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**REMARKS**

*I liked Tom's revision, but it didn't fit into the document. I think with a little work it could be made into a Nd OS ff pub.*

*Bob Mason*

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**LAUNDERING SECTION OF NIOSH TAKE-HOME TOXINS REPORT**  
DECEMBER, 1994      Thomas K. Hodous

(NOTE: This is revised to include reference to three new articles given to me recently by Bob Mason, and one comment from outside reviewers. Also, at the end is a separate section to be used in a summary/executive summary. Note also that the format is not exactly that of the hard copy sent me last month.)

**(e) Effectiveness of Laundry Procedures**

This section will review articles dealing primarily with the ability of laundering procedures to adequately clean workplace clothing. Properly cleaned protective clothing should prevent contamination of other clothing and the skin, thus reducing the chance of bringing workplace toxins into the home. It must be emphasized that the wearing or taking home of workplace (protective) clothing, often for the purpose of laundering, is the major mechanism of exposure of homes and family members to workplace toxins. As described elsewhere, this mechanism of exposure has been documented for asbestos, silica, lead, fiberglass, arsenic, beryllium, mercury, asthmatogens, pharmaceuticals, many pesticides, chlorinated hydrocarbons, explosives, and other toxins. As many articles note, it follows that great care must be utilized in laundering contaminated clothing, and that one must consider appropriate risk evaluation, work practices, engineering and other controls, and protective clothing when involved in this process.

An obvious solution (besides ending or reducing the hazardous exposure itself) to the problem of home contamination by soiled workclothes is to leave all such clothing at work, as required for several workplace hazards in federal regulations. Even this practice, which has been recognized and advocated for many years (Oliver, 1914), may not be totally effective unless scrupulous separation of home and work clothes and other measures are followed (Richter et al, 1985; Lundquist, 1980). Because of the often incomplete cleaning, some articles have recommended

the replacement of work clothes on a periodic basis (Masek et al, 1972). The use (and subsequent proper disposal) of disposable protective clothing is another means of avoiding home contamination.

A related issue is the potential contamination of waste water effluents during laundering. This is under federal control for commercial laundering operations (Textile Rental Service Association of America, 1994). Other potential hazards of laundering include local exposures to perchloroethylene from commercial dry cleaning facilities (Stasiuk, 1993).

Through the years, most sources have recommended daily laundering of workclothes for virtually all exposures (Katzenellenbogen, 1956; Marceleno et al, 1974; Benning, 1958; NIOSH, 1973; Seixas and Ordin, 1986; Venable et al, 1993). As noted below, the effectiveness of this practice is often inadequately studied, and is frequently incomplete.

#### (1) Fibers

Studies are limited regarding the effectiveness of cleaning of materials for fibers. Fiberglass from contaminated workclothes or fiberglass textiles can contaminate other clothing in the wash (Peachey, 1967; Abel, 1966; Madoff, 1962). In addition, the Peachey paper found continued dermatitis after wearing clothes undergoing two washes of fiberglass-contaminated clothing, indicating incomplete fiber removal during the laundering. A NIOSH study of dry cleaning a coat made with 8% asbestos fiber also showed that fibers were picked up by other clothes in the same wash (NIOSH, 1971). Unpublished data show that in one commercial laundering setting, clothing contaminated with ceramic fibers (50 to 500 fibers per square millimeter) were, after washing, reduced to not detectable to 7 fibers per square

millimeter (Textile Rental Services Association of America, 1994).

**(2) Non-Fibrous Dusts**

The general practice of laundering assumes that appropriate laundering should remove most non-fibrous dusts from clothing. However, Cohen and Positano (1986) in a small study showed considerable retention of beryllium in old shirts versus new ones, even after laundering. The ability to resuspend the dust in the laundered clothing was quite reduced, however. In the case of silica, one small study found that laundering could be done without contamination of the home area. (Versen and Bunn, 1989). However, in other studies, as noted above, the process of home laundering was a major cause of home contamination.

**(3) Firefighter's Protective Clothing and Chemical Protective Clothing**

Several NIOSH investigations in this area have been done (Kominsky, 1984a,b,c; Kominisky, 1987; Kominisky and Singal, 1987; Orris and Kominisky, 1984). Most were related to contaminations with polychlorobiphenyls (PCBs) during electrical fires. These efforts indicated that, in one setting, a standard detergent wash followed by a water wash did not effectively remove the PCBs from the (Nomex) protective clothing, and may in fact have increased the contamination. The recommended wash was an alkaline (trisodium phosphate base) or nonionic (octylphenoxypolyethoxyethanol base) synthetic detergent. It was noted that the lack of visible contamination should not be used to guide cleaning needs in this setting; testing for residua is needed. The need to collect, test, and properly dispose of the wash water was also noted.

One research effort indicated that a trichlorotrifluoroethane (Freon 113) based dry cleaning machine with a revolving chamber

system reduced site-contaminated garment PCB levels by an average of 88%, and of laboratory-contaminated garments by 99% (Kominsky, 1987). Since safe levels of surface contamination are not known, it could not be stated if this would prevent worker or home contamination. Perkins et al (1987) found that Freon decontamination reduced toluene to 0.8 percent of the original exposure on a butyl rubber test material. A soap and water decontamination reduced the level to 1.1 percent. However, air drying the test material at 50 degrees Centigrade for 24 hours reduced the level to 0.25%. This research also showed that the 50 degree temperature air drying reduced seven other solvent contaminants to the limit of detection levels. Finding evidence of no damage to the material with this process, the authors recommended it as the preferred means of decontaminating chemical protective clothing against solvents. They noted that with small amounts of contamination from solvents with "substantially different solubility properties from the protective clothing," air drying at room temperature for 24 hours should be adequate to remove the toxin.

**(4) Laundering for Pesticide Removal from Work clothing**

Numerous studies have examined the effect of laundering for pesticide (or herbicide) removal from work clothing (Anonymous, 1994; Chiao-Cheng et al, 1988; Clifford and Nies, 1989; Easley et al, 1981a, 1981b, 1982a, 1982b, 1983; Easter, 1983; Finley and Rogillio, 1969; Finley et al, 1974, 1979, undated; Goodman et al, 1988; Graves et al, 1980; Hild et al, 1989; Keaschall et al, 1986; Kim et al, 1982, 1993; Kim and Wang, 1982; Laughlin and Gold, 1988, 1989a, 1989b; Laughlin et al, 1981; Lillie et al, 1981, 1982; Mullen and Lehrburger, 1991; Nelson et al, 1992; Oakland et al, 1989; Obendorf and Solbrig, 1986; Rigakis et al, 1987; Satoh,

1979; Stone and Wintersteen, 1988;). Other articles have addressed related issues, such as the effectiveness of various types of clothing, typical use patterns, etc. (Cloud et al, 1983; Stone et al, 1986; Orlando et al, 1981; Oakland et al, 1992; Kim and Kim, 1988; Rucker et al, 1986). Most of these articles deal with pesticide exposure. In general, herbicides are less toxic than insecticides, although the former have a wide range of toxicity and must be handled carefully (Lavy, 1988).

Several review articles and recommendations are of particular use to those interested in the hazard of bringing toxins into workers' homes (Easley, Laughlin, and Gold [1981]; Laughlin and Gold [1988]; Nelson et al [1992]; Stone and Wintersteen [1988]. Nelson et al (1992) found a range of pesticide post-wash residue of 0 to 41% of the pre-wash level for six classes of pesticides, with an average of 13%. Keaschall (1984) found laundering to reduce contamination of several pesticide classes approximately 90% to 95%. However, Easley et al (1982) and Laughlin et al (1985) found only 67% of concentrated (54%) methyl parathion was removed from clothing after ten washes. Because of the many unknowns, some authors recommend yearly replacement of coveralls in pesticide application work (Stone and Stahr, 1989).

While the cited articles discuss laundering considerations, several also note the importance of primary prevention (Ware et al, 1973). For example, it has been shown that clothing contamination with methyl parathion is reduced by 90% if one waits two days before entering the treated field instead of just one day (Finley et al, 1977; Finley et al, 1979). Because of the incomplete removal of clothing contaminants, heat, ultraviolet light, microwave (Kim, 1989), and antitoxic chemicals have been

suggested as soil degraders . However, these have not been extensively studies, and are not commonly used.

The following summary of findings and practical recommendations is based primarily on research of pesticide exposures cited above, which generally involved home washing equipment. **It is important to note, therefore, that different or additional recommendations, as described in other parts of this section, may apply to the decontamination of workplace toxins other than pesticides.**

**Summary of Laundry Findings:**

1. Although many generalizations can be made, the effectiveness of laundering depends on the specific toxic chemical exposure, and its formulation.
2. Pesticides can leach from contaminated clothing during laundering to contaminate other parts of the same garment, to other clothing in the same wash, and to a lessor extent to the washing equipment, thus potentially contaminating later washes. The solubility of the pesticide is a major factor in this process.
3. The pesticides that leach from contaminated clothing to other clothing or surfaces have been found to be biologically active, and thus capable of causing disease.
4. Although laundering can effectively reduce the level of contamination of clothing, it almost never completely removes the toxic residues.
5. Most experts note that, although further research is needed, it

has not been established that the amounts of residue left after a careful laundering process constitute a health hazard for humans. This statement assumes complete washing after every use, using a prewash and the optimal wash conditions, and "normally" soiled clothing. It should be emphasized that clear examples of human toxicity have occurred in laundered workclothes (Clifford and Nies, 1989).

6. The removal of pesticides from clothing is increased by using hot water (e.g., 60° C.); a prewash or pre-rinse stage; multiple washings; a heavy duty detergent, especially for those chemicals that are oil-based; full volumes of water and a full wash time; and a prolonged drying time.
7. Heavily contaminated clothing (such as from a spill of full strength solutions) has been shown to be toxic to humans even after multiple washings.
8. The repeated use of clothing in exposure settings without laundering after each use leads to an accumulation of residues.
9. Laundry additives such as bleach or ammonia have not been found to contribute to the removal of pesticide residues.

**Summary of Laundering Recommendations from Cited Literature:**

In most work settings, there is no quantitative assessment of the toxin contamination of the clothing. The recommendations thus rely on qualitative assessments of exposure, and are meant to represent practical yet effective approaches to the problem, taking various factors into account.

1. One should always read the chemical toxin label carefully for



information regarding handling and recommended laundering procedures.

2. Heavily contaminated clothing should be discarded and/or burned. Because of the many unknowns, some authors recommend yearly replacement of coveralls in pesticide application work, even when heavy contamination is not known to have occurred (Stone and Stahr, 1989).
3. Pesticide-contaminated clothing should be washed separately from other clothing.
4. Laundering methods should include the use of a prewash/pre-rinse step, hot water (e.g., 60° C.), and full cycle water volumes and time (12-14 minutes, and a double rinse if possible). It is best to wash only a few garments in any one wash.
5. Two washes are recommended routinely by some; and where significant contamination is expected by others.
6. Contaminated clothing should be laundered after each use.
7. Line air drying is recommended, both to avoid contamination of an automatic dryer which is difficult to clean, and to allow sunlight and time to further reduce the toxic residues.
8. After laundering contaminated clothing, the washer should have an "empty load" wash with detergent and full volume and time settings to reduce the chance of contamination of later wash cycles.
9. One should wear rubber gloves to handle pesticide-soiled clothing,

and dispose of these when deterioration is noted, and at the end of the pesticide season. A separate garbage-bag lined cardboard box should be used as a hamper, and discarded at the end of the application season. All appropriate safety and health measures should be taken when handling the clothing.

#### **Airshowers and Shoecleaners**

Simonson and Mecham (1983) showed that airshowers removed from 5 to 72% of lead dust from clothing in workplace studies, and 23% to 69% in laboratory studies. Some small amount of breakthrough the clothing (posing a possible skin exposure) was noted. Shoe cleaners were observed (non-quantitatively) to be effective, although potential problems with adequate maintenance were noted.

#### **Other Agents**

Several articles, and general recommendations (Joint Committee on Health Care Laundry Guidelines, 1983) exist regarding laundering to remove biologic agents, such as anthrax, which can be transmitted to laundry personnel via workclothes (Hardy, 1965), or fungal spores which can be brought into farmers' homes on workclothes (Pasanen et al, 1989).

In the medical facility setting, laundering is universally recommended, and is believed to be substantially effective in killing or markedly reducing biological contamination of clothing and linens (Garner and Favero, 1987). Although a major emphasis of laundering in this setting to prevent contagion spread in the medical facility, effective laundering and other decontamination practices also help to protect employees from bringing infectious diseases into their homes. A number of mechanisms are probably active in this process, including dilution and inactivation or the microbicidal properties of heat, detergents, pH changes, chlorine, and drying. Studies of bacterial survival after

various types of hospital laundering have shown marked reduction of viable bacteria (Walter and Schillinger, 1975), (Christian et al, 1983), (Blaser et al, 1984). Careful procedures and appropriate equipment are needed to ensure that the laundry staff themselves are not contaminated with the hazardous biological materials (Garner and Favero, 1987; McKay-Ferguson and Mortimer, 1977).

**ADDITIONAL REFERENCES TO BE ADDED:**

Garner JS, Favero MS [1987]. Guideline for handwashing and hospital environmental control, 1985. MMWR, August 21, 1987, Vol. 36/No. 2S Supplement.

Oliver T [1914]. Lead poisoning: from the industrial, medical, and social points of view. PB Hoeber, New York.

Walter WG, Schillinger JE [1975]. Bacterial survival in laundered fabrics. Appl Microbiol 29:368-373.

Christian RR, Manchester JT, Mellor MT [1983]. Bacteriological quality of fabrics washed at lower-than-standard temperatures in a hospital laundry facility. Appl Env Microbiol 45:591-597.

Blaser MJ, Smith PF, Cody HJ, Wang WL, LaForce FM [1984]. Killing of fabric-associated bacteria in hospital laundry by low-temperature washing. J Infect Dis 149:48-57.

## SUMMARY OF LAUNDRY SECTION

The effectiveness of laundry procedures to remove workplace toxins from clothing depends on many factors, including the contaminant, its concentration and duration of exposure, the fabric, and the frequency and details of the laundry method. In general, it appears that, if properly done, laundering can effectively reduce most toxins in clothing, rendering them acceptable for reuse. However, limited studies suggest that at least some fibers are more difficult to remove from clothing. In addition, because laundering almost never totally removes the toxin, very heavily contaminated clothing may need to be discarded in some cases.

The process of laundering itself can expose people and environments to the involved toxins. Obviously, the problem of home contamination through laundering is most effectively avoided by having all laundering of contaminated clothes done elsewhere. Where this is not considered feasible, careful procedures and partial isolation of workclothes laundering can reduce home and family exposures.

**"Your Right to Know: A Health and Safety Guide for the Lead Industry"**, a 15-minute program intended for major lead using industries such as primary and secondary smelters, battery plants or others that might have high lead exposure. A Spanish version is available. (\$50.00)

**"Control of Exposure to Lead in the Brass and Bronze Industry"**, a 14-minute program for owners and workers in industries that produce brass or bronze ingots, or castings made of brass or bronze. (\$27.99)

**"Control of Lead Exposure in the Radiator Repair Industry"**, a 14-minute program for owners and workers in the radiator repair industry, co-produced with the National Automotive Radiator Service Association. (\$22.95)

**"Lead Exposure at Indoor Firing Ranges"**, jointly produced with the National Rifle Association, reviews the proper procedures for minimizing lead dust exposure at indoor firing ranges. (\$17.99)

**"Control of Lead Exposure for the Stained Glass Professional and Hobbyist"**, a 12-minute program produced with the Stained Glass Association of America for stained glass professionals and hobbyists. (\$17.95)

**"Controlling Lead Exposure for Ceramics Professionals and Hobbyists"**, an instructional video for the hobbyists and professionals working with ceramics. (\$17.99)

All of the above videos are available by sending a check to the Lead Industries Association, 295 Madison Avenue, 19th Floor, New York, NY 10017.