Ann. Occup. Hyg., Vol. 50, No. 7, pp. 657–664, 2006

doi:10.1093/annhyg/mel023

Exposure to Antineoplastic Drugs Outside the Hospital Environment

T. MEIJSTER, W. FRANSMAN, R. VELDHOF and H. KROMHOUT*

Institute for Risk Assessment Sciences, Utrecht University, Utrecht, The Netherlands

Received 20 January 2006; in final form 20 March 2006; published online 5 May 2006

Objectives: **The objectives were (i) to identify occupational populations outside hospitals working with antineoplastic drugs, (ii) to determine the size of the populations 'at risk', (iii) to identify major determinants and routes of exposure outside hospitals and (iv) to estimate exposure levels and frequencies relative to levels found in hospitals.**

Methods: **The survey consisted of two phases; (i) identification of activities with potential exposure to antineoplastic drugs by literature review, interviews, questionnaires and workplace visits, (ii) exploratory measurements of exposure and surface contamination in selected sectors.**

Results: **Eight sectors were identified with potential exposure to antineoplastic drugs: pharmaceutical industry, pharmacies, universities, veterinary medicine, nursing homes, home care, laundry facilities, and waste treatment. Four sectors were of primary concern: veterinary medicine, home care, nursing homes and industrial laundries. The populations potentially exposed in these sectors vary considerably (from several tens to thousands of workers), as do their levels of exposure. Exposure measurements collected in the veterinary medicine sector showed that workers are indeed exposed to antineoplastic drugs and, in some cases (on gloves after administration), levels were 15 times higher than levels measured during administration in hospitals. Workers sorting contaminated hospital laundry in industrial laundry facilities were exposed to antineoplastic drugs through inhalation. For the home care and nursing homes sectors the highest exposure levels were found when cleaning toilets and washing treated patients. These two sectors are expected to have the largest exposed population (5000–10 000 individuals).**

Conclusions: **This study has resulted in a comprehensive overview of populations with potential exposure to antineoplastic drugs. Exposure levels can potentially be high compared with the hospital environment, because exposure routes are complex and awareness of the hazard (and therefore use of protective measures) is low. The number of individuals outside hospitals in The Netherlands exposed to antineoplastic drugs is estimated to be between 5000 and 15 000.**

Keywords: antineoplastic drugs; home care; industrial laundry facilities; nursing homes; occupational exposure; veterinary medicine

INTRODUCTION

Exposure to antineoplastic drugs has been associated with adverse health effects (reproduction and carcinogenic) (Selevan *et al*., 1985; Stücker *et al*., 1990; Sessink *et al*., 1994a, 1995; Fransman , W., Peelen, S., Roeleveld, N. *et al*., manuscript submitted). Exposure to antineoplastic drugs has been extensively studied in The Netherlands. Pharmacy personnel and nurses were shown to be exposed to antineoplastic drugs during hospital tasks and contamination of (work) surfaces by these agents occurs (Sessink *et al*., 1992, 1994b, 1997; Kromhout *et al*., 2000; Fransman *et al*., 2005, Fransman, W., Peelen, S., Hilhorst, S. *et al*., manuscript submitted). A recent study on dermal exposure to antineoplastic drugs showed that dermal exposure to cyclophosphamide occurs during nursing tasks and antineoplastic drugs were present in bedding and sweat of patients (Fransman *et al*., 2005). These findings indicate that there is a potential for exposure to antineoplastic drugs in sectors related to hospitals (i.e. home care, nursing homes, pharmacies) and in sectors where people are working with contaminated 'rest products' from hospitals (i.e. industrial laundries, waste treatment plants). To our knowledge, exposure to antineoplastic drugs has not been studied in sectors outside hospitals and there is a need to identify

*Author to whom correspondence should be addressed.
Tel: +31 30 2539440; fax: +31 30 2539499;
e-mail: h.kromhout@iras.uu.nl

possible exposure to these hazardous drugs outside the hospital environment.

The main objectives of this study were; (i) to identify occupational populations outside hospitals working with antineoplastic drugs, (ii) to determine the size of the populations potentially exposed, (iii) to identify major determinants and routes of exposure outside hospitals and (iv) to estimate exposure levels and frequencies relative to those found in hospitals.

METHODS

Identification of exposed population

In the first phase scientific literature and other information sources (e.g. internet) were consulted to perform a structured inventory of all occupational groups that could come in contact with antineoplastic drugs. This information was used to construct a 'flow diagram' to describe the route of antineoplastic drugs through different work sectors.

In the second phase all activities with antineoplastic drugs were identified. This information was obtained by walk-through surveys in individual companies and through interviews with company personnel.

Questionnaires were used to get detailed information on work characteristics (i.e. frequency of task performance, use of personal protective equipment) and number of workers involved. Questionnaires were designed based on experience with similar kind of surveys in the hospital setting (Fransman, W., Peelen, S., Roeleveld, N. *et al*., manuscript submitted; Meijster *et al*., 2006). For home care and universities a special questionnaire was developed and sent to all individual institutes. This questionnaire contained questions with respect to frequency of use of antineoplastic drugs, methods of use, conditions with respect to personal protective equipment, etc. For nursing homes it was not possible to send a questionnaire to all individual institutes. Here a questionnaire containing similar questions as the ones described above was sent to a small sub-sample of institutes to get a general idea about the use of antineoplastic drugs in this sector. Additional information was obtained from experts in the branch organization.

The total number of workers in each occupational group was obtained from the Central Bureau for Statistics (CBS) and from branch and trade organizations.

Exposure measurements

Exploratory task-based measurements were collected in sectors with high potential for exposure to antineoplastic drugs, to confirm exposure and to get an indication of exposure levels. Dermal exposure was measured through collection of gloves or by washing both hands using an isopropanol solution when no gloves were worn (Fransman *et al*., 2005). Inhalation exposure was measured through personal sampling using PAS6 samplers with glass fibre filters (diameter: 25 mm) and a flow rate of 2.0 l min^{-1}. Environmental air samples were taken using a stationary high volume sampler (flow = 28.3 l min^{-1}) with glass fibre filters (diameter: 37 mm). All air samples were short-term measurements (maximum 60 min) focusing on the exposure during a specific activity or set of activities. Wipe samples were collected using two tissue and 20 ml of 0.03 M sodium hydroxide solution. Wipe samples were taken from the full surface of the object except for wipe samples from the floor, which were 0.5 m^2 of floor surface. Cleaning cloth and cleaning water after cleaning a toilet or living area and washing water and washing cloth used to wash a patient who recently received chemotherapy were collected to look for contamination with antineoplastic drugs.

Measurements were focussed on tasks with carboplatin, cyclophosphamide, or 5-fluorouracil to be representative for exposure to antineoplastic drugs. Samples were analysed for cyclophosphamide using a previously described GC-MSMS analysis method (Sessink *et al*., 1993). 5-Fluoracil was determined using a previously described HPLC method (Sessink *et al*., 1992). Carboplatin was determined using voltametry as described by Connor *et al*. (2005) and Schmaus *et al*. (2002) for analysis of surface contamination.

RESULTS

Eight sectors were identified with potential exposure to antineoplastic drugs: home care, nursing homes, pharmacies, laundries, waste treatment, pharmaceutical industry, veterinary medicine, and universities (Fig. 1). Detailed information per sector collected by company visits, interviews, and questionnaires elucidated that tasks and complexity of routes and determinants varies widely among all occupational sectors, as does the size of the potentially exposed population. Below the results are discussed per occupational sector.

Home care

Home care institutions in The Netherlands are agencies that provide assistance in nursing care and domestic work (primarily cleaning) to patients in their own home environment.

For home care of patients or administration of chemotherapy in domestic settings no information could be found in the literature. Literature did describe a trend towards treatment at outpatient clinics and intensive home care in patients receiving chemotherapy (Del Gaudio and Menonna-Quinn, 1998).

In total, 123 900 workers are employed by home care institutions in The Netherlands, of whom, based

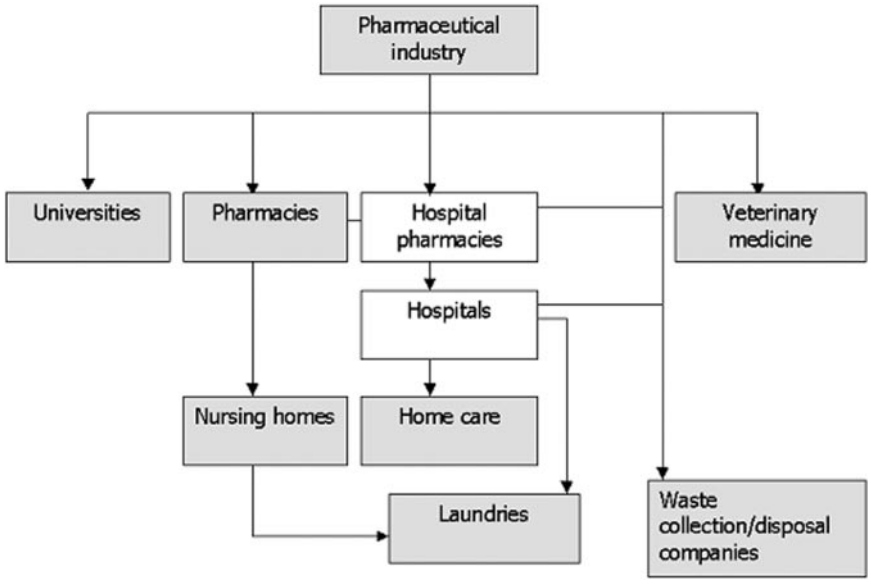

Fig. 1. Schematic overview of the occupational groups with possible exposure to antineoplastic agents.

on the figures of presence of chemotherapy in the home situation, presumably 5000–10 000 work with patients receiving chemotherapy. Results from the questionnaire survey among all Dutch home care institutions (response = 60%; $N = 59$) showed that mainly nursing tasks are performed by home care institutions, but that also antineoplastic drugs are administered to patients [mainly sub-cutaneous (46%) and oral administration (46%)] (Table 1). This shows that in The Netherlands administering of antineoplastic drugs is not limited to the hospital environment and does (although often prescribed by oncologists) also occur in the home environment performed by non-specialized home care nurses. Gloves are used in the majority of home care institutions during administration, but less frequently during nursing tasks. Some nurses use an additional apron or mask (Table 1). Only 36% of home care institutions were able to give information on the number of clients receiving chemotherapy (either in a hospital or at home). Consequently a large number of nurses unknowingly work with antineoplastic drugs.

Dermal exposure to antineoplastic drugs was not detected during nursing tasks in home care institutions, except for the gloves used during cleaning (70 ng per pair) (Table 2). Contamination was detected in the cleaning cloth (3314 ng) and cleaning water (0.73 ng ml^{-1}) once (Table 2).

Nursing homes

In nursing homes (primarily elderly homes in The Netherlands) tasks with potential exposure to antineoplastic drugs were comparable with those in home care institutions. No additional literature was available on working with antineoplastic drugs in these institutions.

The number of nursing homes was >1700 and they employ ~200 000 workers. The number of workers potentially exposed was estimated to be >1000. A survey performed by the branch organization showed that registration of activities was very poor and no information could be given on frequencies of activities with potential exposure to antineoplastic drugs. Nurses reported that patients were occasionally treated with antineoplastic drugs in nursing homes, but generally patients in nursing homes received chemotherapy in outpatient clinics of hospitals and were subsequently nursed in nursing homes.

Measurement results identified that dermal exposure occurred during washing of patients (range: 32–450 ng), but not during emptying a pot/urinal or during cleaning (Table 3). Washing water (5.1 ng ml^{-1}) and cleaning cloths (range: 125–3253 ng) appeared to be contaminated with antineoplastic drugs.

Pharmacies

Exposure to antineoplastic drugs has been extensively studied in hospital pharmacies (Sessink *et al*., 1994b, 1997; Fransman *et al*., 2005). These studies indicate that pharmacy technicians are potentially exposed to antineoplastic drugs during daily activities. The questionnaire in home care institutions indicated that 66% of institutions that administered chemotherapy obtained their antineoplastic drugs (primarily for oral or subcutaneous administration) from pharmacies outside hospitals, and not from hospitals like the remaining 34%. The Royal Dutch Pharmaceutical Society (KNMP) of which more than

Table 1. Percentage of home care institutions where tasks with antineoplastic drugs are performed and the use of personal protective equipment

Task	Home Care Institutions with task (%) (N = 59)	Gloves (% used)	Apron (% used)	Mask (% used)
Administering IV drip	8	100	25	25
Administering IV pump	7	100	50	50
Administering push	5	100	50	50
Administering sub-cutaneous	46	96	30	4
Changing 5FU cassette	17	100	25	13
Administering orally	46	61	9	4
Administering nasal tube	2	100	100	100
Intramuscular administration	5	100	67	33
Preparing antineoplastic drugs	0	—	—	—
Washing of patient	69	54	46	6
Emptying pot/urinal	66	66	60	17
Assisting at administration	15	44	22	0
Cleaning after vomiting	68	83	56	8
Physical examination of patient	17	50	40	0
Wound care	5	67	67	0
Other	10	100	75	25

90% of all pharmacists are a member stated that the policy was to obtain these treatments as much as possible in ready-to-use form from the pharmaceutical industry to prevent exposure of pharmacy personnel to antineoplastic drugs. Nevertheless, they acknowledged that incidental preparation of antineoplastic drugs in pharmacies (outside hospitals) took place, but that strict protective measures were taken.

Laundries

Nurses are exposed via the skin to antineoplastic drugs while removing contaminated bed sheets from patients receiving chemotherapy (Fransman *et al.*, 2005). Company visits in two laundries showed that contact with (contaminated) bedding occurred while manually sorting laundry. Between 100 and 200 workers were estimated to be involved in these activities. Although work protocols advise wearing of personal protective equipment (especially gloves), gloves were not worn by workers during both visits.

Table 2. Indicative measurements of tasks performed in home care institutes regarding antineoplastic drugs or patients receiving chemotherapy

Task	Agent	Sample	N	$N >$ LOD	Range (ng)
Administering	5FU	Gloves	2	0	—
	5FU	Hand wash	2	0	—
Washing patient	CP	Hand wash	1	0	—
Emptying pot/urinal	CP	Hand wash	1	0	—
Cleaning sanitary	CP	Gloves	3	1	ND–70
	CP	Hand wash	3	0	—
	CP	Cleaning water (ng ml^{-1})	2	1	ND–0.73
	CP	Cleaning cloth	3	1	ND–3314
Cleaning other	CP	Hand wash	1	0	—
	CP	Cleaning cloth	1	0	—

N = number of samples taken; CP = cyclophosphamide; 5FU = 5-fluorouracil; ND = not detectable. Detection limits: 5FU gloves = 3200 ng per pair; hand wash = 50 000 ng per pair; CP gloves = 8 ng per pair; hand wash = 12.5 ng per pair; cleaning water = 0.05 ng ml^{-1}; cleaning cloth = 8 ng.

Inhalation exposure was detected in three out of five measurements when sorting contaminated sheets with a median value of 4.5 ng m^{-3} (Table 4). Contamination was not detected in stationary air samples. Actual dermal exposure was not detected in any of the handwash samples.

Waste treatment plants

In The Netherlands there is one treatment plant for hospital waste, which receives all chemical and biological hospital waste (~6500 tonnes per year) for combustion. The manual loading of sealed containers from the truck onto a conveyor belt is the only process with potential contact with antineoplastic drugs. This activity is performed by 16 employees in rotating shifts of 2 workers. A previous study showed that the hospital waste containers from oncology wards are contaminated with antineoplastic drugs (Fransman, W., Peelen, S., Hilhorst, S. *et al.*, manuscript submitted). Workers wear gloves when loading containers and, in case of visual contamination or spillage, containers were decontaminated before loading.

Pharmaceutical industry

Most studies on exposure to antineoplastic drugs outside hospitals focus on workers in pharmaceutical industries during the production of antineoplastic drugs. Antineoplastic drugs have been detected on the outside of workers' gloves during almost all tasks and in urine of workers weighing ingredients

Table 3. Indicative measurements of tasks performed in nursing homes regarding antineoplastic drugs or patients receiving chemotherapy

Task	Agent	Sample	*N*	*N* > LOD	Range (ng)
Washing patient	CP	Gloves	1	1	32
	CP	Hand wash	2	1	ND–450
	CP	Washing water	1	1	5.1
	CP	Washing cloth	1	0	—
Emptying pot/urinal	CP	Gloves	1	0	—
	CP	Hand wash	2	0	—
Cleaning sanitary	CP	Gloves	1	0	—
	CP	Hand wash	1	0	—
	CP	Cleaning cloth	1	1	923
Cleaning pot chair	CP	Hand wash	1	0	—
	CP	Cleaning cloth	1	1	3253
Cleaning other	CP	Gloves	1	0	—
	CP	Hand wash	2	0	—
	CP	Cleaning cloth	2	1	ND–125

N = number of samples taken; CP = cyclophosphamide; ND = not detectable. Detection limits: CP gloves = 8 ng per pair; hand washing sample = 12.5 ng per pair; cleaning water = 0.05 ng ml^{-1}; cleaning cloth = 8 ng.

(Sorsa *et al*., 1988; Sorsa and Pyy, 1990; Jeebhay *et al*., 1993; Sessink *et al*., 1997).

Only one company producing antineoplastic drugs was identified in The Netherlands. Other pharmaceutical plants did not have any activities concerning antineoplastic drugs or were solely distributors. In the company that did produce antineoplastic drugs, ~20–40 employees worked at stages of the process where antineoplastic drugs were handled and could be released into the work environment. Exposure during these processes is unlikely, because workers performing these tasks make use of strict control measures and personal protective equipment. Workers are routinely monitored on exposure to antineoplastic drugs and protective measures are improved where necessary.

Veterinary medicine

Antineoplastic drugs are being used on a regular basis in veterinary medicine, primarily treating small pets (dogs and cats) (Pellicaan and Teske, 1999). Preparing and administering of antineoplastic drugs were identified as activities with potential for exposure to antineoplastic drugs. However, conclusions are mainly based on information available from studies in hospital settings.

In The Netherlands, ~10–15 veterinary clinics treat pets (primarily dogs and cats) with chemotherapy for a variety of cancers and immunological diseases and between 20 and 100 workers are potentially exposed. During visits of these clinics, dermal exposure and splashes were visible during administration and preparation of antineoplastic drugs, while protective clothing was not consequently worn during these activities. Circumstances under which these treatments and associated activities take place were obviously different from the hospital environment. Nursing tasks were not performed and animals almost always immediately leave the clinic after treatment.

Exposure does occur in veterinary clinics during preparation and administration of antineoplastic drugs and 63% (*N* = 8) of gloves collected from the veterinarian were found contaminated with carboplatin (Table 5). On one occasion an assistant's gloves were also contaminated with antineoplastic drugs while changing the infusion system (Table 5). Wipe samples from all surfaces in the preparation and administering room were all contaminated with antineoplastic drugs (LAF-cabinet: 63–20 621 ng; floor in preparation room: 3.8–12 ng; door handle: 1.0–13 ng; administering table: 2.7–104 ng) (Table 5).

Universities

Occupational health departments of Dutch universities reported that antineoplastic drugs were being used there. However, universities did not register the use of these chemicals, which made it impossible to gain insight into the number of workers handling antineoplastic drugs at universities. In general, occupational health professionals of the different universities did provide information that working with any hazardous materials would be performed using strict laboratory protocols minimizing the chance of exposure. This could, nevertheless, not be confirmed for the use of antineoplastic drugs.

In general

Potentially exposed populations in the identified sectors were relatively small, except for the sectors home care and nursing homes (Table 6). The last two columns in Table 6 are an estimate of frequency and intensity of exposure to antineoplastic drugs in each of the identified sectors relative to comparable situations in hospitals, based on all information that was obtained in this study. Home care, nursing homes, and veterinary medicine were compared with oncology nurses in hospitals, while pharmacies and pharmaceutical plants were compared with pharmacy technicians in hospitals. For laundries and waste plants the comparison was made for specific exposure scenarios, which apply to these sectors (handling contaminated bed sheets and contact with waste containers, respectively). Knowledge of the use of antineoplastic drugs at universities was lacking (Table 6).

Table 4. Cyclophosphamide exposure when sorting contaminated bedding in laundry facilities

Task	Agent	Sample	*N*	*N* > LOD	Median (ng m^{-3})	Range (ng m^{-3})
Sorting laundry	CP	Personal air sample	5	3	4.5	ND–12.7
	CP	Stationary air sample	5	0	ND	—
					(ng)	(ng)
Sorting laundry	CP	Hand-wash sample	5	0	ND	—

N = number of samples; ND = not detectable.

Table 5. Carboplatin levels measured during several tasks in two veterinary clinics

Task	Sample	*N*	*N* > LOD	Median (ng)	Range (ng)	
Preparation	Gloves doctor	4	2	5.0	ND–91	
Administering	Gloves doctor	4	3	9.7	ND–534	
	Gloves assistant (fixating animal)	3	0	ND	—	
	Gloves assistant (changing infusion)	1	1	14	—	
	Wipe sample					Surface (cm^2)
Preparation	LAF-cabinet	4	4	652	63–20 621	2300–3830
	Floor in front of LAF-cabinet	2	2	8.0	3.8–12	5000
	Door handles preparation room	2	2	7.0	1.0–13	80
Administering	Administering table	4	4	43	2.7–104	10 500–11 250

N = number of samples; ND = not detectable; detection limit gloves carboplatin = 4.8 ng per pair gloves.

Table 6. Number of employees, potentially exposed employees, most important tasks, and estimated frequencies and levels of exposure to antineoplastic drugs for each identified sector relative to oncology nurses in hospitals

Occupation sector	Number of employees	Potentially exposed employees	Most important tasks	Relative exposure frequency	Relative exposure intensity
Home Care	123 900	5000–10 000	Administering, nursing, cleaning	<	>
Nursing homes	200 000	>1000	Administering, nursing, cleaning	<	>
Pharmacies	17 500	100–200	Preparation	<[a]	=[a]
Laundries	12 200	100–200	Sorting laundry	>[b]	=[b]
Waste plant	5200	20	Loading waste containers	<	<
Pharmaceutical industry	14 900	20–40	Producing antineoplastic drugs	<[a]	<[a]
Veterinary medicine	4100	20–100	Preparation, administering	>[c]	>[c]
Universities	56 300	10–40	Experiments	<	?[d]

[a]Relative to pharmacy technicians in hospitals.
[b]Relative to oncology nurses only while handling contaminated bed sheets.
[c]Only for veterinarians that use antineoplastic drugs.
[d]No information available on the way of use of antineoplastic drugs at universities.

DISCUSSION

This study showed that exposure to antineoplastic drugs can occur in a variety of occupational sectors outside the hospital environment. In some of the studied sectors the exposure and associated risks were very limited and the number of people potentially exposed rather small. Four sectors were identified where exposure to antineoplastic drugs is potentially high: (i) home care, (ii) nursing homes, (iii) veterinary medicine and (iv) laundry facilities.

When comparing the situation of these four sectors with information from hospitals (Table 6) it is likely that the risk for workers in home care is equal to that of hospital nurses. Their frequency of exposure will probably be lower than that of oncology nurses, because the number of patients treated is believed to be relatively small for an individual nurse. However since awareness of potential exposure is low, protective equipment is hardly used. This might lead to high dermal exposure levels, which is primarily caused by lack of information exchange between hospitals and home care institutions (Table 6). Most home care institutions indicated that registration of patients receiving antineoplastic drugs is poor or non-existing. Even if an employee is aware of the fact that he or she is working with a patient who has received chemotherapy, protocols

and guidelines, especially for nursing or cleaning tasks were often not available.

For nursing homes it was more difficult to make a detailed comparison with hospitals since information obtained was not as elaborate as for home care. Nevertheless, it is unlikely that awareness in this sector is better than that observed in home care. Exposure frequencies were believed to be somewhat lower than in home care since patients in nursing homes were more likely to be admitted to the hospital (Table 6).

For laundries, inhalation seems to be the primary route of exposure when actively handling contaminated sheets. Since exposure was not found in the background work environment only workers directly involved in handling sheets seem to be at risk of exposure to antineoplastic drugs. Although dermal exposure was not detected, measurements in hospitals indicate that dermal exposure does occur when handling contaminated sheets (Fransman *et al*., 2005). The higher frequency of contact with contaminated bed sheets in laundry facilities in combination with the inhalation exposure found in this study, indicates that workers in laundry facilities are potentially higher exposed to antineoplastic drugs than oncology nurses during the handling of bed sheets.

For veterinary medicine, activities performed were very similar to those performed in hospitals except that hardly any 'nursing tasks' occurred in veterinary medicine because animals leave the clinics after administration. Since antineoplastic drugs are administered only in a few clinics in The Netherlands and the number of treatments was estimated to be between 500 and 1000 per year, frequency of exposure could be very high for individual workers (Table 6). In addition, use of protective equipment was limited increasing the potential for high dermal exposure levels (Table 6). Based on this we believe that for a small group of veterinarians and assistants exposure might be higher than that observed for oncology nurses in hospitals. This was confirmed by measurements where levels of antineoplastic drugs found on the gloves of veterinary doctors preparing were similar to levels found on gloves in hospitals. The levels found when administering antineoplastic drugs in veterinary medicine were, nevertheless, higher by a factor of 15 than levels found in hospitals (Minoia *et al*., 1998). An important factor for this is probably the way administration is performed in veterinary medicine. Closed IV-systems with Luer–Lock connections, which is standard procedure in hospitals, are not used in veterinary clinics increasing the chance of leakage of high concentrations of antineoplastic drugs during inserting and releasing the IV system from the animal. The use of antineoplastic drugs in veterinary clinics is undergoing several developments in The Netherlands. New treatments are introduced and more clinics are interested in using chemotherapy. This is stimulated by the pharmaceutical industry increasingly advertising antineoplastic drugs as veterinary drugs and making efforts to get them registered as such. If no regulatory actions are taken this might result in a strong increase in number of workers exposed.

For the pharmaceutical industry, universities, waste plant workers and pharmacies protective measures were believed to be sufficient to prevent exposure when performing daily activities with potential contact with antineoplastic drugs (Table 6). Even though literature shows that exposure is common in some pharmaceutical plants outside The Netherlands (Sorsa *et al*., 1988; Sorsa and Pyy, 1990; Jeebhay *et al*., 1993; Sessink *et al*., 1997), we believe that this information does not reflect the Dutch situation as it was observed during our visit to the plant. State-of-the-art of protective equipment was high and regular monitoring was performed on the 'high risk' workers to ensure occupational exposure does not occur. Nevertheless, workers should be cautious in case of calamities or inadequate use of personal protective equipment. This is especially important when working with high levels of antineoplastic drugs, for example in pharmaceutical industry or waste treatment. In these cases compulsory use of hygiene procedures and protocols is essential.

This study succeeded in identifying the most important sectors outside hospitals where potential exposure to antineoplastic drugs exists. The measurements, although only exploratory, confirm this for four sectors with assumed highest exposure: home care, nursing homes, veterinary medicine and laundry facilities. More research is needed to quantify exposure levels to antineoplastic drugs outside hospitals. This paper can be used as an important first step in the identification of sectors where exposure to antineoplastic drugs might exist. It is, nevertheless, important to look beyond the limitations of this study since situations might be different in other countries.

Acknowledgements—This study was facilitated by The Dutch Ministry of Social Affairs and Employment. The authors are indebted to the management and workers of the companies for their participation in this study.

REFERENCES

Connor TH, Sessink PJM, Harrison BR *et al*. (2005) Surface contamination of chemotherapy drug vials and evaluation of new vial-cleaning techniques: Results of three studies. Am J Health Syst Pharm; 62: 475–84.

Del Gaudio D and Menonna-Quinn D. (1998) Chemotherapy. Potential occupational hazards. Am J Nurs; 98: 59–65.

Fransman W, Vermeulen R, Kromhout H. (2005) Dermal exposure to cyclophosphamide in hospitals during preparation, nursing and cleaning activities. Int Arch Occup Environ Health; 78: 403–12.

Jeebhay M, Mbuli S, Uebel R. (1993) Assessment of exposure to chloramphenicol and azathioprine among workers in a

South African pharmaceutical plant. Int Arch Occup Environ Health; 65: 119–22.

Kromhout H, Hoek F, Uitterhoeve R *et al*. (2000) Postulating a dermal pathway for exposure to anti-neoplastic drugs among hospital workers. Applying a conceptual model to the results of three workplace surveys. Ann Occup Hyg; 44: 551–60.

Meijster T, Fransman W, van Hemmen JJ *et al*. (2006) A probabilistic assessment of the impact of interventions on the exposure to antineoplastic agents of oncology nurses. Occup Environ Med published online 21 March 2006. doi:10.1136/oem.2005.022723.

Minoia C, Turci R, Sottani C *et al*. (1998) Application of high performance liquid chromatography/tandem mass spectrometry in the environmental and biological monitoring of health care personnel occupationally exposed to cyclophosphamide and ifosfamide. Rapid Commun Mass Spectrom; 12: 1485–93.

Pellicaan CH, Teske E. (1999) Risks of using cytostatic drugs in veterinary medical practice [article in Dutch]. Tijdschrift voor Diergeneeskunde; 124: 210–5.

Schmaus G, Schierl R, Funck S. (2002) Monitoring surface contamination by antineoplastic drugs using gas chromatography-mass spectrometry and voltammetry. Am J Health Syst Pharm; 59:956–61.

Selevan SG, Lindbohm ML, Hornung RW *et al*. (1985) A study of occupational exposure to antineoplastic drugs and fetal loss in nurses. N Engl J Med; 313: 1173–8.

Sessink PJM, Boer KA, Scheefhals APH *et al*. (1992) Occupational exposure to antineoplastic agents at several departments in a hospital. Environmental contamination and excretion of cyclophosphamide and ifosfamide in urine of exposed workers. Int Arch Occup Environ Health; 64: 105–12.

Sessink PJM, Scholtes MM, Anzion RBM *et al*. (1993) Determination of cyclofosfamide in urine by gas chromatography-mass spectrometry. J Chromatogr B Biomed Appl; 616: 333–7.

Sessink PJ, Cerna M, Rossner P *et al*. (1994a) Urinary cyclophosphamide excretion and chromosomal aberrations in peripheral blood lymphocytes after occupational exposure to antineoplastic agents. Mutat Res; 309: 193–9.

Sessink PJ, van de Kerkhof MC, Anzion RB *et al*. (1994b) Environmental contamination and assessment of exposure to antineoplastic agents by determination of cyclophosphamide in urine of exposed pharmacy technicians: is skin absorption an important exposure route? Arch Environ Health; 49: 165–9.

Sessink PJ, Kroese ED, van Kranen HJ *et al*. (1995) Cancer risk assessment for health care workers occupationally exposed to cyclophosphamide. Int Arch Occup Environ Health; 67: 317–23.

Sessink PJ, Wittenhorst BC, Anzion RB *et al*. (1997) Exposure of pharmacy technicians to antineoplastic agents: reevaluation after additional protective measures. Arch Environ Health; 52: 240–4.

Sorsa M, Pyy L. (1990) Exposure assessment of workers in the production of cyclophosphamide. Pol J Occup Med Environ Health; 3: 185–9.

Sorsa M, Pyy L, Salomaa S *et al*. (1988) Biological and environmental monitoring of occupational exposure to cyclophosphamide in industry and hospitals. Mutat Res; 204: 465–79.

Stücker I, Caillard JF, Collin R *et al*. (1990) Risk of spontaneous abortion among nurses handling antineoplastic drugs. Scand J Work Environ Health; 16: 102–7.