ERGONOMICS AND HEALTH IN MODERN OFFICES

Edited by
E. Grandjean

Ergonomics and Health in Modern Offices

Edited by

Etienne Grandjean

Institut für Hygiene und Arbeitsphysiologie,
Zurich, Switzerland

Proceedings of the International Scientific Conference on Ergonomic and Health Aspects in Modern Offices, held in Turin, Italy on 7–9 November 1983 under the auspices of the International Ergonomics Association, the Permanent Commission and International Association of Occupational Health, the University of Turin, the Societa Italiana di Medicina del Lavoro e di Igiene Industriale and the Regione Piemonte

Taylor & Francis
London and Philadelphia
1984

UK Taylor & Francis Ltd, 4 John St, London WC1N 2ET
USA Taylor & Francis Inc., 242 Cherry St, Philadelphia, PA 19106–1906

British Library Cataloguing in Publication Data

International Scientific Conference on
Ergonomic and Health Aspects in Modern
Offices *(1983 : Turin)*
Ergonomics and health in modern offices.
1. Video display terminals—Human factors
I. Title II. Grandjean, E.
651.8' 443 TK7882.16

ISBN 0-85066-270-2

Library of Congress Cataloging in Publication Data

International Scientific Conference on Ergonomic and
Health Aspects in Modern Offices (1983: Turin, Italy)
Ergonomics and health in modern offices.

"Proceedings of the International Scientific Conference on Ergonomic and Health Aspects in Modern Offices, held in Turin, Italy on 7–9 November 1983 under the auspices of the International Ergonomics Association, the Permanent Commission and the International Association of Occupational Health, the University of Turin, the Societa Italiana di Medicina del Lavoro e di Igiene Industriale, and the Regione Piemonte."
Bibliography: p.
Includes index.
1. Offices—Hygienic aspects—Congresses. 2. White collar workers—Diseases and hygiene—Congresses. 3. Occupational diseases—Congresses. 4. Human engineering—Congresses. I. Grandjean, E. (Etienne) II. International Ergonomics Association. III. Title
RC965.03158 1983 616.9'803 84-8470
ISBN 0-85066-270-2

Typeset by Red Lion Setters, London WC1
Printed in Great Britain by Taylor & Francis (Printers) Ltd, Basingstoke, Hants.

Preface

Most of the papers presented at the Turin Conference reveal, in different ways, that office life is becoming more technical and more complicated and that several office jobs are today more strenuous than they were in the first half of this century. Greater investments in offices are associated with an increased need for more productivity and these conditions have led, among other changes, to large, open offices. Such offices pose new environmental problems and there is an increasing use of office machines, especially computer terminals. The result is the transformation of the former 'paper office' into the present 'electronic office'.

At the traditional office desk an employee has a great variety of physical activities and a large space for various body postures and movements: he/she may look for some documents, read some texts, exchange information with colleagues, type for a short while and carry out many other activities during the course of the working day. Ergonomic shortcomings are unlikely to cause annoyance or physical discomfort.

The situation is entirely different for an operator working continuously at a VDT for several hours or for a whole day. Such an operator is tied to a man–machine system: movements are restricted, attention is directed to the screen or source documents and the hands are linked to the keyboard. These operators are more vulnerable to ergonomic shortcomings, to constrained postures, to unsuitable lighting conditions and to uncomfortable furniture. They are more sensitive to visual loads and to unnatural body postures. The recognition of these changing circumstances was the main reason for organizing an International Scientific Congress on Ergonomics and Health in Modern Offices. The aim of the Congress and of course also of the present Proceedings is to analyse objectively the effects of the new office conditions and to lay the foundations for improvements of working life in offices.

Zurich, 12 January 1984 *Etienne Grandjean*

Acknowledgement

The International Scientific Conference on Ergonomics and Health in Modern Offices (Turin, 7–9 November 1983) and the publication of the present Proceedings were generously supported by the following sponsors:

Burroughs Corporation (Plymouth, USA)
Camera di Commercio Industria Artigianto e Agricoltura (Turin, Italy)
Cassa di Risparmio di Torino (Turin, Italy)
COMAU (Turin, Italy)
Giroflex Entwicklungs A.G. (Koblenz, FR Germany)
IBM World Trade Corporation (White Plains, USA)
ILTE (Moncalieri, Italy)
Istituto Bancario San Paolo di Torino (Turin, Italy)
Olivetti (Ivrea, Italy)
Regione Piemonte (Turin, Italy)
SEAT (Turin, Italy)
Siemens (FR Germany)
Siemens Data (Milan, Italy)
SIP (Rome, Italy)
Standard Telephon and Radio A.G. (Zurich, CH)
Tandberg Data (Norway)
Toro Assocurazioni (Turin, Italy)
Università degli Studi di Torino (Turin, Italy)

Contents

Toxic Agents Emitted from Office Machines and Materials (Introductory paper)

GIOVANNI SCANSETTI

Institute of Occupational Health, Turin University, Turin, Italy

1. *Introduction*

Office work mainly deals with handling, transmitting and storing information. For such a purpose, paper is the means currently used, although its replacement by magnetic and electronic devices is expected and partly in progress. Therefore we may look forward to tomorrow's office without paper. In time the silicon machine will replace the carbon one.

With regard to today's office only, I will consider some points of possible toxicological interest. First I will deal with the few simple instruments currently used and then the new automated systems for treating information. Finally some components of office environment will be considered.

2. *Paper, Carbon Paper*

Paper dermatitis has been reported to represent 0·8% of all occupational dermatitis (Meneghini *et al.*, 1963; Adams, 1983) though paper is extensively used in modern society.

Carbon paper can cause allergic dermatitis: this applies less to the so-called smudging type than to the non-staining one; the sensitizing substance is tricresyl phosphate (TCP), reported by Hjort (1964) to be present at a concentration of 30% in the film emulsion of the carbon paper used by a man who had a positive patch test to that particular type of carbon paper, to TCP, and to triphenyl phosphate through cross-sensitization. TCP, the *ortho* isomer of which is so toxic that the amount is kept as low as possible, is widely used as a plasticizer in the most common plastics but not frequently in the manufacture of carbon paper.

Some four other cases of sensitization to carbon paper were identified among 40 000 eczema patients at the Finsen Institute, Copenhagen: one of them had positive skin reaction to oleyl alcohol, whereas details of an allergen identified in the other three cases were not given (Hjorth, 1964).

Calnan and Connor (1972) described a case of allergic contact dermatitis due to nigrosine base (C I. 42535B, solvent black 7), a tricyclic azine dye derived from phenazine, used to obtain extremely good black copies in high-speed computer printers.

Calnan and Fregert (personal communication to Jordan, 1975) have also documented allergy to methyl violet in carbon paper, and Jordan (1975) described a case of bilateral dermatitis in a young female secretary who had a strongly positive patch test to two types of typewriter correcting paper. The implicated chemical was probably identified in a modified phenol formaldehyde maleic anhydride resin, already found responsible for allergic dermatitis in the use of a commercial marking pen ink (Mailbach, personal communication to Jordan, 1975).

3. *Carbonless Copy Paper*

In 1954 the National Cash Register Company (Dayton, Oh.) introduced its 'no carbon required' paper (NCR): this is a carbonless copy paper (CCP) or pressure-sensitive paper working by mechanical or chemical transfer. In the former the undersurface of the top sheet is coated with a carbon-like film and the coloured ink is simply transferred by pressure to the top surface of the underlying sh et. In the chemical type the undersurface of the top sheet (called 'coated back') holds ome colour-forming chemicals, while the reacting material is place on the top surface of the underlying sheet (called 'coated front'). The number of copies can be increased by coating the second and subsequent sheets on the undersurface with a colour-forming emulsion, and the top of the underlying sheets with reacting material. Moreover some areas of the top surface of the second and following sheets may have a special coating of desensitizing ink (D-ink), which is applied by printers (Dodds and Butler, 1981), to prevent the dye from being transferred (Menné *et al.*, 1981).

Colour forming chemicals mainly derive from triphenyl- and triaryl-methane are encapsulated in a colourless state. They include crystal violet (methyl violet) and malachite green lactones, of the triphenyl-methane group, and benzoyl leucomethylene blue and fluoran derivatives.

The solvents used to disperse them must have low volatility, in order to prevent drying of the capsule content (Göthe, 1981); from 1954 (the date of the original paper) until 1970 the main solvent used was a chloro-biphenyl (Aroclor), thereafter it was replaced by hydrogenated terphenyls (Weaver *et al.*, 1979), diaryl-ethanes, alkylnaphthalenes, cyclohexane, dibutyl-phthalate, often diluted with odourless kerosene for economic reasons.

Gelatin and gum arabic were used in the first commercially valuable microencapsulation process developed by NCR, the reaction forming viscous liquid microdroplets of polymer coacervate. The capsule wall may be hardened, e.g. by the addition of formaldehyde. Using two gelatins of different isoelectric point, hardening may be accomplished by adding glutaraldehyde (Sparks, 1981). Carboxymethylcellulose and synthetic polymers are now frequently used in combination, the latter including polyesters, polyamides and polyurethanes: encapsulation proceeds through a chemical method of interfacial polymerization.

The emulsion of the capsule is spread, dried and held adherent to the undersurface of the paper with water-soluble starch.

It is worth noting that four men working in a factory producing this emulsion were reported to be suffering from hand eczema; they were positively patch-tested with 1, 2-benzisothiazolin-3-one contained in Proxel, ICI, a gelatin preservative in the capsule; in two cases this sensitization was only an aggravating factor of a pre-existing eczema (Cronin, 1980).

The reactive material on the top surface of the copy sheet contains a montmorillonite clay, alkaline on the surface but acid inside, or an alternative coreacting system material, spread, dried and adhered by a styrene–butadiene latex. Attapulgite clay, the chief ingredient of fuller's earth, was used for this purpose, but recently it has been replaced by other materials in NCR paper; at the present time research is in process to produce a chemically processed bentonite, kaolin or sepiolite clay, or their combination, for use in duplicating paper (Grim, 1979).

Sepiolite, and perhaps attapulgite, occur in fibrous form, very familiar to chrysotile fibrils (Leineweber, 1980; Bignon *et al.*, 1980); mesotheliomas have been induced through peritoneal injection of attapulgite fibres in rats (Pott *et al.*, 1976), and lung fibrosis has been observed in a worker after inhalation of fibrous attapulgite (Sors *et al.*, 1979).

The complaints related to the use of CCP have frequently an epidemic characteristic, involving people engaged in various office functions such as writing, carrying out surveys on recently written documents, or collating papers. Also there is often a positive correlation between the number of forms used and discomfort; the rupture of the capsules seems important, since generally only used paper causes the complaints. These concern the skin of the exposed parts of the body, namely face and hands, consisting of dryness, itching, rashes, burning or prickling sensations and swelling, and, in some cases, of active eczema. Eyes are also involved with itching red and swollen eyelids, soreness, photophoby and injection of conjunctiva. Mucous membranes symptoms include dryness and/or burning of lips, tongue and throat, soreness in the throat and chest, sneezing, stuffed nose, and hoarseness. Symptoms such as headache, drowsiness and thirst also occur.

Patch tests with samples of papers and colour formers have always been negative. The only exception is the case described by Marks (1981), of a young woman with allergic contact dermatitis from CCP who was positive to Michler's hydrol (4, 4′ -bis(dimethylamino)benzhydrol) a component of the colour former molecule, the *para*-toluene-sulphinate of Michler's hydrol, a colourless dye salt.

Prick and photo-patch tests with the papers themselves and the different substances of the papers usually gave negative results. Prick tests with some papers which were positive in a group of cases, have been related to a non-immunological histamine liberation (Menné *et al.*, 1981).

Generally speaking it seems that the companies marketing CCP have received health complaints on a much greater scale than previously to introducing these papers 20 years ago.

Altogether the reactions to CCP look irritative in nature rather than allergic; tracing the causative agent(s) is more difficult. The first claims arose in 1972 when Masuda *et al.* demonstrated that the solvents of colour former in the capsules were frequently polychlorinated biphenyls

(PCBs): at that time the amount detected in Japanese brands of CCP was 22–64 mg/g of paper for gelatin coated sheet, and 200–280 p.p.m. for the uncoated ones. PCBs, quickly absorbed through the skin (Voes and Beems, 1971), were the cause of Yusho, the epidemic illness from oil-treated rice which exploded in Japan in the late 1960s affecting more than a thousand people. This caused the suspension of PCBs production in that country in 1972.

Because of the tendency of these products to accumulate and persist in the environment and biota, and owing to their toxic effect, production was also stopped in USA in 1976, and their use was generally restricted to closed systems.

Even if since the early 1970s PCBs have no longer been used in dissipative systems as CCPs are, it is possible that some older CCPs stocks, containing PCBs, were still in use in the mid-1970s, e.g. in Italy, as pointed out by conflicting analytical results (Belliardo *et al.*, 1979; Benvenuti *et al.*, 1979; Sampaolo *et al.*, 1980).

Moreover, the picture of CCP complaints does not agree with PCBs type of biological activity; other hypotheses were related once more to unspecified solvents (Calnan, 1979; Menné *et al.*, 1981), also because of the similarity of the symptoms to those noticed among users of photocopying machines with wet toners (Jensen and Roed-Petersen, 1979); or to the clay of the receiving surface (Magnusson, 1974). In the experience of Magnusson (1974) the use of a formaldehydic resin as adhesive for clay stopped it from being airborne, and the complaints disappeared. Such an observation is partly in contrast with the results, and subsequent interpretation, of sampling and analysing air drawn through columns containing cut-up and crumpled forms: a significant release of formaldehyde from copy paper, especially if coming from unopened new packages, was demonstrated. Formaldehyde was thus suspected of causing the irritation, although not being the only source of it (Gockel *et al.*, 1981; Schumacher, 1981). It is worth recalling that contact lens wearers are greatly sensitive to very low concentrations of formaldehyde (Steinberg, 1982).

Of course, we cannot forget that most of the complaints started from used CCP; however a formaldehyde allergy was suspected at the beginning of the 1970s by the Swedish National Board of Occupational Safety and Health as a possible cause of discomfort due to the use of NCR papers (Lidblom, 1981). More recently Swedish authors (Nörback, 1981) found that there was a significant relationship between the occurrence of complaints and the presence of D-ink on the form. Two out of seven of these inks turned out to be primary irritants, predominantly of the skin, while symptoms related to NCR papers not treated with D-ink predominantly concern mucous membranes. Suspicions have been directed to the amines contained in the irritant D-ink (Löfström, 1981). A linkage between a particular D-ink and severe skin and eye irritation was already present in an outbreak in Belgium in 1975, reported by Dodds and Butler (1981) with particular emphasis on one of its ingredients, namely 1-hydroxyethyl-2-oleyl-imidazoline.

As itching is one of the main symptoms associated with NCR paper exposure, the itchy sensation was studied quantitatively with an 'itch test' on patients with this symptom when handling copy paper who turned out to be more sensitive to an itch-producing agent than controls matched for sex and age (Jeansson, 1981).

Mucous membranes symptoms turned out to be significantly related with papers containing mono-isopropyl-biphenyl (MIPB) in the capsule as solvent (Nörbäck, 1981).

This is the most important of alkylated biphenyls, and is primarily used in the production

of NCR paper (Weaver *et al.*, 1979). An abnormally large amount of MIPB impurities (biphenyl, methylbiphenyl and diisopropylbiphenyl) were found in specimens of Norwegian CCP associated with the only hitherto known epidemic in that country (Levy and Hanoa, 1980). In MIPB containing papers related to complaints both in Norway and Sweden, a specific unprecised colour former was also present.

4. *Rubber Sensitization*

Rubber fingerstalls were used by office staff as an aid to counting bank notes in Swedish Post Giro Offices (Eriksson and Östlund, 1968). British (Kirton and Wilkinson, 1972) and Danish post-sorters (Roed-Petersen *et al.*, 1977) as well as Copenhagen Telephone Company workers used them when handling no-carbon-required paper (Menné *et al.*, 1981).

This has caused outbreaks of contact band dermatitis localized on the dorsum and sides of distal phalanx: the patients were two-day patch-tested both with the rubber and its individual compounds. Swedish and British workers experienced sensitivity to rubber accelerators of similar structure, namely *N*-cyclohexyl-2-benzothiazole-sulphenamide (CBS) (Eriksson and Östlund, 1968) and dibenzthiazyl-disulphide (Kirton and Wilkinson, 1972).

The 51 Danish cases had a positive reaction to *N*-isopropyl-*N'*-phenyl-*p*-phenylendiamine (IPPD), a rubber antioxidant. Following the BRMA Code of Practice (1978) IPPD is a potent skin sensitizer; rubber which contains this compound may also cause skin sensitization.

5. *Diazocopying*

Diazocopying technique (or dye line or diazo process) utilizes a diazo-sensitized paper, into which the image of a transparent original is projected by a bright fluorescent light passing through it. Then the paper is developed (coloured) by either ammonia gas or a liquid chemical giving a positive blue-print copy. The process is used in particular for plan printing.

Sensitivity to diazonium salts (chloride; acid sulphate) was described in industrial settings: occupational asthma in men engaged in the production of the reactive dyes (Armeli, 1968), or in the first stages of the manufacture of the sensitized paper, i.e. the weighing and mixing of powders including diazonium chloride (Graham *et al.*, 1981). Contact eczema in man involved in coating rolls of paper with the diazo solution is also reported: patch-tests with the copy paper ('Amonax') and a 10% concentration of the solution were strongly positive (Harman *et al.*, 1968).

Diazocopying may induce desquamative or degenerative dermatitis, caused by ammonia impairing fingertip skin whilst handling copies (Gertler and Laubstein, 1963) and also severe cases of contact eczema starting from the hands and elbows and spreading in some cases to the whole body. The sensitivity was traced to *p*-diethylamino-azobenzene chloride, zinc chloride double salt, the active substance of the paper, as well as to other '*para*'

compounds through cross-sensitization (Gertler and Laubstein, 1963). Sensitivity to diazo paper, to the aforementioned substance, and to one of its intermediates, *N,N*-diethyl-*p*-perylene-diamine, was also present in a woman engaged in diazocopying and suffering from bronchial asthma which lasted 10 years (Gertler and Laubstein, 1963).

Itching dermatitis to the hands (dorsa and palms) and face with subsequent photosensitivity was recently observed (van der Leun *et al.*, 1977; Nurse, 1980). Undeveloped and developed papers gave rise to positive patch tests; in different situations sensitivity to sunlight, indoor light, and UV-A and UV-B, was demonstrated by photo-patch tests. Thiourea was the substance involved in the manufacture of the paper which turned out to be the cause of the severe reactions to light persisting several years after the contact ceased.

Thiourea, which is also a rubber additive, and, in the past, an antithyroid drug, is used in almost all kinds of these photocopying papers as an antiyellowing agent to prevent discoloration of the paper after the breakdown of diazocompounds (Gertler and Laubstein, 1963; IARC, 1974).

Diazo-type reproducing equipment should have mechanical local exhaust ventilation to reduce the ammonia released by the machine, by the paper discharged after printing and when refilling reservoirs (Utidjian, 1976). Mainly in diazocopying discomfort and annoyance have been reported from a short exposure to concentrations of ammonia as low as 20 p.p.m. (Mangold, 1971), a little less than the present (1982) TLV-TWA (25 p.p.m.): however general experience confirms that the health of inured workers is not adversely affected by exposure to ammonia up to a TWA of 100 p.p.m., with excursions to 150 or higher levels (Ferguson *et al.*, 1977).

6. *Photocopying*

In the 1960s and 1970s office copying underwent an extremely rapid expansion, following the introduction of dry-copying which initially concerned coated paper copiers, and plain paper copiers after 1975. Both are known as indirect electrophotographic or transfer xerographic methods.

In transfer xerography the preliminary step of the process consists of producing, on the surface of a photoreceptor, a deposition of gas ions produced by a corotron. This is a corona discharge device which, operating at a voltage of 6–8 kV, ionizes the surrounding air (Wolf and Weigel, 1979). The transfer of the developed image from photoreceptor to the paper is also accomplished by charging the back of the paper by a corotron. Air breakdown by corona discharge is the first of the only two methods of any commercial importance in producing ozone, the second being UV-C irradiation of air or oxygen (Nebel, 1981). In corona discharge technology an electron propelled to a high velocity and containing energy of 6–7 eV can dissociate oxygen molecules into two atoms, which react rapidly with molecular oxygen to form ozone. This fact is also known to have been a side-effect of early corona discharge air ionizers (Hedge, 1982). Thus there is the possibility of ozone production during the activity of corona discharge devices of electrophotocopiers (Greenberg, 1965), and eventually this fact can lead to increases in indoor concentration of ozone during

the activity of photocopying machines (WHO, 1978). Ozone was the only substance found by NIOSH to exceed, near a photocopying machine, the concentration existing in the rest of a studio (*O.H.a.S. News*, 1982).

For indoor settings with no identified inside sources, levels of ozone are typically 40–70% of outside concentrations (Allen *et al.*, 1978), because of destructive reactions which occur on most surfaces (WHO, 1978), the decay occurring faster on organic ones. In a room with many furnishings the half-life is in the order of minutes (Mc Intyre, 1980). Also smoking easily destroys ozone in indoor settings through the production of elevated nitric oxide concentrations (Schuck and Stephens, 1969).

Monitoring of a copier with a maximum voltage of 11 kV under normal working conditions (door open) showed at equilibrium an ozone concentration at the operators breathing zone of 0·068 p.p.m.; ozone emissions varied from less than 1 μg to 54 μg/copy (Selway *et al.*, 1980). An ozone hazard may exist when operating in badly ventilated areas, and in the summer, around midday (Bouhuys, 1974), in areas open to the outside air when outside concentrations are greater than 0·05 p.p.m. (Allen *et al.*, 1978).

Servicing turned out to be very important in reducing ozone emissions, but the return to preservicing conditions was very rapid, indicating that the procedures in use do not produce long-lasting results (Selway *et al.*, 1980). The increasing emission of ozone with time may possibly be related with interferences between residual toner on the photoreceptor, or on the corotron itself, and the deposition of electrons and charged particles which, remaining airborne, contribute more heavily to ozone production.

The pulmonary function adaptation phenomenon which occurs with repeated ozone exposure has been well documented; e.g. at a level of 0·4 p.p.m. (four times the current TLV-TWA), and consists of decreases of FVC and FEV_1 in the first 2–3 days, returning to the baseline by the fourth and fifth day (Kulle *et al.*, 1982).

Near the TLV the major health concern is eye irritation, since, on inhalation, ozone is largely removed in the nose (Buohuys, 1974); this was documented in the 1950s among female office workers who did not complain of symptoms until the TLV was reached and experienced painful ocular sensations above it (Richardson and Middleton, 1958). On the contrary asthmatic people did not differ from control subjects using forced expiratory measures, lung volume or single breath nitrogen indices after repeated exposure to ozone concentrations approximating 0·2 p.p.m. (Linn *et al.*, 1978). ACGIH (1980) recommends that exposure to the TLV of 0·1 p.p.m. should not be prolonged because of the possibility of premature ageing in a manner similar to that of other radiomimetic agents.

Toners are the thermoplastic pigmented powders which give the printed image of an original in transfer xerography. Seven out of eleven toners used in photocopiers turned out to be mutagenic in the Ames *Salmonella* assay; the same behaviour was displayed by the extracts of copies printed on plain paper (Löfroth *et al.*, 1980).

The range of the mutagenic response corresponded to a variation between 40 and 4000 revertants per mg of toner. The mutagenic activity was mainly present in the fraction of extract eluted by benzene (aromatic fraction). The further separation of this fraction was found to elute close to pyrene. The testing for mutagenicity of the smaller fractions showed that the mutagenicity peaks coincided with samples of 1,6- and 1,8-dinitropyrene.