in any documentation and records has become a part and parcel of life across the world today. It is performed by Xerox machine that are suspected to emit volatile organic compounds, toner dust as well as other chemicals such as styrene, iron oxide, black carbon and polycyclic aromatic hydrocarbon etc. These may become the potential source of pollutant gases. Thereby, it also represents a risk of health hazards of the employees and general public. Owing to extensive application of photocopier on daily basis, the present study was undertaken to investigate the risk assessment of Xerox toner dust on the health of operators in certain areas of Guwahati where the machines are used in an extensive way. The present work was executed through case studies by conducting a survey on individual interview with standard questionnaire. The result was analyzed on the basis of initial, short term and long term exposure during machine operation. Out of 150 studied cases, 88 cases were recorded as affected along with 62 normal cases. Middle age group i.e., 25-45 years were affected mostly. Symptoms were generally nausea, backbone pain, eye irritation, loss of hair, running of noses in initial exposure whereas headache, dizziness, itching of body, skin loss of palm, pharyngeal mucosa, respiratory problem and asthma like cough were recorded in the individuals exposed to long term machine operation. Some striking cases revealed gastric ulcer and allergic rhinitis and obstructive respiratory disease with 'Lung overloading' that might be caused from photo copier dust. Depending on the photo copier utility as "urgent need for documentation" in the present day as well as concern with the risk of hazardous impact on public health, a thorough investigation both in experimentation and a detailed survey works are essentially required in this line, which may lead to establish some unwanted physical disorders.

Keywords : Photocopy, Documentation, Health hazards, Respiratory problem, Lung overloading.

1. Introduction

The rapid technological advancement has resulted in the release of thousands of newer chemicals day by day into the environment without having a detailed information about their impact. Humans are thus exposed to a variety of these xenobiotics on daily basis on account of their occupation or living in a toxic environment. One such technological advancement is the photocopier which is an essential need for documentation and records. Therefore, photo imaging has become a part of life for the people

across the world. This is performed by Xerox or photocopier machine which is suspected to emit some harmful compounds like toner dust, Volatile Organic Compounds (VOC), ozone and other chemicals such as styrene, black carbon, iron oxide, polycyclic aromatic hydrocarbons etc (Ewers and Nowak 2006, ILSI 2000). Powdered toner contained in the photocopier are used for printing character and images. Thus a certain section of population may be currently exposed to the toner powder. Among them, a group of population have high level of frequent exposure to

toner particles due to direct contact during the process of manufacturing and changing toner powder and cartridges as well in maintaining active devices. On the other hand another group such as machine operators and other staffs near the place of imaging process are likely to be exposed to the emissions produced by photocopying rather than have less chance of being exposed to toner dust directly. Whereas people receiving Xeroxed copy are getting exposed to ultrafine particles (diameter < 0.1 μm) emitted from the hard copy that has become a point of public health concern (He *et al.*, 2007, Schripp *et al.*, 2008 and Wensing *et al.*, 2008). A policy is adopted by Xerox corporation that all products and materials marketed worldwide meet recognized standards for safety, health and environment and to ensure that "good practice" is followed where no such standards exist or apply. In spite of this adopted policy for safety measure, standard protocols for operation of these devices were not maintained in many countries especially developing countries like India, Pakistan and Bangladesh. As a result a number of harmful substances are released during the operation of the machine which may directly affect operators and indirectly affect the consumers and general public.

Xerox toners consist of fine powder composed of plastics, colorants and are typically designed using styrene-acrylic, styrene butadiene or polyester polymers. In black toners, several different specially grade carbon blacks (GCB) or iron oxide are used as colorants. Besides some organic and inorganic impurities like nitropyrenes and polycyclic aromatic hydrocarbon (PAH) as well as trace elements are found to be contained in black carbon and iron oxide (Lo'froth *et al.*, 1980 and Jungnickel *et al.*, 2002). Toner dust belongs to the group of respirable fine particles (having diameter 2 to 10 μm) (Lin and Mermelstein, 1994; Moller *et al.*, 2004) and on inhalation lead to the predominant deposition in the tracheo-branchial and alveolar region. Long term inhalation exposure to higher toner concentration results in accumulation of toner particles in the

lung causing chronic inflammation and lung fibrosis (Bellmann *et al.*, 1991 and Muhle *et al.*, 1990, 91 and 98). It is reported that inhalation exposure to toner may be associated with symptoms of the upper and lower airways in sensitive subjects (Ewers and Nowak 2006). A minor fraction may also be deposited in the nose, the larynx and the pharynx. Polycyclic aromatic hydrocarbons (PAH) represent a danger because of their potential carcinogenic and mutagenic capabilities (Gallardo *et al.*, 1994). The consequences of exposure to concentrations of ozone is the most common concern amongst users of photocopiers and laser printers. As ozone is highly reactive substance, any adverse health effects will be found essentially at the sites like the respiratory tract (nose, throat and airways), and lungs at initial contact while in the eyes with higher concentration.

Under the contemplated background of the excessive public utility and the mixed effect (positive/negative) of toner and Xerox particles on humans, the present epidemiological study was undertaken to assess the risk of health hazards on human subjects on their occupational exposure to photocopier particles or Xerox toner in several areas of Guwahati city.

2. Study design and Methods

The study was designed to conduct a survey work on the volunteer subjects in some selected places of Greater Guwahati, where Xerox machines are used regularly in an extensive way. These selected areas are viz Pan Bazar area, Guwahati High Court and CJM Court area, Jalukbari area, Gauhati University market area, Maligaon area, Uzan Bazar area, Guwahati Medical Colloge Hospital area. Two categories of individual subjects were taken into consideration in the study. Category I : includes human subjects those who operates photocopier machine get constant exposure from fine toner dust particles and machine emissions. Category II : includes Technicians and other individuals involved in maintenance of the machine who are directly exposed to toner powder. Less number of

individuals were interacted in category II during the study period as they were not frequently available in the survey sites. Therefore, special emphasis was given to study individuals belonging to category I.

The evaluation was made upon standard questionnaires. Prior to commencement of investigation the details of the questionnaire and the purpose of the survey was explained to the individuals who participated voluntarily in this program and written consent was obtained from each of the individual during the survey. The investigation was conducted on the basis of different duration of exposure and the various age groups of both the sexes. In this study four different terms of exposure viz Initial exposures (0 to 15 days), Short term exposure (1 to 3 years), Mid term exposure (3 to 10 years), Long term exposure (10 years and above) were taken into account. During the survey period operators belonging to category I were divided into four age groups which include 15 years to 25 years, 25 years to 35 years, 35 years to 45 years, 45 years to 55 years which are marked as Group I, II, III and IV respectively. Whereas only male individuals were considered in the category II who belonged to the age group between 25 to 35 years. This is because more number of individuals who are professionally involved to perform this work generally belonged to this age group. Cases were evaluated on the basis of presence of different physical ailments and their intensity in relation to different age group and exposure of Xerox particles and emissions. Assessment was done by scoring grade ('+', and '-' sign). Statistical calculation was done by method of Snedecor and Cochran (1967).

3. Results

A total of 150 cases were studied during the survey, out of which 88 cases were recorded as affected and 66 were recorded as normal unaffected cases during operation and maintenance of Xerox machine. The details of affected and non affected cases in the Category I and Category II with their different age groups along with their percentage are given in table I (Fig.1). During study period,

the condition of the room in most of the cases where photocopying is performed, were found to be damp, congested, dark and not well ventilated [Plate I (A & B)]. Persons were found to be have continuous exposure from Xerox particles and emissions during operation and maintenance as well as changing toner cartridges [Plate I (B, C, D)]. An average of 4-8 hrs of duration of operation of machine were recorded in different individual cases. Maximum percentage of affected cases were recorded in the age group between 25 to 45 years i.e. in the Group I and Group II of category I showing 75.68% and 66.67% respectively. On the other hand, mostly affected individuals were found in the cases having an exposure period of 10 years and above. Among various affected cases in both categories, six numbers of individual cases were found to be mostly affected in each age group in relation to their duration of exposure along with various ailments [Table 2 (A, B and C)]. In group IV only one case of 50 years of age was found to have more symptoms of physical ailments. Again various physical ailments scored by graded intensity ("+" and "-") in the affected and non affected cases are shown in table 3 (A and B) in relation to different age groups and various duration of exposures. Physical ailments scored by +4 and +5 was recorded in mid term and long term exposure period, whereas in terms of age groups three different age groups (i.e. 25-35 yrs, 35-45 yrs and 45-55 yrs) depicted the highest score. Symptoms mostly reported are running noses, irritations of the conjunctiva and pharyngeal mucosa as well as asthma like cough, an allergic rhinitis and obstructive respiratory disease. The patients increasingly had respiratory problems like infections of the upper and lower respiratory tract, breathing difficulties, cough and sinusitis. The operators were also found to suffer from some other major physical ailments like nausea, backbone pain, eye irritation, loss of hair, running noses in initial exposure whereas headache, dizziness, itching of body, skin loss of palm, pharyngeal mucosa, gastric, disorder in digestion, gall bladder stone, kidney stone, respiratory problem and asthma like cough were recorded in long term machine operators.

Table - 1 : Shows details of individuals exposed to chemical components of Xerox machine

Major category	Total no. of cases studied	Total no. of affected cases	% of affected studied	Total no. of unaffected cases	% of unaffected cases
Category I	113 M=74, F=39	72	63.72	41	36.28
a) Group I (15-25yrs)	25 M=17, F=8	15	60	10	40
b) Group II (25-35yrs)	37 M=23, F=14	28	75.68	9	24.32
c) Group III (35-45yrs)	33 M=18, F=15	22	66.67	11	38.33
d) Group IV (45-55yrs)	18 M=16, F=2	7	38.89	11	61.11
Category II (25-35yrs)	37 M=37	16	43.24	21	56.77

M — male and F — female.

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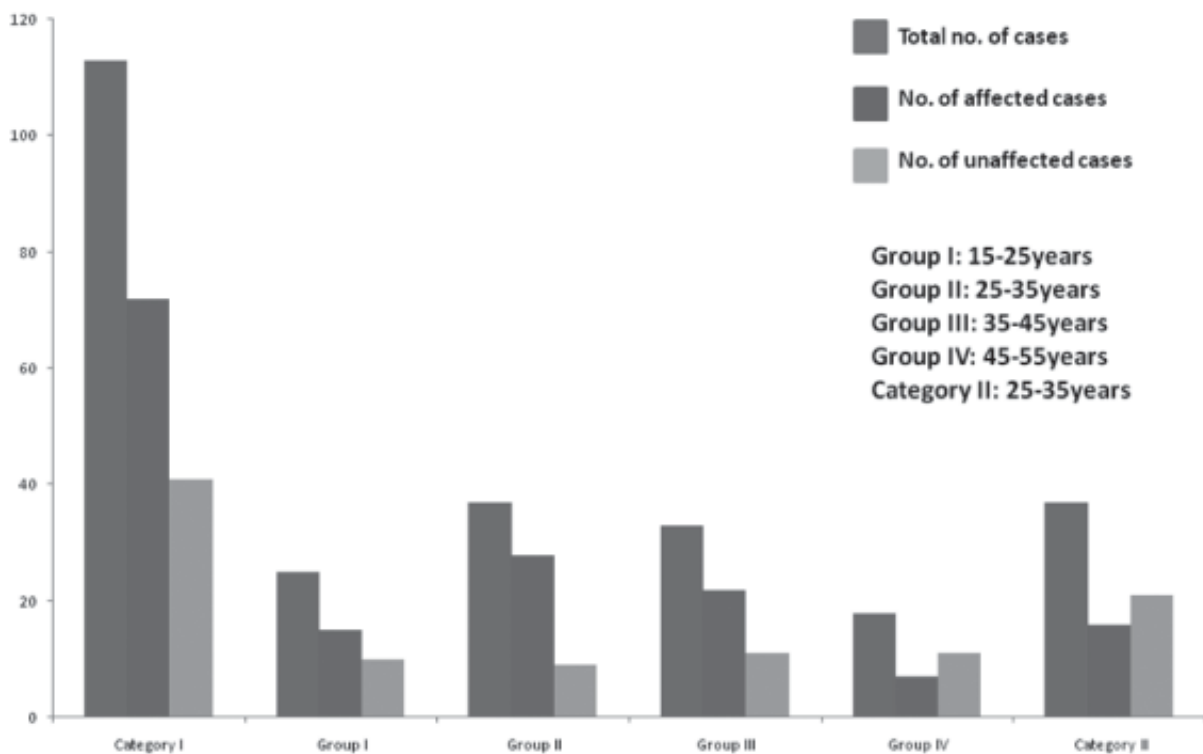


Fig. 1 : Shows total number of the surveyed cases along with affected and unaffected cases of operators and maintainers exposed to xerox emissions and particles.

Table - 2A : shows xerox component's affected cases of individuals between age group (15-25yrs) in relation to physical ailments and duration of exposure (M-male and F-female)

Case no.	Age of operation (yrs)	Duration of operation per day	Duration of operation (yrs)	Initial exposure (0-15 days)	Short term exposure (1-3 yrs)	Mid term exposure (3-10 yrs)	Long term exposure (10 yrs onwards)
1.	18 (M)	6	3	Nausea, backbone pain, eye and skin irritation	Nausea, headache, eye irritation, hair loss	Giddiness, headache, skin itching, vision disorder, indigestion, hair loss	—
2.	21 (F)	4	3	-Do-	-Do-	-Do-	—
3.	25 (F)	5	10	-Do-	-Do-	-Do-	Giddiness, headache, skin loss of palm, sleep disturbances, itching, vision disorder, indigestion, hair loss, gastric, ulcer, respiration problem (Asthma)
4.	23 (M)	8	8	-Do-	-Do-	-Do-	—
5.	24 (F)	8	10	-Do-	-Do-	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, gall bladder stone	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, gastric, ulcer
6.	22 (M)	7	7	-Do-	-Do-	-Do-	—

M — male and F — female.

Table - 2B : Shows xerox component's affected cases of individuals between age group (25-35yrs) in relation to physical ailments and duration of exposure

Case no.	Age of operation (yrs)	Duration of operation per day	Duration of operation (yrs)	Initial exposure (0-15 days)	Short term exposure (1-3 yrs)	Mid term exposure (3-10 yrs)	Long term exposure (10 yrs and above)
1.	27 (M)	2	12	Nausea, backbone pain, eye irritation	Nausea, headache, eye irritation, hair loss	Giddiness, headache, skin loss of palm itching, vision disorder, indigestion, hair loss	Giddiness, headache, skin loss of palm itching, vision disorder, indigestion, hair loss, liver problem (Jaundice)
2.	28 (M)	7	13	-Do-	-Do-	-Do-	-Do-
3.	30 (M)	5	10	-Do-	-Do-	-Do-	-Do-
4.	29 (F)	8	11	-Do-	-Do-	-Do-	-Do-
5.	31 (M)	4	13	-Do-	-Do-	-Do-	-Do-
6.	32 (F)	6	14	-Do-	-Do-	-Do-	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, gastric, ulcer, respiration problem (Asthma), gall bladder stone

M—male and F— female.

Table - 2C : Shows xerox component's affected cases of individuals between age group (35-55yrs) in relation to physical ailments and duration of exposure

Case no.	Age of operation (yrs)	Duration of operation per day	Duration of operation (yrs)	Initial exposure (0-15 days)	Short term exposure (1-3 yrs)	Mid term exposure (3-10 yrs)	Long term exposure (10 yrs onwards)
1.	36 (M)	8	12	Nausea, backbone pain, eye and skin irritation	Nausea, headache, eye irritation, hair loss	Giddiness, headache, skin loss of palm itching, vision disorder, indigestion, hair loss	Giddiness, headache, skin loss of palm itching, vision disorder, indigestion, hair loss
2.	37 (M)	4	14	-Do-	-Do-	-Do-	-Do-
3.	39 (M)	8	15	-Do-	-Do-	-Do-	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, asthma
4.	42 (M)	5	16	-Do-	-Do-	-Do-	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, asthma, gall bladder stone
5.	43 (F)	3	17	-Do-	-Do-	-Do-	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, asthma, gall bladder stone, jaundice
6.	50 (M)	6	19	-Do-	-Do-	-Do-	Giddiness, headache, skin loss of palm, itching, vision disorder, indigestion, hair loss, gastric ulcer, respiration problem (Asthma), kidney stone

M—male and F— female.

Table - 3A : Intensity of different physical ailments in relation to different exposure period

Period of exposure (yrs)	Hair loss, skin irritation, skin loss (A)	Vision disorder (B)	Headache Nausea (C)	Indigestion Gastric (D)	Liver disease Gall Bladder stone (E)	Kidney problem/lung overloading (F)
Initial stage (0-15 days)	— = 0	— = 0	— = 0	+ = 1	— = 0	— = 0
Short term (1-3 years)	++ = +2	++ = +2	++ = +2	+++ = +3	— = 0	— = 0
Mid term (3-10 yrs)	+++ = +3	++++ = +4	++ = +2	+++ = +3	++ = +2	+ = +1
Long term (10 yrs-onwards)	+++++ = +5	+++++ = +4	+++ = +3	+++++ = +4	+++ = +3	++ = +2

Table - 3B : Intensity of different physical ailments in relation to different age group

Age Group (yrs)	Hair loss, skin irritation, skin loss (A)	Vision disorder (B)	Headache Nausea (C)	Indigestion Gastric (D)	Liver disease Gall Bladder stone (E)	Kidney problem/lung overloading (F)
15 to 25 yrs	— = 0	— = 0	— = 0	+ = 1	— = 0	— = 0
25 to 35 yrs	++ = +2	++ = +2	++ = +2	+++ = +3	— = 0	— = 0
35 to 45 yrs	+++ = +3	++++ = +4	++ = +2	+++ = +3	++ = +2	+ = +1
45 to 55 yrs	+++++ = +5	+++++ = +4	+++ = +3	+++++ = +4	+++ = +3	++ = +2

Intensity Grade :

— = no effect, + = Low, ++ = Average, +++ = Moderate, ++++ = High and +++++ = Extensive.

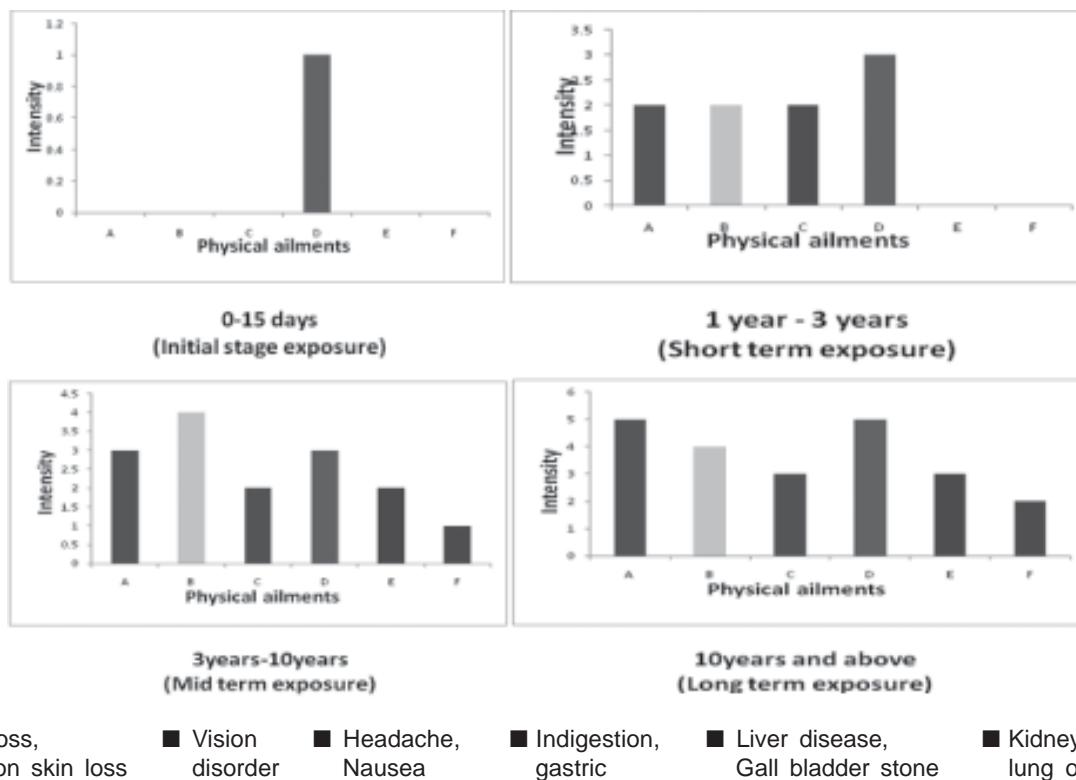


Fig. 2A : Shows the intensity of different physical ailments during various exposure periods.

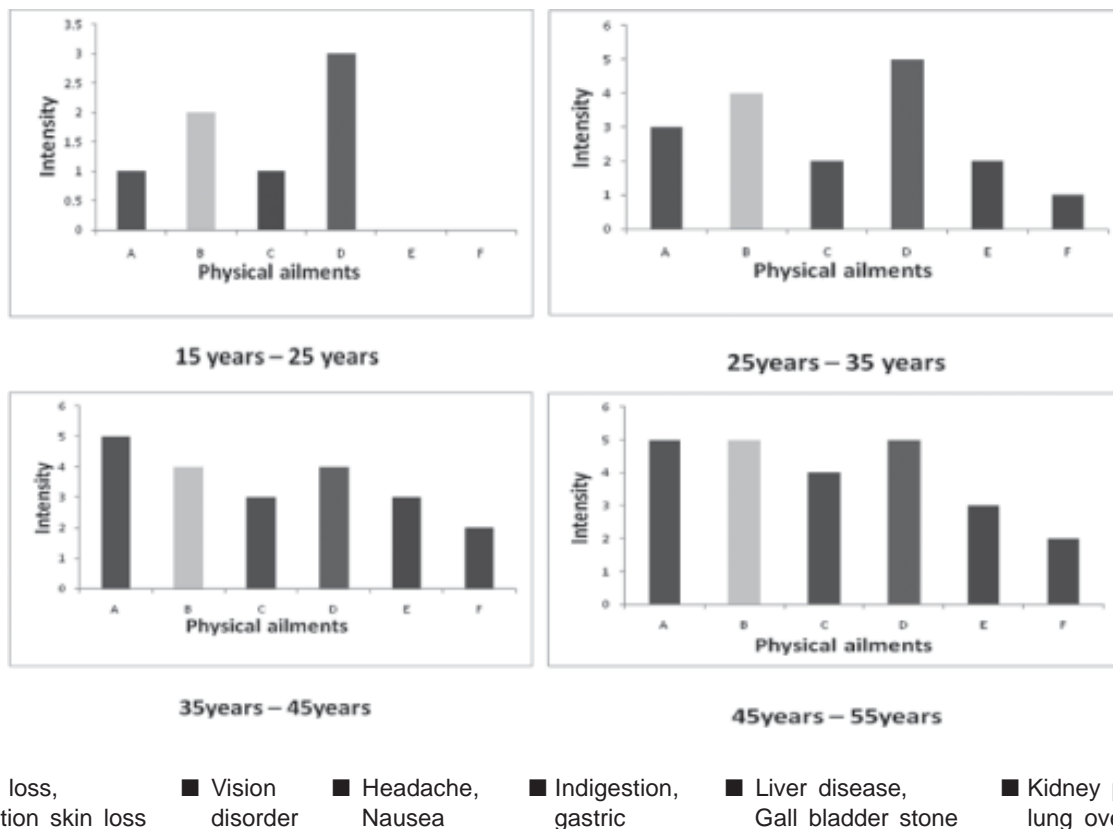


Fig. 2B : Shows the comparison of intensity of different physical ailments among different age groups.

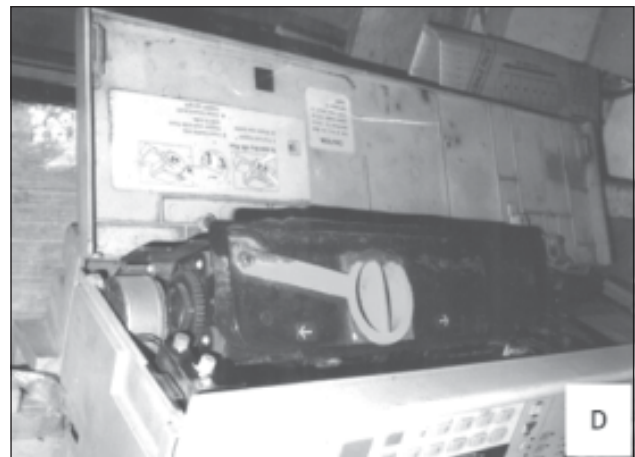
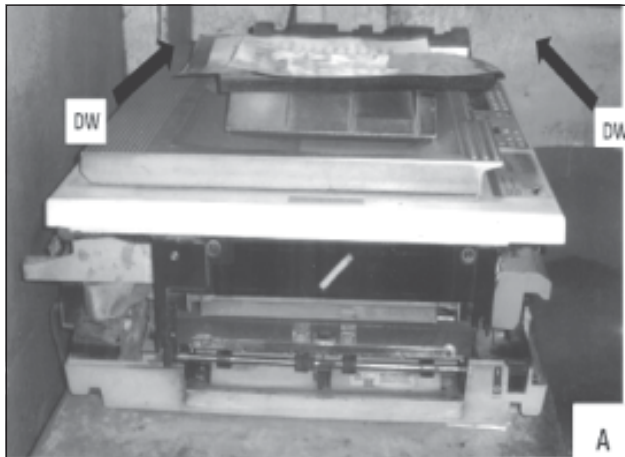


Plate - I (A-D) : Shows different photocopier machine and their exposure to individuals during operation.

A, B and C; photocopier machine placed in congested and dark room [damp wall → DW].

B and C; exposure of individuals to photoemissions (↑) and toner powder.

D; interior of device during changing of toner cartridges.

4. Discussion

Photocopiers are used world wide and have entered the mass market in the last three decades as it is an essential need for documentation. The present project was undertaken to study the effects of photocopier emissions especially toner dust, VOA etc on the health of the operators. The study emphasized on some of the major physical ailments obtained in the case of the operators, technicians and persons involved in maintenance and its possible relation with their exposure duration to the photocopier machine. Analysis of the case studies revealed that initial exposure (0-15 days) leads to the development of Nausea, backbone pain, eye irritation and skin itching.

These signs may indicate the unspecific immediate hypersensitivity reaction caused due to emissions and toner particles emitted during operation of photocopier machine. A growing number of people have reported to react sensitively when exposed to toner powder and toner emission (Arbeitsgruppe *et al.*, 2005 and Stelting 2006) supported the present findings. Development of different symptoms like headache, nausea, indigestion and giddiness in the individual cases during period of initial as well as long term exposure of Xerox emissions may be due to release of high amount of volatile gases, aromatic components and dust particles that are unable to escape from congested damp room on account of

poor ventilation as recorded in our study. Ewers and Nowak (2006), UE (2010) and Gminski *et al.*, (2011) reported that volatile organic compounds, aromatic hydrocarbons and fine particles are released during operation of photocopier due to fusion of toner and the heating of paper. In most of the cases of medium to long term exposure, operators suffered from infections of the upper and lower respiratory tract, breathing difficulties, cough and sinusitis. This may be attributed to the constant exposure to toner dust emitted from photocopiers. Earlier reports of a case study of a 48 year old patient showed symptoms of allergic rhinitis and obstructive respiratory disease caused by toner dust emitted from printers and copiers that was reported by physicians (2002) as occupationally related poisoning disease (Arztliche 2006). In case of long term exposure ie more than 10 years, operators were found of having various problems associated with the respiratory system like "lung overload", infections of the upper and lower respiratory tracts, asthma etc. This may be because of the fact that toner dust particles having a diameter of 2 to 10 μ m belongs to the group of respirable fine particles which upon inhalation get accumulated in the tracheobronchial and alveolar region (Ewers and Nowak 2006). Chronic exposure to toner leads to the accumulation of particles in the lung as well as to persistent inflammatory processes and slight to moderate fibrotic changes in the lungs of rat (Muhle, *et al.*, 1990, 1991 and 1998, Moller *et al.*, 2004, Rimal *et al.*, 2005 and Wang *et al.*, 2007). The toner particles thus accumulated in the lung tissue is attributed to a damage and overload of the lung clearance mechanism and this condition is called "Lung Overloading". The biological effects produced by the inhalation of toner dust are primarily related to particle properties such as insolubility and persistence in the biological environment, particle size distribution and specific gravity. Earlier reports revealed that toner dust might cause lung tumors and as such are carcinogenic (Pott and Roller 2003) and genotoxic (Goud *et al.*, 2001, 2004, Gadhia *et al.*, 2005 and Gminski *et al.*, 2011) as well as

cytotoxic (Hetland *et al.*, 2001 and Ovrevik *et al.*, 2004). Further sonication or heating process during photocopier operation destroy the polymer substances releasing carbon black including polyaromatic hydrocarbon which are bioavailable to epithelial cells (Bayram *et al.*, 1998). This may be accounted to loss of hair and skin of the palm. Symptoms of jaundice in a 27 year old male operator, ulcer and gall bladder stone in the case of 32 years old female and kidney stone in the case of 50 years old man might have no direct relation with the emission of Xerox particles but it may have an indirect relation. This may be on account of ingestion of dust particles as well as lessen in duration of sleep due to constant exposure to sound during operation of photocopier machine which in turn causes indigestion which again might lead to formation of stones in different organs. Thus analysis of the present study clearly revealed that the photocopier emissions of the various toner particles as well as receiving hard photocopies are a great risk of human health hazard in terms of development of various physical problems that may even lead to cancer. Therefore, a thorough investigation in this line is very essential.

5. Conclusion

Photocopiers are used worldwide for the urgent need of documentation. Although, it is an inseparable part of modern society, but it may cause various physical ailments on human health of an unpredictable nature. It is established that the toner dust and aromatic hydrocarbons are emitted during the process of photocopying which cause the various occupationally related diseases to the individuals. Various physical ailments found in the present study may be due to improper installation of the photocopier device in an unhealthy atmosphere. Therefore, proper installation, operation, maintenance and utilization of the photocopying device as far the rules of the Xerox cooperation must be strictly followed to reduce the risk of human health hazard to some extent.

References

- Arbeitsgruppe, Arbeitsbedingte Gefährdungen und Erkrankungen der Lunge und der Atemwege. 2005. Arbeitsmedizinische Leitlinien der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin: Arbeitsplatzbezogener Inhalationstest (AIT). *Arbeitsmed. Sozialmed. Umweltmed.* 40 no. 4, pp. 260-267. www-dgaum.med.uni-rostock.de/leitlinien/AIT.pdf
- Ärztliche Mitteilungen bei Vergiftungen nach §16e Chemikaliengesetz. Hrsg. 2002. Bundesinstitut für Risikobewertung (BfR), Berlin, p. 57 f.
- Bayram, H., Devalia, J.L. and Sapsford, R.J. 1998. The effects of diesel exhaust particles on cell function and release of inflammatory mediators from human bronchial epithelial cells in vitro. *Am J Respir Cell Mol Biol* 18, pp. 441-48.
- Bellmann, B., Muhle, H., Creutzenberg, O., Dasenbrock, C., Kilpper, R., MacKenzie, J. C., Morrow, P. and Mermelstein, R. 1991. Lung clearance and retention of toner, utilizing a tracer technique during chronic inhalation exposure in rats. *Fundam. Appl. Toxicol.* 17, pp. 300-13.
- Ewer, U. and Nowak, D. 2006. Health hazards caused by emissions from laser printers and copiers. *Reinhalt. Luft* 66 no. 5, pp. 203-10.
- Gadhia, P., Patel, D., Solanki, K., Tamakuwala, D. and Pithawala, M. 2005. A preliminary cytogenetic and haematological study of photocopying machine operators. *Ind J Occup Environ Med* 9, pp. 22-25.
- Gminski R, Decker K, Heinz C, Seidel A, Konczol M, Goldenberg E, Grobety B, Ebner W, Giere R, Sundermann VM. 2011. Genotoxic effects of three selected black toner powders and their Dimethyl Sulphoxide extracts in cultured human epithelial A549 lung cells in vitro. *Environmental and Molecular Mutagenesis* 52, pp. 296-309.
- Goud, K.I., Shankar, B., Vijayashree, B., Ahuja, Y.R. 2001. DNA damage and repair studies in individuals working with photocopying machines. *Int J Hum Genet* 1, pp. 139-143.
- He C., Morawska, L., Taplin L. 2007. Particle emission characteristics of office printers. *Environ Sci Technol* 41, pp. 6039-45.
- Hetland, R.B., Schwarze, P.E., Johansen, B.V. 2001. Silica-induced cytokine release from A549 cells, importance of surface area versus size. *Hum Exp Toxicol* 20, pp. 46-55.
- ILSI (= International Life Sciences Institute), Risk Science Institute. 2000. The relevance of the rat lung response to particle overload for human risk assessment : A workshop consensus report. *Inhal. Toxicol.* 12, p. 1-17.
- Jungnickel, F., Kubina, A. and Patrzek F. 2002. Content of heavy metals in toner powders. *Umweltmed Forsch Prax* 5, pp. 289-91.
- Lin, GHY, Mermelstein R. 1994. Acute toxicity studies of Xerox reprographic toners. *J Am Coll Toxicol* 3, pp. 2-20.
- Lo'froth, G., Hefner, E., Alfheim I. and Moller, M. 1980. Mutagenic activity in photocopiers. *Science* 209, pp. 1037-39.
- Muhle, H., Bellmann, B., Creutzenberg, O., Dasenbrock, C., Ernst, H., Kilpper, R., MacKenzie, J. C., Morrow, P., Mohr, U., Takenaka, S., Muhle, H. and Mermelstein, R. 1991. Pulmonary response to toner upon chronic inhalation exposure in rats. *Fundam. Appl. Toxicol.* 17, pp. 280 - 299.
- Muhle, H., Bellmann, B., Creutzenberg, O., Koch, W., Dasenbrock, C., Ernst, H., Mohr, U., Morrow, P. and Mermelstein, R. 1998. Pulmonary response to toner, TiO₂ and crystalline silica upon chronic inhalation exposure in Syrian golden hamsters. *Inhal. Toxicol.* 10, pp. 699-729.

Ovrevik, J., Lag, M., Schwarze, P. and Refsnes, M. 2004. p38 and Src-ERK1/2 pathways regulate crystalline silica-induced chemokine release in pulmonary epithelial cells. *Toxicol Sci* 81, p. 480–90.

Rimal, B., Greenberg, A.K. and Rom, W.N. 2005. Basic pathogenetic mechanisms in silicosis, current understanding. *Curr Opin Pulm Med*.11, pp. 169–173.

Schripp, T., Wensing, M., Uhde, E., Salthammer, T., He C, Morawska, L. 2008. Evaluation of ultrafine particle emissions from laser printers using emission test chambers. *Environ Sci Technol* 42, pp. 4338–43.

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical methods*. 6th edn. Oxford & IDH publication co, Calcutta.

University of Edinburgh. 2010. Photocopiers and laser printers health hazards. Health and Safety department, the University of Edinburgh, pp. 1-6.

Wensing, M., Schripp, T., Uhde, E. and Salthammer T. 2008. Ultra-fine particles release from hardcopy devices : Sources, real-room measurements and efficiency of filter accessories. *Sci Total Environ* 407, pp. 418–27.

