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Summary and Conclusion

Service personnel in xerographic industry are routinely exposed to emissions from xerographic machines in a manner comparable to operators. However, the milieu of pollutants to which these personnel are exposed is varied due to the differences in the photocopier machines, associated factors and indoor environments. Therefore, evaluating the risks of exposure among service personnel is imperative. Chronic exposure to air pollutants has been documented to affect both the respiratory and cardiovascular systems. Till date no attempt has been made to evaluate the effects of photocopier exposure among the maintenance personnel. Hence, it is imperative to assess the health status of service personnel in xerographic units.

Objectives of the study

The present study was undertaken with the following two main objectives:

Phase I: Air quality analysis

- To elucidate the physical characteristics of both the selected xerographic units and machines.
- To analyse the ambient air quality of the selected xerographic centers.
- To determine physico-chemical characteristics of four selected brands of toner by Scanning Electron Microscopy Energy dispersive X ray Spectra (SEM EDX) elemental composition and head space Gas Chromotography Mass Spectrometry (GC-MS)

Phase II: Health surveillance of photocopier service personnel in xerographic units

- To assess lung function by spirometry

- To assess the status of biochemical, oxidative, inflammatory, selenium, cadmium and selenoprotiens (invasive systemic biomarkers levels) in occupational settings amongst the study population.
- To assess genotoxicity exposure among study population
- To determine metablomic differences in excretory urinary biomarkers by non invasive approach

Work Plan

Phase I: Air Quality Monitoring

- Air quality monitoring were made on working days in twelve xerographic units for a period of 8 hours by an ISO 2001 certified commercial laboratory after obtaining consent and questionnaire from the proprietor of the photocopier units. The air quality parameters assessed includes Particulate Matter (2.5 µ), carbon monoxide, nitrogen dioxide, sulphur dioxide, ammonia, ozone, benzene, benzo (a) pyrene and heavy metals (arsenic, lead, and nickel).
- The toner powder was characterised for its physical characteristics namely particle size and the morphology using SEM and composition by energy dispersive X ray spectra (EDX).
- The toner powder were also screened for its chemical composition especially volatile organic compounds that possibly would emanate from toner powder were identified by a NABL certified commercial laboratory using head space gas chromatography mass spectrometry using the simulated fusion temperature (180 – 200°C) of xerographic machines.

Phase II: Health surveillance of photocopier service personnel in xerographic units

Health surveillance study was carried out in an observational cross sectional design in Coimbatore district of Tamilnadu, India among the photocopier service

personnel, to test the hypotheses whether occupational exposure to toners and emissions affect the health of the xerographic service personnel in xerographic units. The study was approved by the Human Ethical Committee of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore (HEC.2009.14). The participants of the study were enrolled after acquiring written informed consent and interview schedule.

- The participants underwent anthropometric measurements namely age, weight, height and BMI by standard procedures followed by blood pressure measurements specifically for exclusion of participants with aberrant blood pressure.
- Lung function was assessed using spirometry (Vitalograph Alpha 6000 spirometer, UK by the researcher who was trained for this purpose) as per the recommendations of American Thoracic Society / European Respiratory Guidelines. The percentage predicted values for all lung function parameters were calculated using published values for Asians – ERS 1993.
- Consequently 5 ml of venous blood was collected to analyse complete blood count and assess the levels of systemic biomarkers followed by collection of 20 ml of urine for identification of non-invasive excretory biomarker through metabolomics study.
- Assessment of lung function test was carried out on participants (100 – service personnel and 77 – controls). Blood samples could not be obtained from 14 participants in the study. Hence, systemic biomarkers (haematological, biochemical, oxidative stress and inflammatory markers) were assessed in 90 service personnel and 73 controls and excretory urinary biomarkers (non-invasive) were assessed in 17 service personnel and 23 controls.
- Haematological parameters in whole blood included white blood cell count (WBC), lymphocytes count, neutrophils count, red blood cell

distribution width (RDW), platelets, Red Blood Cell count (RBC), Haemoglobin (Hb), Haematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), Platelet Distribution Width (PDW), Mean Platelet Volume (MPV) and Platelet Large Cell Ratio (P-LCR).

- Oxidative stress biomarkers namely TBARS, free 8-isoprostane and antioxidative markers TEAC and FRAC were analyzed.

- Other biomarkers that were assessed include CC16, LTB4, IL-6, IL-8, ECP, C Reactive Protein (CRP), Total Nitrates (Nox), MPO, ICAM-1. Selenoproteins namely GPx, thioredoxin reductase. Trace elements selenium and cadmium were assessed in a sub sample of study participants [Control (n = 24) and exposed (n = 14)].

- Genotoxicity in photocopier service personnel due to xerographic occupational exposure was assessed by comet assay in whole blood (Single cell gel electrophoresis) in a subsample of participants [Control (n = 45) and exposed (n = 62)].

- A pilot study of ^{1}H NMR metabolomics approach was used to analyse the metabolic fingerprint of the urine, to identify excretory non-invasive occupational biomarker among a sub sample of the study participants. Metaboanalyst 2.0 webserver was used for metabolomic processing and statistical analysis.

Salient findings of the study

Phase I: Air Quality Monitoring

- All the xerographic centres studied used local toners A, B and C rather than global toner D except for one centre.

- Ambient air quality assessment showed the presence of high levels of fine particulate matter ($PM_{2.5}$) emissions equivalent to about 3.8 fold

higher than the permissible daily air quality levels in xerographic units during machine operation and maintenance.

- Physical characterization of the toner revealed toner particle size to fall in the range of that ranged between 2 and 10 µm Hence they can be classified as $PM_{2.5-10}$ ("coarse" particles, 2.5 to 10 µm) and $PM_{2.5}$ (fine particles, < 2.5 µm) size.

- The element composition as measured by Energy Dispersive X ray spectroscopy showed that carbon is the most abundant element in the investigated monochrome toner materials that constitutes the toner core resin with > 50%.

- Qualitative screening of toners showed whether manufacturer is global or local release different hazardous organic compounds that include, volatile organic hydrocarbon compounds that include aliphatic, aromatic, heterocyclic and polycyclic aromatic hydrocarbons compounds as a by-product of xerographic process.

Phase II : Health Surveillance

- Prevalence of respiratory symptoms, headache allergies and skin problems were found to be influenced by occupational exposure to photocopiers and their toners among photocopier service personnel

- There was a significant decrease in lung function parameters as indicated in table 57. This is observed by the decline in VC, FEV1 and MVV suggesting restrictive pattern among photocopier service personnel that might be due exposure to particulate matter emissions in xerographic units.

- Higher incidences of restrictive ventilatory pattern followed by obstructive and mixed ventilatory pattern defect were also observed

among photocopier service personnel. Causative factor of likelihood of lung dysfunction is merely because of occupational exposure and not because of the confounding smoking effect as observed in table 57.

- Among the bood cell indices indices, Haemoglobin, RDW levels were found to be significantly increased among the photocopier service personnel that might be due to oxidative stress induced haemolysis by exposure to pollutants in work settings which inturn indicates hypoxic cardio-pulmonary inflammation and dysfunction (table 57).

- In contrast there were few parameters found to be positively associated with pack years of cigarettes smoked namely MCV, MPV and P-LCR.

- An increased level of globulin indicates inflamamtion. Hyperglobulinemia with A/G ratio of 1.1, noticed in photocopier service personnel indicates positive acute phase reaction caused by progressive decline in lung function with inflamamtion.

Table 57

Health and biomarkers outcome

S.No	Dependent Variable	Status	Independent varaibles		Indication
			CE	PY	
1.	VC (% pred)	↓	✓	×	Restrictive lung disease
2.	FEV1 (% pred)	↓	✓	×	Restrictive lung disease
3.	MVV (% pred)	↓	✓	×	Restrictive lung disease
4.	Hb (g/dl)	↑	✓	×	Hypoxia
5.	RDW (fL)	↑	✓	×	Inflammation, Lung disease, cardiovascular disease
6.	MCV (fL)	↑	×	✓	Hypoxia
7.	MPV (fL)	↑	×	✓	Inflammation
8.	P-LCR(%)	↑	×	✓	Inflammation
9.	Lymphocytes (10^3/µl)	↓	×	✓	inflammation
10.	Globulin (g/L)	↑	✓	×	chronic inflammation and lung dysfunction
11.	TBARS (µM)	↑	✓	×	Increased oxidative stress
12.	FRAC (mM)	↓	✓	×	antioxidant defense
13.	CC16 (ng/ml)	↑	✓	×	Lung epithelial injury
14.	IL-6 (pg/ml)	↑	✓	×	Inflammation
15.	IL-8 (pg/ml)	↑	✓	×	Inflammation
16.	CRP (µg/ml)	↑	✓	×	Inflammation
17.	ICAM-1(ng/ml)	↑	✓	×	Inflammation, CVD, Lung disease
18.	DNA in tail (%)	↑	✓	×	Genotoxicity

- An increased level of TBARS among photocopier service personnel indicates oxidative stress mediated by particulate matter on exposure leading to lung inflammation. In tune with this, the decreased levels of FRAC indicate the counteraction of the oxidative stress among the photocopier service personnel caused on exposure to xerographic machines.

- Pneumoprotein, CC16 levels were found to be significantly increased among the photocopier service personnel and the leakage of the same into systemic circulation indicates pulmonary damage thereby decline in lung function.

- Among the inflammatory endothelial markers, ICAM-1 and nonspecific inflammatory markers IL-6, IL-8 and CRP were significantly increased among photocopier service personnel (table 57) indicates associated co-morbidity of cardio problems coupled with lung dysfunction.

- Among the biomarkers studied, CC16 was found to be the best indicator of lung function. ICAM-1 was found to be the best cardiovascular marker.

- Photocopier service personnel evidenced increased levels of % DNA content in tail that indicates the genotoxic effect of photocopier exposure.

- Urine metabolomics study showed the metabolite discrimination model to be moderate with R2 = 0.7 and Q2 = 0.2 with urinary discriminate metabolite as 3 – aminoisobutanoic acid (δH 1ppm, 2.943) due to exposure to UV rays among photocopier service personnel as part of their maintenance activity. Thus the pilot study conducted with few subjects give new insight into the use of 3-Aminoisobutanoic acid, as efficient non invasive biomarker to study for biomonitoring studies among the photocopier service personnel.

Conclusion

The results of the study suggest that chronic exposure to xerographic machines may cause restrictive lung disease, high oxidative stress, inflammation and endothelial dysfunction among photocopier service personnel. High exposure to fine particulate matter in the form of toner and photocopier emissions leads to cardio pulmonary disease among the service personals. Invasive biomarker CC16 was found to be the best indicator of lung function whereas ICAM-1 was found to be the best cardiovascular marker among the photocopier service personnel. The non-invasive urinary biomarker discriminated by metabolomics was found to be 3 – aminoisobutanoic acid.

Limitations of the study

- Toners were not quantified for their toxic components
- Assessment of local air way inflammation is suitable for any indoor air pollution study. However, it was not done in the present study due to practical difficulties in the collection of the samples either sputum, nasal lavage or bronchioalveolar lavage fluid among the participants in the field
- Personal air monitoring exposure devices were not used among the photocopier service personnel for bio monitoring studies due to inconvenience for their work

Recommendations for further research

- Quantification of toners for their toxic components
- Characterization of the particulate matter emitted from the xerographic machines
- Improvisation of toner formulations and regulatory guidelines to minimize the xerographic emissions in India.