EXPOSURE AND RISK ASSESSMENT OF DIOXIN IN BLEACHED KRAFT PAPER PRODUCTS

BY

ARTHUR D. LITTLE, INC.

TO

MONITORING AND DATA SUPPORT DIVISION
OFFICE OF WATER REGULATIONS
AND STANDARDS

U.S. ENVIRONMENTAL PROTECTION AGENCY

U.S. EPA CONTRACT NO. 68-01-6951
WORK ASSIGNMENT NO. 18
AMENDMENT NO. 1

JUNE 25, 1987

52967-02

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0. INTRODUCTION

Results from the National Dioxin Study have indicated that 2,3,7,8-TCDD is present in fish and river sediments collected downstream from some pulp and paper mills. The highest levels appeared to be associated with bleached Kraft mills. As a result, a concern has arisen regarding the potential exposure and risk to consumers using products containing bleached Kraft pulp and several research projects have been undertaken. For example, the Pulp and Paper study, a cooperative effort between the U.S. Environmental Protection Agency, the American Paper Institute, and the National Council of the Paper Industry for Air and Stream Improvement, was initiated to determine possible sources of dioxins and furans in bleached Kraft mills.

Also, the Monitoring and Data Support Division (MDSD) of the Office of Water Regulation and Standards of the U.S. Environmental Protection Agency requested that Arthur D. Little, Inc., as part of its continued support for the National Dioxin Study, conduct an exposure and risk assessment study of dioxin in bleached Kraft paper products.

2.0 OBJECTIVE AND APPROACH

The objective of this task was to evaluate and quantify, to the extent possible with available data, the exposures and the risks to health that may occur through use of bleached Kraft paper products that may contain dioxin.

The general approach was to define the universe of bleached Kraft paper products, to quantify their production and to determine the potential implications of product use on dioxin exposure. Because of the uncertainty regarding the exact mixture of chlorinated dibenzo-p-dioxin isomers contained in bleached Kraft pulp, the generic term "dioxin" has been used throughout this study, except where reference to the specific isomer (e.g., 2,3,7,8-TCDD) is made.

The potential exposures associated with a variety of use situations were evaluated and more detailed evaluations were conducted for a few selected products which appeared to represent greater risks.

There were four major steps in this task.

- Exposure Assessment
- Hazard Identification
- Risk Characterization
- Report Production

2.1 Exposure Assessment

The exposure assessment was probably the most difficult and uncertain aspect of this project because many of the issues had never been considered, and there was limited information to describe and quantify product use patterns. The assessment involved the following steps.

2.1.1 Identify consumer products made from bleached Kraft pulp

Products were identified through review of the literature and discussions with staff members of Arthur D. Little, Inc., experienced in the pulp and paper industry.

2.1.2 Characterize use situations

Additional data were collected to provide information on the use of these products. In addition, staff members from the Product Technology Section at Arthur D. Little, Inc., were consulted and project team discussions were held in order to develop additional information. The types of information developed during this step included the potential number of users, the extent and/or duration of average use and descriptions of the typical conditions of use. It was anticipated that use situations would include usual activities such as handling sheets of paper and unusual activities such as oral contact and ingestion of paper by children.

2.1.3 Identify and characterize exposure pathways

In this step exposure scenarios were developed from the use situations identified in the previous step. Limited data were available for this purpose, and through use of related information and group discussions, reasonable scenarios which were consistent with past experience were developed. This subtask produced the methods which were used to calculate the exposure for each product/use situation.

2.1.4 Evaluate dioxin concentrations in the consumer products being evaluated

Although it had been anticipated that some data might be available to determine initial product concentrations, no such data were available. Therefore, with the advise of MDSD, it was assumed that bulk bleached Kraft pulp contains 10 parts per trillion (ppt) of dioxin.

2.1.5 Estimate exposure associated with product/use situations

This step was an integration of the results of steps 3 and 4 of the exposure assessment. In step 3, the methods or models were developed for the product/use combinations and in step 4 rough estimates of concentrations were developed. This step resulted in estimates of the average or range of exposures for each product use situation.

2.1.6 Estimate exposure associated with incineration of contaminated products

Independently, the potential impact of dioxin-contaminated paper on dioxin emissions from municipal solid waste incinerators was considered within the limitations of this task.

2.2 Hazard Identification

This step, while extremely important to a risk assessment, did not represent a large part of the effort. Primarily, confirmation was obtained from the EPA Project Officer that the current EPA cancer risk assessment methodology for 2,3,7,8-TCDD would be utilized.

2.3 Risk Characterization

In this step, the exposure estimates developed above, as well as the unit risk value from the hazard identification step, were used to quantify the risks associated with the product/use situations. The need to identify the uncertainties associated with the estimates was also anticipated.

3.0 EXPOSURE ASSESSMENT

3.1 Identification of Consumer Products Containing Bleached Kraft Pulp

3.1.1 Production of Bleached Kraft Pulp

Bleached Kraft pulp is a major component in a wide variety of paper, paperboard and pulp products. In order to identify and classify specific consumer end products from an exposure assessment perspective, it is necessary to understand how various paper and converted products are manufactured.

In general, pulp, paper and paperboard production consists of five distinct steps: pulping, bleaching, stock preparation, papermaking, and converting. Figure 1 is a simplified block flow diagram of these processes. In the discussion that follows, each step is described briefly.

In the pulping process, cellulosic material, primarily wood, is converted by mechanical or chemical means into papermaking fibers. Mechanical processes separate the wood fibers by attrition using large grind stones or metal plates. The lignin which holds the cellulose fibers together is not dissolved or separated and appears in the final product. This method produces a very economical grade of fiber (groundwood) and is typically used in newsprint.

Semi-chemical processes combine chemical and mechanical steps. The wood is softened by means of a chemical solution at low temperature. Excess chemical is removed and the wood is defiberized mechanically. Essentially all of the lignin remains with the pulp. The primary use is for corrugating medium, i.e., the fluted middle layer of boxes and shipping containers.

Chemical pulping is used to produce fiber for a wide range of products including printing and writing papers, tissue and packaging paper, paperboard and fluff pulp. The raw material is reduced to a fibrous state by cooking with solutions of various chemicals. Essentially all of the lignin is removed from the wood fiber. The most important chemical pulping process is the Kraft or sulfate process.

The second step in the production sequence is chemical bleaching. Typically, the agents used for bleaching include chlorine compounds and oxygen. The purpose of this step is threefold: to remove any coloring matter within the pulp, to extract residual lignin and to achieve brightness or whiteness, which is desirable in printing and writing papers, food packaging and sanitary applications. Fibers that undergo the Kraft chemical pulping process and bleaching sequence are

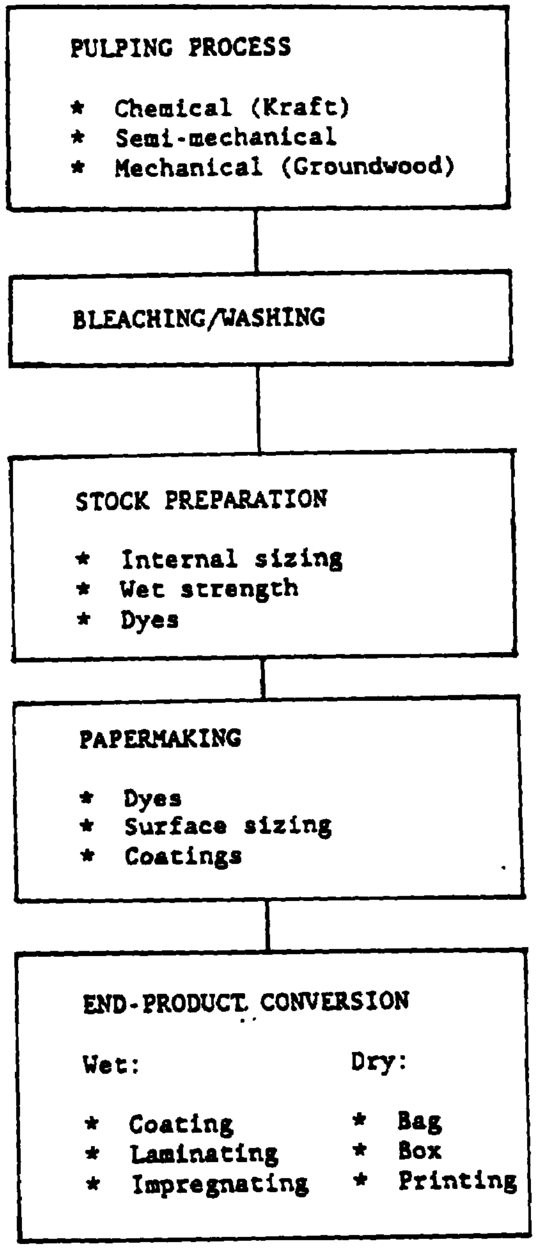

FIGURE 1: END-PRODUCT MANUFACTURE OF PAPER/PULP PRODUCTS

referred to as bleached Kraft fibers or bleached Kraft pulp.

The third step, stock preparation, refers to several operations that may take place between pulping (and bleaching) and the formation of the paper or board on a machine and may include heating, refining and repulping. The purpose of these operations is to shorten or to hydrate the fiber for specific paper properties. Fibers from different processes can be blended in various proportions to produce a wide range of products. Fillers, dyes, pigments, wet strength resins and conventional sizing may be added during stock preparation.

As a fourth step, the prepared stock is conveyed to the paper machine where the paper web is formed and subsequently dried.

The final step in the production of a paper or paperboard product is the converting process. There may be one or many converting operations that follow the papermaking process. These operations include, for example, waxing, gumming, off-machine coating, printing, bag, envelope, box and container manufacturing. With the exception of tissue mills, paper and board mills are typically not responsible for the converting process. This is handled by companies which use the different grades of paper produced at the paper and paperboard mills as their raw materials.

The manufacture of paper and paperboard products is distributed among three distinct industries: paper mills, paperboard mills, and construction paper and board mills. In Figure 2, the three mill industries are presented along with the grades of paper and board they produce. The various grades of paper and board produced are, in turn, processed by "converters" into consumer end-products.

Since the focus of this study is limited to consumer end-products which consist primarily of bleached Kraft pulp, various paper and board grades will not be considered in this analysis. These include all the grades produced by the construction paper and board mills,

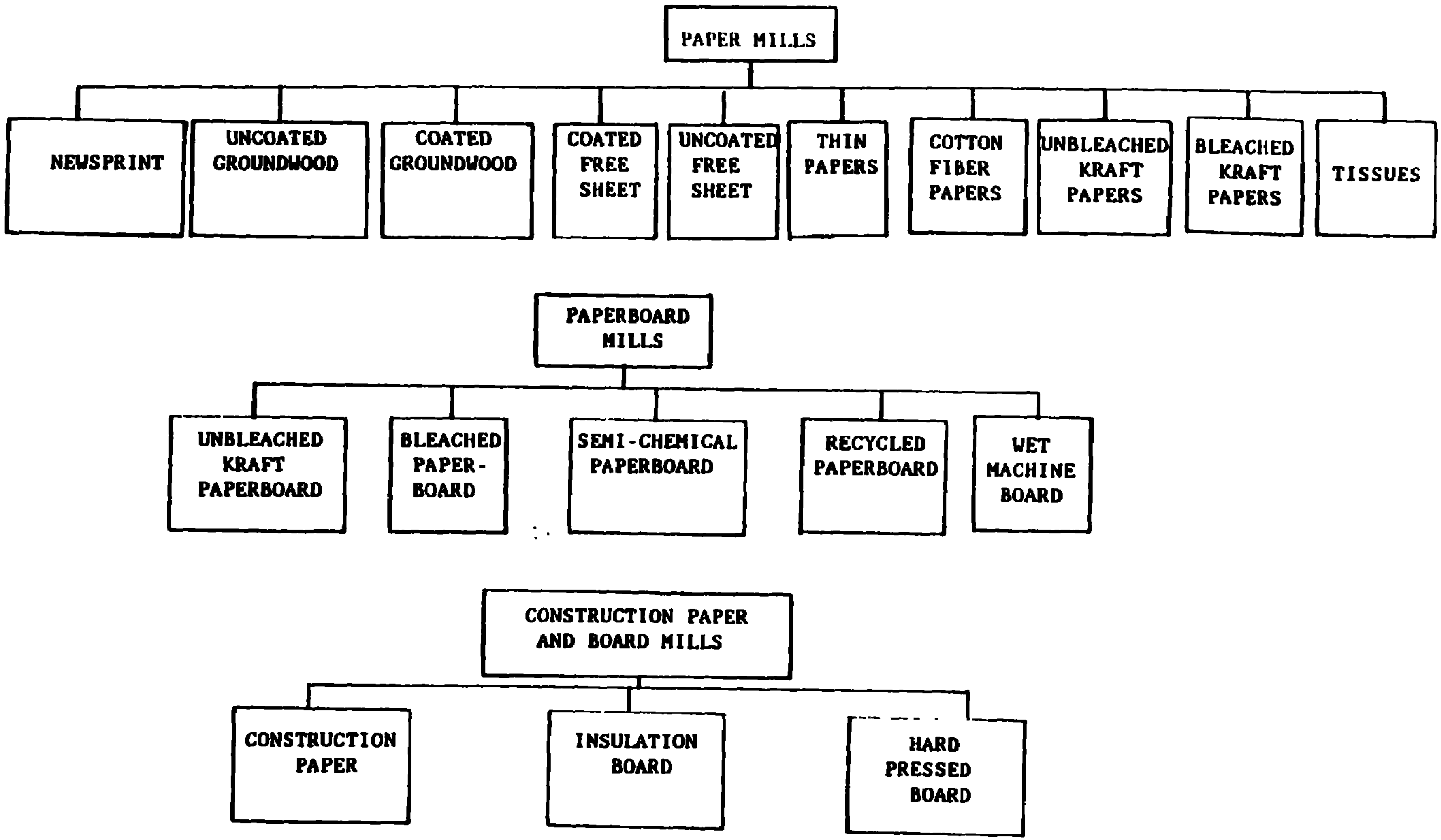

FIGURE 2: PAPER PRODUCING MILLS AND THE RESPECTIVE PAPER GRADES

Source: Arthur D. Little, Inc., Based on U.S. Department of Commerce and Industry Paper Classification Schemes unbleached Kraft paperboard and specific grades from paper mills, such as newsprint, uncoated/coated groundwood, cotton fibers and the majority of packaging and industrial papers (except glassine, greaseproof and vegetable parchment papers).

In particular, consumption patterns of consumer products manufactured from the following paper, board and pulp categories will be assessed and used for exposure assessment and risk evaluation:

- coated/uncoated free sheet;
- thin papers;
- bleached bristols;
- special industrial papers: glassine, greaseproof, etc.;
- tissue papers;
- packaging paperboard;
- non-packaging paperboard; and
- fluff pulp.

3.1.2 Product Categories and Production Data

There are numerous consumer end-products that comprise the bleached Kraft paper, board and pulp categories. Annual production data for 1985 were acquired from the published literature, statistics from the American Paper Institute, Bureau of Census Reports, Industrial Outlook and other in-house sources. Primarily, these data are restricted to the larger product categories and are not broken down as individual products.

The estimated production tonnages for products whose major component is bleached Kraft pulp are summarized in Table 1. Examples of consumer end-products that comprise the respective categories are also listed. As mentioned earlier, the actual bleached Kraft pulp content varies among the categories. The remainder may be fillers, laminations, and resins. For example, only about 75 percent of the milk carton stock is actually bleached Kraft. Alternatively, tissue papers are almost exclusively bleached Kraft.

Due to the variation in bleached Kraft content, the total production tonnage is not necessarily equal to the consumption of bleached Kraft pulp. Using an average percent bleached Kraft content within these respective categories, the annual pulp consumption can be estimated. These totals are also presented in Table 1. For the remainder of this analysis, the per capita usage and percent distribution will be based on values of consumption of bleached Kraft, not production of converted end-products.

Several assumptions are implicit in the data of Table 1. The net effects of imports and exports on the tonnages are assumed to be minor (± 10 percent); accordingly, the totals have not been adjusted. The numbers also include recycled paper that is bleached. Certain product categories, such as coated free sheets, are "semi-bleached," i.e., the Kraft pulp undergoes fewer bleach/wash cycles than fully bleached fiber. However, from the perspective of potential dioxin contamination in the end product, it is assumed that a semi-bleached pulp is equivalent to a fully bleached fiber. It is important to note that there may be variation in the bleached Kraft content within a given product category; however, in this analysis an average value has been used to represent the majority of end-products that fall within each category. Finally, the examples listed in Table 1 are not all-inclusive. There is some overlap whereby a given product may be found in more than one category. Nevertheless, the example products are representative of typical consumer products containing bleached Kraft.

The relative distribution of bleached Kraft pulp among the selected product categories was calculated from the data generated in Table 1, and is summarized in Table 2. It should be noted that this percentage breakdown does not account for the sum total of bleached Kraft pulp produced and consumed in all the grades of paper and allied products,

TABLE 1

CONSUMER PRODUCTS CONTAINING BLEACHED KRAFT(BK) (A) (B)

PRODUCT CATEGORIES	TOTAL 1985 PRODUCTION THOUSAND STONS/YR (I)	AVERAGE PERCENT BK	BK CONSUMPTION(H) THOUSAND STONS/YR
TOTAL PAPER, PAPERBOARD, PULP	27078		22864
** PAPER(C)(D)**	22198		19121
*PRINTING	16665		13848
COATED FREE SHEET(E)	5875	70	4113
E.G. PRINTED PRODUCTS			
MAGAZINES			
PUBLISHED BOOKS			
CATALOGUES			
ANNUAL REPORTS			
UNCOATED FREE SHEET(E)	9625	90	8663
E.G. CORRESP.TABLETS			
DESK PADS			
LOOSELEAF FILLER			
MEMO BOOKS			
OFFICE PAPER			
TYPING PAPER			
FINAN/BUSINESS FORMS			
ENVELOPES			
PRINTED BOOKS			
STATIONERY			
THIN PAPERS	241	100	241
E.G. CIGARETTE PAPER			
BIBLE PAGES			
LENS TISSUE			
CARBON PAPER			
BLEACHED BRISTOLS	924	90	832
E.G. WEDDING INVITNS.			
CALLING CARDS			
FILE FOLDERS			
POSTCARDS			

TABLE 1

CONSUMER PRODUCTS CONTAINING BLEACHED KRAFT(BK) (A) (B)

PRODUCT CATEGORIES	TOTAL 1985 PRODUCTION THOUSAND STONS/YR (I)	AVERAGE PERCENT BK	BK CONSUMPTION(H) THOUSAND STONS/YR
*PACKAGING	593	95	563
FOOD WRAPPING	31	95	29
BAG&SACK	266	95	253
SHIPPING SACK	80	95	76
GLASSINE,GRSPRF,ETC.	216	95	205
*TISSUE(F)	4940	95-98	4710
TOILET TISSUE	1882	95	1788
FACIAL TISSUE	354	95	336
NAPKINS	579	98	567
TOWELLING	1700	95	1615
WIPER/OTHER	282	95	268
E.G. INDUST.CLEANSING			
PACKAGING			
TOT ALL OTHER	143	95	136
E.G. UNCOATED WRAPPER			
CONFETTI			
CREPE PAPER			
DOILIES			
GIFT WRAP			
NOVELTIES			
COFFEE FILTERS			
** PAPERBOARD **	3948		3160
*PACKAGING	3881		3100
MILK CARTON STOCK(G)	609	75	457
E.G.MILK CONT.			
YOGURT CONT.			
CHEESE CONT.			
NON-DAIRY BEVRG CONT			
NON-CARB. DRINK CONT.			
JUICE CARTON			

TABLE 1

CONSUMER PRODUCTS CONTAINING BLEACHED KRAFT(BK) (A) (B)

PRODUCT CATEGORIES	TOTAL 1985 PRODUCTION THOUSAND STONS/YR (I)	AVERAGE PERCENT BK	BK CONSUMPTION(H) THOUSAND STONS/YR
FOLDING CARTONS	1780	80	1424
E.G. TOBACCO			
MEDICINAL			
COSMETICS			
CONT. (GELS, SAUCES)			
DRY FOOD			
PREPARED/PKGD FOOD			
PAPERCUPS/LIDS	438	80	350
PAPER PLATES/TRAYS	284	80-90	241
OTHER	656	75-85	525
E.G. OVENABLE TRAYS			
LIQUID VESSELS			
MOIST/OILY FOOD VESSELS			
LINERBOARD	114	90	103
*NON-PACKAGING	67	90	60
E.G. DISPLAY BOARD			
** PULP *	932		582
*DISPOSABLE DIAPERS	800	60	480
*FEM HYGIENE PRODS	66	95	63
E.G. SANITARY NAPKINS			
TAMPONS			
*GERIATRIC ACCESSORIES	66	60	40
E.G. INCONTINENCE PADS			

NOTES FOR TABLE 1:

A. SOURCES: AMERICAN PAPER INSTITUTE STATISTICS(1985); INDUSTRY OUTLOOK; PREDICASTS FORECASTS; ADL ESTIMATES. SEE REFERENCES.
B. THIS LIST IS NON-EXHAUSTIVE; SOME PRODUCTS FALL INTO SEVERAL CATEGORIES
C. INCLUDES RECYCLED PAPER THAT IS BLEACHED
D. IMPORTS&EXPORTS INCLUDED IN TOTAL; NET DIFFERENCE MAY BE +/- 10%.
E. ASSUME SEMI-BLEACHED PRODUCTS AND BLEACHED PRODUCTS EQUIVALENT FROM RISK PERSPECTIVE.
F. DOES NOT INCLUDE FLUFF PULP CONSUMPTION IN SANITARY TISSUE
G. TOTAL WEIGHT INCLUDES BK PLUS COATINGS,LAMINATIONS, ETC.
H. BK TONNAGE REPORTED DOES NOT INCLUDE CONTENT IN OTHER CATEGORIES OF PAPER PRODUCTS NOT CONSIDERED IN THIS ANALYSIS.
   THUS, ACTUAL BK CONSUMPTION EXCEEDS TOTAL LISTED HERE.
I. STONS/YR = SHORT TONS(2000 LBS/STON) PER YEAR

but mainly represents the relative consumption among those product categories whose main component is bleached Kraft. From Table 2, it is evident that bleached Kraft consumption is dominated by the printing papers; the tissue papers are at a distant second place, followed by the packaging paperboard. The fluff pulp and packaging papers utilize a relatively small fraction of the total bleached Kraft tonnage.

If an exposure assessment were based purely on relative tonnages, then several product categories would not be considered for further analysis. However, the per capita annual consumption for specific products provides a more realistic perspective on bleach Kraft tonnage consumed. For example, the relative distribution of both disposable diapers and milk carton stock is about 2 percent each. However, the size of the population using disposable diapers, namely infants, is significantly smaller than the size of the population using milk carton/juice cartons, etc., i.e. children, adolescents, adults, etc. Therefore, the actual per capita consumption of bleached Kraft for disposable diapers would greatly exceed that of products made from milk carton stock. This analysis is illustrated for the various product categories in Table 3. Note that the second column "Annual Bleached Kraft Production" includes the fractional content as listed in Table 1.

The user population, tabulated in the third column of Table 3, specifies whether typical products within a given category are used by a segment of the population, or the total US population. Products in categories such as tissue or packaging paperboard are generally used by all age brackets. For the printing papers and packaging papers, children under five years of age are excluded. For a specific use of an uncoated free sheet, which may be chewed and/or eaten, such as a spitball, however, the user population consists of children between the ages of 5 and 13. The disposable diapers are specific for children under three years of age. The use of feminine hygiene products is limited to the female segment of population between the ages of 10 and 50. Finally, the geriatric accessories are primarily

TABLE 2

RELATIVE PERCENT DISTRIBUTION OF BLEACHED KRAFT IN SELECTED PRODUCT CATEGORIES

TOTAL PAPER, PAPERBOARD, & PULP
100.0

** PAPER **	83.6
*PRINTING	60.6
CTD FREE SHEET	18.0
UNCT FREE SHEET	37.9
THIN PAPERS	1.1
BL. BRISTOLS	3.6
*PACKAGING	2.5
FOOD WRAPPING	0.1
BAG&SACK	1.1
SHIPPING SACK	0.3
GLASSINE, GRSPRF	0.9
*TISSUE	20.6
TOILET TISSUE	7.8
FACIAL TISSUE	1.5
NAPKINS	2.5
TOWELLING	7.1
WIPER/OTHER	1.2
TOT ALL OTHER	0.6

** PAPERBOARD **	13.8
*PACKAGING	13.6
MILK CARTON STOCK	2.0
FOLDING CARTONS	6.2
PAPERCUPS/LIDS	1.5
PAPER PLATES/TRAYS	1.1
OTHER	2.3
LINERBOARD	0.4
*NON-PACKAGING	0.3

** PULP *	2.5
*DISP. DIAPERS	2.1
*FEM HYGN PRODS	0.3
*GERIATRIC ACCESS	0.2

TABLE 3

CHARACTERIZATION OF PRODUCT USE

PRODUCT CATEGORY	ANNUAL BK PRODN (000) STONS/YR	USER POPULN. CATEGORY (A)	PER CAPITA USAGE KG/PERSON /YR	PRODUCT USE/ MISUSE
** PAPER **				
*PRINTING				
COATED FREE SHEET	4113	5	16.9	READING
UNCOATED FREE SHEET	8663	5	35.7	READING/CORRESPONDENCE
		6		INGESTION
THIN PAPERS	241	5	1.0	READING
				SMOKING
				TYPING
				CLEANING
BLEACHED.BRISTOLS	832	5	3.4	CORRESPONDENCE
*PACKAGING				
FOOD WRAPPING	29	5	0.1	PACKAGING
BAG&SACK	253	5	1.0	PACKAGING
SHIPPING SACK	76	5	0.3	PACKAGING
GLASSINE,GRSPRF,ETC.	205	5	0.8	PACKAGING
*TISSUE				
TOILET TISSUE	1788	1	6.8	WIPING/CLEANING
FACIAL TISSUE	336	1	1.3	WIPING
NAPKINS	567	1	2.2	WIPING
TOWELLING	1615	1	6.1	DRYING
				GREASE ABSORPTION
WIPER/OTHER	268	1	1.0	WIPING
TOT ALL OTHER	136	1	0 5	CLEANING/WIPING
** PAPERBOARD **				
*PACKAGING				
MILK CARTON STOCK	457	1	1.7	BEV STORAGE
FOLDING CARTONS	1424	1	5.4	FOOD STORAGE
PAPERCUPS/LIDS	350	1	1.3	HOT/COLD LIQUID SERVICE
PAPER PLATES/TRAYS	241	1	0.9	FOOD SERVICE
OTHER/OVENABLE BRD	525	1	2.0	HEATING FOOD
LINERBOARD	103	1	0.4	PACKAGING
*NON-PACKAGING	60	1	0.2	
** PULP *				
*DISPOSABLE DIAPERS	480	2	40.3	INFANT CARE
*SANIT NAPKINS&TAMPONS	63	3	0.8	FEMIN. HYGIENE
*GERIATRIC ACCESSORIES	40	4	16.4	ELDERLY INCONT.

NOTES FOR TABLE 3:
A. USER POPULATION CATEGORIES DEFINED AS FOLLOWS:

	(MM)
1- TOTAL US 1985 POPULATION	238.74
2- CHILDREN < 3 YEARS	10.82
3- FEMALES 10-50 YEARS	71.06
4- ELDERLY >=65 W/ INCONTINENCE	2.20
5- TOT POPULN > 5 YRS	220.70
6- CHILDREN BETWEEN 5-13 YEARS	30.11

used by the elderly population (greater than age 65) with the medical condition of incontinence. The sources for population data used in Table 3 are the U.S. Bureau of Census (1985) and the National Center for Health Statistics (1986).

Characterization of product use provides an estimate of the consumption for a typical user of a given product. Referring to the example mentioned earlier, it is apparent that, although the tonnages of bleached Kraft are similar for milk carton stock and disposable diapers, the relative per capita consumption, as shown in the fourth column, indicates a difference in bleached Kraft consumption of more than a factor of twenty.

Based on the per capita consumption for all categories in Table 3, the printing paper products and pulp categories indicate a high level of consumption; tissue and packaging paperboard products reflect intermediate levels and the packaging papers represent low bleached Kraft consumption levels.

The last column in Table 3 exemplifies the use (or misuse) of typical products. Definitions of product uses provide further insight into potential routes of dioxin exposure, i.e., how is the product used, and how does it come in contact with the user? While the bulk of the printing papers are used for reading and writing, there are some exceptions: fractions of uncoated sheets may be chewed or ingested and thin papers may serve as lens tissue, cigarette papers or carbonizing paper. Similarly, in the tissue category, the majority of products are used for wiping or cleaning purposes; however, with the increased use of microwave cooking, paper towels may also be used for absorption of grease, e.g., in cooking bacon. Numerous scenarios of product use/misuse can be postulated. As the exposure assessment and analysis of exposure routes are discussed further, the rationale for selection of particular scenarios and products will become evident.

3.1.3 Characterization of Product Use

In conducting a product-related exposure assessment, the product must be characterized both in terms of the type and size of the user population and in terms of its patterns of use. Estimation of per capita consumption essentially defines the user population that is exposed. There are several parameters that characterize the use of a given paper product, such as the duration, frequency and multiplicity of use. Each of these parameters can be ranked in a semi-quantitative manner, so that low-risk categories may be screened out. As a result, further analysis can focus on potentially high-risk product types. In Table 4, a qualitative risk matrix is presented, characterizing both product use and the user.

The first column lists the product categories. The second column defines three levels of per capita consumption of bleached Kraft, based on data from earlier tables, i.e., low refers to less than 1 kg/person/year; medium implies between 1 and 10 kg/person/yr; and high refers to use in excess of 10 kg/person/yr. The unit use duration, which is shown in the third column, may be short, i.e., on the order of a few seconds, as with facial tissues. Alternatively, the use may be of medium duration, on the order of a few minutes, as with coated paper cups or extended over one or more hours as with a large juice carton.

The relative frequency of use, tabulated in the fourth column, is based on annualized daily averages. The criteria needed to distinguish frequency levels are as follows: low implies usage not exceeding once per week, such as use of shipping sacks; medium refers to a range between once per week and once per day, such as use of paper plates; high-frequency indicates use exceeding once a day, such as use of disposable diapers.

The multiplicity of use for each product category is shown in the fifth column. Essentially, it answers the question: can repeated exposure occur from the same product (not product type)? Due to the basic disposability of the majority of paper products, such as single

TABLE 4

QUALITATIVE EXPOSURE/RELATIVE RISK MATRIX

PAPER PRODUCT AND USAGE	PER CAPITA CONSUMP. L,M,H(A)	DURATION PER USE OF UNIT S,M,L(B)	RELATIVE FREQUENCY OF USE L,M,H(C)	IS USE PER UNIT REPEATED? N,Y (D)	EXPOSURE ROUTE D,I (E)	DIOXIN EXTRACTION MEDIUM: SKIN OILS	BODY FLUIDS	NON-OILY FOODS	OILY FOODS
PAPER:									
PRINTING PAPER									
COATED SHEET	H								
-READING		S	H	Y	D	*			
UNCT SHEET	H								
-READ/CORRESP		S	H	Y	D	*			
-SPITBALLS		S	H	N	I		*		
THIN PAPERS	M								
-READING		S	H	Y	D	*			
-SMOKING		M	H	N	I (F)		*		
-TYPING/CARBON		S	M	N	D	*			
-CLEANING/WIPING		S	M	N	D	*			
BL BRISTOLS	M								
-CORRESPOND.		S	M	N	D	*			
PACKAGING									
WRAPPING	L								
-PACKAGING		M	L	N	D	*			
BAG&SACK	M								
-PACKAGING		M	L	N	D	*			
SHPNG SACK	L								
-PACKAGING		M	L	Y	D	*			

TABLE 4

QUALITATIVE EXPOSURE/RELATIVE RISK MATRIX

PAPER PRODUCT AND USAGE	PER CAPITA CONSUMP. L,M,H(A)	DURATION PER USE OF UNIT S,M,L(B)	RELATIVE FREQUENCY OF USE L,M,H(C)	IS USE PER UNIT REPEATED? N,Y (D)	EXPOSURE ROUTE D,I (E)	DIOXIN EXTRACTION MEDIUM: SKIN OILS	BODY FLUIDS	NON-OILY FOODS	OILY FOODS
TISSUE									
TOILET	M								
-WIPING		S	H	N	D	*			
FACIAL	M								
-WIPING		S	H	N	D	*			
NAPKIN	M								
-WIPING		M	H	N	D	*			
TOWELLING	M								
-DRYING		S	H	N	D	*			
-GREASE ABSORP		M	M	N	I				
WIPER/OTHER	M								
-WIPING		S	M	N	D	*			
TOT ALL OTHER	L								
-CLEANING/WIP		S	M	N	D	*			
PAPERBOARD:									
PACKAGING									
MILK CTNS	M								
-BEVER STORAG		L	H	N	I	*		*	
FOLD CTNS	M								
-FOOD STORAGE		L	M	N	I	*		*	
PAPERCUPS/LIDS	M								
-HOT/COLD LIQ		M	M	N	I	*		*	*
PLATES/TRAYS	M								
-FOOD SERVICE		M/L	M	N	I	*		*	*
OVENABLE BRD	M								
-HEATING FOOD		M	L	N	I	*		*	*
LINERBRD	L								
-PACKAGING		L	L	N	I				
NON-PKGING	L	L	L	N	D			*	

TABLE 4

QUALITATIVE EXPOSURE/RELATIVE RISK MATRIX

PAPER PRODUCT AND USAGE	PER CAPITA CONSUMP. L,M,H(A)	DURATION PER USE OF UNIT S,M,L(B)	RELATIVE FREQUENCY OF USE L,M,H(C)	IS USE PER UNIT REPEATED? N,Y (D)	EXPOSURE ROUTE D,I (E)	DIOXIN EXTRACTION MEDIUM SKIN OILS	BODY FLUIDS	NON-OILY FOODS	OILY FOODS
PULP:									
DISP DIAPS -INFANT CARE	H	L	H	N	D		*		
SAN NAP & TAMP -FEM. HYGIENE	M	L	H	N	D (G)		*		
INCONT PADS -ELDER INCONT	H	L	H	N	D		*		

NOTES FOR TABLE 4:

A. PER CAPITA CONSUMPTION, BASED ON PRODUCTION TONNAGE & CENSUS DATA, IS DEFINED AS FOLLOWS:
   L- LOW; LESS THAN 1 KG/PERSON/YR
   M- MEDIUM; 1-10 KG/PERSON/YR
   H- HIGH; EXCEEDING 10 KG/PERSON/YR

B. BASED ON ADL ESTIMATES:
   THE CRITERIA USED TO DISTINGUISH THE TIME ARE AS FOLLOWS:
   S- SHORT; ON THE ORDER OF SECONDS ; E.G., FACIAL TISSUE
   M- MEDIUM; ON THE ORDER OF MINUTES ; E.G., CIGARETTES
   L- LONG; ON THE ORDER OF HOURS ; E.G., DISPOSABLE DIAPERS

C. BASED ON ADL ESTIMATES:
   CRITERIA USED TO DISTINGUISH THE FREQUENCY OF USE ARE AS FOLLOWS:
   L- LOW; EXPOSURE NOT EXCEEDING ONCE PER WEEK ; E.G. SHIPPING SACK
   M- MEDIUM; EXPOSURE FREQUENCY RANGES FROM 1/WK TO 1/DAY; E.G. PAPER CUPS
   H- HIGH; EXPOSURE TO UNIT EXCEEDS ONCE PER DAY ; E.G., DISP DIAPERS
   ANNUALIZED DAILY AVERAGES ARE ESTIMATED BASED ON SEGMENTS OF USER POPULATION

D. THE USE PER UNIT MAY BE ONE-TIME FOR SINGLE SERVICE ITEMS SUCH AS PAPER PLATES, VS. REPEATED FOR PAPER GOODS SUCH AS BOUND SHEETS.
   N- NO;   Y- YES

E. EXPOSURE ROUTES TO DIOXIN FROM A GIVEN PAPER PRODUCT INCLUDE THE FOLLOWING:
   D - DERMAL ABSOPPTION
   I - INGESTION

F. ASSUME THAT THE INGESTION ROUTE DOMINATES THE EXPOSURE. ALSO, EFFECTS OF A BURNING CIGARETTE ON POTENTIAL DIOXIN VAPOR GENERATION AND SUBSEQUENT INHALATION HAVE NOT BEEN CONSIDERED.

G. THIS DERMAL ABSORPTION ROUTE DIFFERS FROM ALL OTHER DERMAL CONTACT EXPOSURES IN THAT MUCOUS MEMBRANES FACILITATE THE ABSORPTION OF DIOXIN.

H. "USE" IS DEFINED AS " CONTACT WITH AN EXTERNAL PHASE."

service dinnerware, most of the products are not used repeatedly. However, the reading/writing papers and shipping sacks may be reused, and exposure may occur with each use of the same product unit.

Assuming the three use parameters are equally important, certain generalizations can be made. According to Table 4, a typical user of printing paper product uses a large number of sheets, each for a short period of time, and so may be exposed to the same sheet more than once. Packaging papers, on the other hand, are used infrequently, for an intermediate duration. Tissue papers, like printing papers, consist of high frequency, short/medium duration uses. Paperboard used for food packaging tends to be used for extended periods of time, although the frequency is not high. Finally, the products in the pulp category are typically used frequently and for a lengthy period of time.

In order to determine user exposure, a mechanism for dioxin release from a product to a user must be defined. For this study, an "external phase matrix penetration" mechanism is assumed. In order to release the dioxin from a paper, board or pulp matrix, an external phase or solvent, such as air, skin oil, body fluids or water must penetrate the matrix, solublize and extract the dioxin and come in direct contact with the user. The modes of contact, termed "routes of exposure," may be via ingestion or dermal absorption. External phases that contact the outer skin, such as skin oil touching a sheet of paper, result in exposure by "dermal absorption"; external phases that pass directly to the gastro-intestinal tract, such as by chewing paper, result in exposure by "ingestion." A third route of exposure, where the external phase may come in contact with internal mucous membranes, e.g., with a sanitary tampon, is assumed to be equivalent to ingestion in this analysis.

In Table 4, respective potential exposure routes are characterized for each of the product categories. Additionally, one or more relevant external phases (or extraction media) are identified for each of the product categories. For the majority of products where outer dermal absorption is the primary exposure route, skin oils are the extraction media; the single exception is body fluids (urine) on a disposable diaper. Where ingestion of the external phase containing dioxin is involved, non-oily and/or oily foods usually comprise the external phases. Where internal dermal absorption occurs, body fluids are the extraction media.

The ultimate risk to the user depends not only on the quantity, frequency and duration of use, but also on the route of exposure and extraction medium. These last two parameters lead into a further analysis of dioxin availability, migration rates, and dioxin release from a product. In the sections that follow, these topics are discussed in greater detail.

3.2 Assessment of Potential Availability of Dioxin

3.2.1 Estimation of Dioxin in Bleached Kraft Products

The detection of dioxin in fish and sediment samples collected near bleached Kraft pulp and paper mills has prompted many questions. Several studies are currently underway to evaluate the formation and fate of dioxin in the bleached Kraft process and to determine the potential for dioxin contamination in bleached Kraft pulp and paper products. However, these studies are not complete and the data are not yet available.

For the purposes of this exposure and risk assessment, the EPA has provided a hypothetical contamination level of 10 ppt (pg/g) for all bleached Kraft pulp and paper. As discussed previously, no provision has been made for decreasing or increasing the assumed level of contamination for semi-bleached or highly bleached (several passes through the chlorination process) products. It has been assumed, however, that the 10 ppt contamination is only in the bleached Kraft portion of the product and, therefore, the product contamination level has been adjusted based on the estimated percentage of bleached Kraft pulp or paper contained in each specific product (See Table 1). This assumption is reasonable in light of preliminary data indicating that the highest environmental contamination has been associated with bleached Kraft mills. However, a survey of dioxin contamination in consumer paper products is needed in order to document the fate of dioxins formed during pulp and paper manufacture.

There are no available data describing the potential distribution of the dioxin contamination within the pulp and paper matrices. The dioxin molecule could be chemically bonded or adsorbed to paper components, or it could be loosely incorporated into the matrix and available to migrate. The chemical characteristics of dioxin suggest that it will probably be adsorbed to the molecular structure of the paper matrix; however, in the absence of any specific data and in order not to underestimate potential exposure, it has been assumed that the dioxin is freely available.

Finally, it is acknowledged that the type of coating and the actual coating process used on pulp and paper products may affect the contamination. For example, the coating process may actually initiate an extraction process resulting in a lower dioxin concentration in the paper product itself and a more concentrated contamination in the coatings; or there may be a continual partitioning between the product and the coating; or the coating may be a barrier to dioxin migration. Due to the lack of any data describing the potential behavior of dioxin contamination in coated paper products, it has been assumed that there is no transport to coating materials during or after the coating process and that there is no detectable migration from a coated product.

3.2.2 General Approach to Evaluation of Migration Rates

The overall migration rate of a contaminant from a specific matrix depends on the rate of diffusion within the matrix and the rate of dissolution and dispersion in an external phase in contact with the matrix. Migration is influenced by properties of the contaminant, the matrix and the external environment; interactions among the contaminant, the matrix and the external environment; and the use conditions. Some specific factors potentially affecting contaminant migration during a specific use include:

- size of migrant - molecular weight,
- physical and chemical properties of the migrant,
- concentration of the migrant,
- interaction of the migrant with the matrix,
- characteristics of matrix - rigidity/flexibility,
- contact/penetration of matrix by external phases,
- solubility of migrant in external phases,
- duration of use, and
- temperature.

Migration from a specific matrix is often controlled within the matrix. In such cases, migration is a function of the initial concentration in the matrix and the diffusion coefficient of the migrant/matrix pair.

The driving force for migration is the concentration gradient of the migrant within the matrix and the rate of migration is directly proportional to this gradient. According to theory, migration will continue as long as there is a concentration gradient. However, there may exist cases in which some of the migrant species are bound and unavailable for migration. For example, this has been reported for very low concentrations of monomer in some plastic materials. Most available studies documenting contaminant migration involve synthetic polymers and concentrations of ppm or higher. No information was found to support or refute a "zero migration" concentration for paper products.

Migration through a matrix toward the surface may occur through a diffusive process in which migrating molecules "jump" thermally from one position to a neighboring position. The mechanisms involved are similar to those by which solutes move through liquids and can theoretically be characterized in terms of diffusion coefficients. Diffusion through solid matrices is much more sensitive to migrant molecular weight than is diffusion in water because the migration of small molecules requires only minor shifting of the matrix, while the movement of larger molecules from site to site may necessitate the simultaneous reorientation of segments of the matrix. Thus, diffusion rates in solid matrices (e.g., polymers) are relatively low and decrease sharply as migrant size increases (Till et al., 1983).

In addition to the size and nature of the migrant, other factors related to the thermal energy (i.e., activation energy) needed to stimulate the "jumps" include the stiffness of the matrix and the presence of penetrants, plasticizers, processing aids or other molecules which may affect the flexibility of the matrix or the movement of the migrant.

Elevated temperatures are expected to decrease the activation energy needed for movement within a matrix and increase diffusion. Temperature-induced effects may include: increased migrant vapor pressure, altered partitioning between migrant and matrix, altered behavior of penetrants or other processing aids within the matrix. In a study of migration of various contaminants in polymeric materials, increases in diffusion coefficients of one to four orders of magnitude were observed over the temperature range of 4°C to 40°C (Till et al., 1983).

Once a migrant reaches the interface between the matrix and a contacting external phase, it dissolves in the external phase and effects a partition equilibrium. Assuming constant migrant concentration, migration controlled by diffusion is expected to occur at a rate proportional to the square root of time. However, if migrant concentration in the matrix drops below 50% of the initial concentration or if the migration concentration in the external phase approaches 10-20% of saturation levels, the rate of migration is expected to drop below that which would be associated with the square root of time relationship. If the external phase is not well mixed, boundary conditions may also reduce the migration rate. The interaction of the migrant with the external phase is generally defined as a solubility and partitioning issue; the solubility of the migrant in the external phase, volume of external phase available, time of contact and temperature during contact are all important in evaluating dissolution and dispersion. External phases which are able to remove migrating species as fast as they appear at the surface of the matrix are considered "sinks"; under these conditions, migration is dependent on diffusion and solubility considerations in the matrix.

The interaction between external phase and the matrix itself is also important. Penetration of the external phase into the matrix can accelerate and may control the migration process. After the external phase reaches the contaminant, solubility and partitioning again become important issues.

3.2.3 Potential Release of Dioxin from Paper Products

3.2.3.1 Available Data

The technical literature was searched for information that could provide insight into the mechanism by which dioxin or any other chemical migrates from paper products. Because information specific to dioxin migration was thought unlikely to exist, the search encompassed the migration of any chemical from paper products. Of interest was the form and location of the chemical in the paper, the rates at which chemical migrates from paper and factors that could affect the migration process.

Four data bases were searched:

- Chemical Abstracts -- 1977 to present,
- Food Science and Technology -- 1969 to present,
- Pira -- 1975 to present, and
- World Surface Coatings Abstracts -- 1976 to present.

The first two databases were searched through the online services of Dialog Information Services, Inc. and the latter two through Pergamon InfoLine, Inc. Pira is the Paper and Board, Printing and Packaging Industries Research Association (United Kingdom).

A variety of search strategies and key words were used. Ultimately, the most productive was the combination: MIGRA(...) and PAPER. Of the four databases, the first two yielded the most apparently relevant abstracts. Fifteen articles were obtained and reviewed. In selecting the articles for acquisition, emphasis was placed on those in English, French, Italian or German that could be rapidly obtained. None of the non-English articles were translated; however, they were inspected for useful tables and figures.

Of the fifteen articles, six have some pertinence to the present problem, although none provides quantitative information that would be useful for substantiating estimates of dioxin migration.

Whitfield et al. (1984) associate the contamination of cocoa powder with the presence of chlorophenols in the paper of the sacks in which the powder was packaged. The authors cite Voss, et al. (1980) who state that certain chlorophenols are formed during the bleaching process.

The migration of polychlorinated biphenyls (Aroclor 1242) from bleached Kraft to four foods was reported by Stanovick et al. (1973). The PCB-containing paper was produced by blending the pulp with "carbonless" carbon paper. The foods were dry cereal, cereal grain, a cake mix containing 12% shortening and table spread. At typical commercial ratios of food weight to package surface area, the migrations from paper initially containing 20 and 160 ppm PCB produced concentrations in the foods ranging from 0.1 to 4.3 ppm after periods of 60 or 90 days. Food type appeared to have little or no effect on the amount of migration. In other tests, plastic films and waxed glassine paper were placed between the contaminated paper and the food. Migrations were generally reduced with the polyvinylidene chloride film and the glassine but not with the polyethylene film. Although the procedures section of this publication indicates that data were obtained at several times during the 60 or 90 day durations of the exposures, only the end point values are reported. Presumably the time data along with details on the experiments could be obtained from the authors. From such data the mechanisms and rates of migration might be discernible and, perhaps, applied to the elucidation of the dioxin migration process.

Two other publications discuss the migration of N-nitrosomorpholine (NMOR) from paper products to foods. Sen and Baddoo (1986) compared the amounts of NMOR found in margarine commercially packaged in waxed paper, polymer-coated paper and aluminum-backed paper. In three of five cases, 0.5, 1.1 and 1.4 ppb NMOR were found in the margarine close to its interface with the waxed paper packaging. The initial amount of NMOR in each package ranged from 5 to 34 nanograms. No NMOR was detected in the margarine from the packages of the other materials, although NMOR was present in the packaging. The publication is deficient of any information with which to estimate migration rates. For example, neither the storage times nor package dimensions nor amounts of margarine are given. Hotchkiss and Vecchio (1983) report the migration of NMOR to flour at 100°C. However, no details on the times or exposure areas are given.

Two foreign language articles that could have relevance are Iaccarino et. al. (1982) and Falandysz and Ganowiak (1982).

As mentioned earlier, these studies may not be directly applicable to dioxin migration from paper products because of the different chemicals, higher contamination levels, different matrices and different conditions used. Therefore, for the purpose of this study, several assumptions regarding dioxin migration have been made and are discussed below.

3.2.3.2 Unmediated Diffusion Processes

Table 5 presents some physicochemical properties of 2,3,7,8-TCDD that are relevant for predicting the potential migration from solid matrices. As discussed in Section 3.2.2, diffusion is expected to be highly dependent on the size and nature of the migrant. The high molecular weight and low vapor pressure of 2,3,7,8-TCDD indicate that unmediated diffusion through solid matrices is not expected to be significant. In fact, mobility of 2,3,7,8-TCDD in environmental soils, which are generally more porous than paper, has been shown repeatedly to be very low, e.g., 10 cm migration over 12 years (Freeman and Schroy, 1985). Furthermore, at concentration levels on the order of 10 ppt, there may be very little driving force for diffusive migration.

External factors such as microwaving or exposure to elevated temperatures could possibly affect dioxin mobility and increase the potential for diffusion. However, there are no data describing these effects and they have not been addressed within the scope of this study.

The disposition of dioxin molecules within the paper matrix may also affect its rate of migration. For example, to the extent that the dioxin molecules may be adsorbed or chemically bonded to the matrix, the rate of migration may be reduced. However, there are no available data describing the extent of sorption or bonding of dioxin in the paper matrix. For the purposes of this study and to assess maximum migration potential, it has been assumed that the dioxin molecule is unbound.

TABLE 5

Relevant Physicochemical Properties of 2,3,7,8-TCDD

		Source
Formula	$C_{12}H_4Cl_4O_2$	
Molecular Weight	321.97	
Melting Point	305°C	Schroy *et al.* (1985)
Vapor Pressure (mm Hg)		
25°C	1.5×10^{-9}	Freeman and Schroy (1986)
25°C	7.4×10^{-10}	Podoll *et al.* (1986)
30°C	3.5×10^{-9}	Schroy *et al.* (1985)
Log Octanol Water		
Partition Coefficient ($\log K_{ow}$)	6.15-6.84	Marple *et al* (1986)
Solubility (mg/L) in:		
o-Dichlorobenzene	1400	Schroy *et al.* (1985)
Chlorobenzene	720	Schroy *et al.* (1985)
Benzene	570	Schroy *et al.* (1985)
Chloroform	370	Schroy *et al.* (1985)
n-Octanol	48	Schroy *et al.* (1985)
Methanol	10	Schroy *et al.* (1985)
Acetone	110	Schroy *et al.* (1985)
Water (25°C)	3.17×10^{-4}	Schroy *et al.* (1985)
Water (20-22°C)	7.91×10^{-6}	Adams and Blaine (1986)
Water (22°C)	1.93×10^{-5}	Marple *et al.* (1986)
Water (20-25°C)	2.0×10^{-4}	Mackay *et al.* (1985)

In summary, diffusion of dioxin within the paper matrix and from the surface of paper products is expected to be very low due to its high molecular weight and low vapor pressure at room temperature. Products for which unmediated diffusion represents the only migration process will not be considered further.

3.2.3.3 Migration Mediated by External Phase

Dioxin migration can be facilitated by an external phase that penetrates and swells the paper product and then solubilizes the dioxin. Because air does not swell paper and because the vapor pressure of dioxin is so low, little or no migration is expected with this external phase. It is also likely that coatings on products effectively prevent the external phase from contacting the paper matrix and solubilizing the dioxin. Therefore, migration from dry paper products and from coated paper products under normal use conditions is expected to be negligible and these product categories have been eliminated from further consideration.

External phases that are likely to contact and penetrate consumer paper products were evaluated. The mass of dioxin estimated to be available in a specific product and the volume of external phase associated with a specific use were reviewed to determine whether saturation conditions might be expected. Table 6 lists the types of external phases considered, the types of products expected to be contacted, and a conservative estimate of the volume of external phase expected to be encountered in a specific use.

Using the weight of dioxin available in a specific product and the volume of external phase shown in Table 6, estimated concentrations of dioxin in the external phases can be calculated. These concentrations should be considered maximum concentrations, since all the dioxins in the product may not be contacted by the assumed volume of external phase; and in an actual product, all the dioxin may not be freely available.

TABLE 6

Evaluation of Specific External Phases

External Phases	Product Contacted[a]	Dioxin (pg) Per Unit[a]	Approximate Volume (mL) External Phase[b]	Maximum Estimated Concentration in External Phase (mg/L)
Water				
• Aqueous foods	• paper towel	30	30	1×10^{-6}
	• coffee filter	63	1000	6×10^{-8}
Body Fluids				
• Saliva	• uncoated sheet	0.4	1	4×10^{-7}
• Skin oils	• uncoated sheet	36	0.001	4×10^{-2}
	• paper towel	30	0.001	3×10^{-2}
	• dinner napkin	93	0.001	9×10^{-2}
	• uncoated plate	148	0.001	2×10^{-1}
• Blood	• tampon	24	30	8×10^{-7}
• Urine	• diaper	420	50	8×10^{-6}
Oils				
• Oily foods	• paper towel	30	30	1×10^{-6}
	• uncoated plate	148	30	5×10^{-6}

[a]See Table 7

[b]Volume assumed to be associated with specific use of product, as discussed in Section 3.3.

The concentration estimates in Table 6 can be compared with the solubility data given in Table 5 to determine whether solubility limitations should be considered. The different solvents for which solubility data are available do not directly correspond to the selected external phases; however, some general assumptions about the solubility of dioxin can be made. The concentrations estimated for dioxin in aqueous solutions are less than the aqueous solubility concentrations cited in the literature, and concentrations estimated for dioxin in oily foods and in skin oils are also less than solubility concentrations cited in the literature for most non-polar organics. Therefore, for these three categories, solubility is not expected to limit the extent to which the dioxin in the paper matrix will be transported by the external phase. There are no solubility data available for the other body fluids cited; however, the capacity of saliva, blood, and urine for dioxin is expected to be greater than that of pure water, and the maximum estimated concentrations given in Table 6 probably do not exceed solubilities. In summary, therefore, all of the external phases specified in the following sections of this report may be considered "sinks" with respect to their ability to solubilize dioxin present at 10 ppt in the selected products.

3.2.3.4 Conclusions

For the purpose of evaluating the exposure to dioxin associated with normal use of selected bleached Kraft paper products, the following observations about the release of dioxin from the products have been made.

1. There are no specific migration rate data available for dioxin-contaminated paper products.

2. Unmediated migration is expected to be negligible at 10 ppt dioxin; migration to air is not expected to be significant.

3. Matrix penetration/alteration is necessary for release of dioxin from paper products.

4. Penetration of representative external phases through coating materials is not likely to be significant; dioxin migration from coated paper products is assumed to be negligible.

5. For several representative external phases it is unlikely that saturation and partitioning limitations control the migration process; this conclusion was based on conservative assumptions in that dioxin availability was maximized and the external phase volume was minimized.

6. Since the migration of dioxin will most likely occur under conditions of external phase penetration, individual estimates of dioxin availability will be made for specific uses of specific paper products; penetration will depend on time, temperature, contact area and depth, external phase volume and other considerations.

3.3 Exposure Evaluation of Selected Consumer Products

3.3.1 Product Selection Criteria

Converted end-products which are primarily comprised of bleached Kraft pulp cover a broad spectrum of consumer uses. The analysis of relative tonnages and per capita distribution, as described in Section 3.1, combined with the evaluation of dioxin availability and migration, as discussed in Section 3.2, strongly suggest various products and categories that can be dismissed from further consideration in terms of relative exposure and risk. Specific products with the highest potential for exposure have been selected, based upon a qualitative evaluation of the parameters summarized in Table 4, which include the following: per capita consumption, exposure routes, product use characterization and external phases.

End products which fall in high per capita consumption categories may result in an increased exposure -- either via the dermal absorption or the ingestion route. In terms of exposure routes, if a user were exposed to an available unit of dioxin, only a fraction of the total would actually be absorbed, depending on the mode of contact. This fraction, known as the absorption efficiency, ranges from about 2 percent for direct external skin contact (Poiger and Schlatter, 1980), to 50 percent for ingestion of product containing dioxin (McConnell, et al., 1984), to 100 percent for inhalation of airborne dioxin (ADL estimate). For absorption through internal mucous membranes, an efficiency of 50 percent (similar to ingestion) has been assumed. Due to the physicochemical nature of dioxin, (high molecular weight and low vapor pressure) it has been assumed that under normal use conditions dioxin would not become airborne and thus inhaled.

Since the absorption efficiency for dermal exposure is significantly lower than ingestion, it is likely that those paper products which are only touched by skin oil and which do not come in direct contact with food would have a lower risk. If the consumption, duration and/or frequency of use were also low, then the potential for exposure and subsequent risk would be further reduced. If the product is contacted by an external phase such as water, skin oils, body fluids or edible oils, the matrix could absorb the fluid; swell and release the dioxin for subsequent contact via the skin, membranes or via ingestion. As discussed in Section 3.2, if a product is coated or laminated, the paper matrix has been assumed to be impervious to representative external phases and, even for extended periods of contact time, is not expected to result in an increased risk.

In terms of specific product categories which could potentially be high-or-low risk, the following conclusions have been drawn (refer to Table 4):

- Printing Papers:

- Coated Sheet: Although the per capita consumption is high and exposure to a single unit is repeated during the life of a "page", the route is primarily dermal; furthermore, the coating provides a barrier to potential matrix penetration by skin oils. Therefore, this category comprises a low-risk group.

- Uncoated Sheet: Although the exposure is mainly dermal, there is a subset of users who may also insert smaller pieces of uncoated paper into the mouth for chewing, spitting, or swallowing purposes. This user population introduces a secondary ingestion-related risk. Since the per capita consumption ranks second highest among the list of categories (Table 3), its potential risk could not be dismissed without further analysis.

- Thin Papers: The consumption is low/medium; exposure occurs primarily by touching (dermal). The single exception is the cigarette paper category but, as mentioned earlier, inhalation has not been addressed as a route of exposure. Although the frequency of use may be high, each unit is generally used for a short period of time. Thus, this category has been dismissed from further analysis.

- Bleached Bristols: The product use characterization is similar to that of thin papers, and the bleached Kraft content is similar to uncoated sheets. Since the latter category will be evaluated in further detail, these products do not require additional scrutiny.

• Packaging Papers:

- Wrappings, Bag and Sack, Shipping: These three categories do not appear to be high risk groups for three reasons: consumption is relatively low; exposure is via dermal contact since food packaging paper generally contacts dry food; and since the glassine/greaseproof/vegetable parchment papers that may contact wet or oily external phases are coated, the potential risk via ingestion is minimized.

- Specialty Papers: This category includes a variety of end-user products such as uncoated wrappers, doilies, gift wrap, novelties and coffee filters. While the majority of products represent exposure via dermal contact, one product in particular, namely the coffee filter, involves direct ingestion of the external phase (water). Total per capita consumption is low; but frequency is medium-high. Also, this single product is almost exclusively bleached Kraft pulp. Due to the product use characterization parameters, i.e., thorough contact and saturation with the extracting medium during typical use, an analysis of exposure and risk of coffee filters has been conducted.

- Tissue Papers:

  - Toilet and Facial: These tissues have a medium level of consumption but the duration of use is momentary. Moreover, user exposure is via skin contact. Although the bleached Kraft content is high in these categories, the products generally maintain their integrity during use, implying that the matrix is not greatly affected by skin oils. Therefore, these were not evaluated further.

  - Napkins: Paper napkins, like tissues, also come in contact with external skin and skin oils. However, unlike tissues, the use duration of a typical dinner napkin exceeds that of a facial/toilet tissue. Assuming that skin oil penetration in the matrix is a function of time, this category could pose an increased risk. Therefore, it has been examined in greater detail.

  - Towelling: Products in this category have varied uses which could lead to a range of potential risks. The typical use is for drying or wiping spills. Drying constitutes water absorption into the paper; wiping implies dermal contact with skin oils. The absorbent nature of the products introduces a third use, i.e., grease absorption during microwave cooking. The consumption is medium, and the use duration may be on the order of seconds or minutes. However, the potential risks due to the different external phases justify additional analysis.

- Packaging Paperboard:

  - Milk Carton Stock: There are three reasons that products in this category may be of high-risk: consumption is medium, use is for an extended duration, and exposure is via ingestion of fluids contained within the cartons. However, there is one overwhelming reason to dismiss this category.

i.e., coatings. Since dairy and non-dairy (juice) carton stock is laminated, the coating provides an effective barrier for the paperboard matrix, thereby minimizing the potential risk. One implicit assumption is that the effectiveness of the coating is not time-dependent, i.e., there is no penetration of the liquid into the matrix over several days of contact time. This category has not been further evaluated.

Paper Plates/Trays: The presence of laminations has eliminated consideration of coated plates. For uncoated plates, consumption and duration are medium; exposure may occur by touching the plate surfaces or by ingestion of food that contacts the plate. Due to the potential range of risks in this category, it has been evaluated further.

Paper Cups/Lids: Consumption and use duration of uncoated cups are relatively low. Cups coated on the inside for hot/cold beverages are analogous to the packaging paperboard products: the coating has been assumed to eliminate the potential exposure via ingestion. The exterior surfaces of the cups, uncoated, are exposed to skin oils and dermal contact. However, since the uncoated paper plates constitute a similar exposure scenario, this category has been exempted from a detailed analysis.

Ovenable Board, Linerboards, and Folding Cartons: The use characterization, external phases and exposure route features of products from these categories are all considered in other product categories. Moreover, consumption is low for ovenable board and linerboard. Folding carton products are typically used for dry goods storage such as medicines, cosmetics or prepared/packaged food. Thus, the matrix is not penetrated by an external fluid phase. Hence, these categories have not been considered for further evaluation.

- Pulp:

  - Disposable Diapers: The product use parameters, i.e., high frequency and per capita consumption, imply a high exposure level. Although the mode of contact is dermal absorption, the extended duration for external phase saturation in the pulp matrix may increase the potential dioxin availability to a significant degree. Accordingly, this category has required further analysis.

  - Feminine Hygiene Products: The sanitary napkin product is analogous to the disposable diaper. However, the tampon may pose a different type of exposure risk, as the mode of contact is not external absorption via the skin, but rather internal absorption through mucous membranes. The frequency on an annualized basis is medium for the female segment of the population, and the duration of each use has been characterized as long. Given the high content of bleached Kraft in the product unit, this could potentially be a high-risk category.

The scope of this study does not allow for a detailed risk analysis on all paper products or even all products within categories identified as high-risk. The qualitative assessment of exposure for the range of pulp, paper, and paperboard products has resulted in a selection of seven products, representing those with the highest potential for dioxin exposure. The sample products which have been further evaluated to determine potential dioxin exposure levels and associated cancer risks include the following:

- uncoated paper plate,
- disposable diaper,
- sanitary tampon,

- dinner napkin,
- paper towel,
- coffee filter, and
- uncoated free sheet.

3.3.2 Estimate of Potential Dioxin Exposure Levels

Assuming a dioxin concentration level of 10 ppt or 10 pg/gm of bleached Kraft fiber, the amount of dioxin mass available for exposure can be calculated for a prototypical product as a function of several estimated factors which include the following: mass of the unit product, surface area contacted, external phase penetration in the matrix and fraction of the external phase ingested or absorbed. For the seven products representing potential high-risk categories, the total dioxin mass available for exposure following a typical use situation is summarized in Table 7. The methodology for estimating the potential exposure levels is outlined in this section.

Column (A) of Table 7 lists the seven sample products and their associated bleached Kraft content. Although the primary component in each product is bleached Kraft fiber, the actual fraction ranges from 60 to 100 percent, depending on the quantity of other components such as fillers or resins. Also it is important to note that for three products (the uncoated paper plate, paper towel, and uncoated sheet) multiple use situations have been postulated. Each use effectively results in a different potential exposure level. In subsequent analysis, only the highest exposure level is considered. For the remaining products, a single use situation adequately defines the potential dioxin mass to which a user could be exposed.

Although the dioxin concentration in bleached Kraft fiber has been assumed to be constant, the amount of dioxin in each product varies with the mass of bleached Kraft fiber in a product unit. Column (B) presents the mass of each prototypical unit as measured during this

TABLE 7

ESTIMATES OF POTENTIAL DIOXIN EXPOSURE LEVELS BASED ON UNIT CONSUMPTION OF PAPER PRODUCTS CONTAINING BLEACHED KRAFT (BK)

				FOR A TYPICAL USE SITUATION						
PRODUCT & PERCENT BK/UNIT (A)	UNIT MASS (GM) (B)	EST. DIOXIN WT/UNIT (PG) (C)	PRODUCT SURF AREA (SQ.CM) (D)	EXTERNAL PHASE (EP) (E)	EXPOSURE TIME (F)	CONTACT AREA PERCENT (G)	DEPTH PENETRN FRACTION (H)	DIOX MASS IN EP VOL CONTACTED (PG) (I)	EP EXPOSURE PERCENT (J)	DIOX MASS AVAILABLE FOR EXPOSURE (PG/UNIT) (K)
UNCOATED PAPER PLATE 90.0	16.5	148.5	324.0	SKIN OIL OILS	30 MIN 30 MIN	23 16	0.01 0.50	0.3 11.9	0.1 25.0	3.4E-04 3.0E+00
DISPOSABLE DIAPER 60.0	70.0	420.0	826.0	URINE	4 HRS	60	1.00	252.0	5.0	1.3E+01
SANITARY TAMPON 95.0	2.5	23.8	16.1	BLOOD	4 HRS	100	0.50	11.9	10.0	1.2E+00
DINNER NAPKIN 98.0	9.5	93.1	1865.0	SKIN OIL	30 MIN	80	0.01	0.7	0.1	7.4E-04
PAPER TOWEL 95.0	3.2	30.4	671.0	SKIN OIL WATER OILS	15 SEC 15 SEC 3 MIN	100 100 100	0.01 1.00 1.00	0.3 30.4 30.4	0.1 0.1 1.0	3.0E-04 3.0E-02 3.0E-01
COFFEE FILTER 100.0	6.3	63.0	881.0	WATER	5 MIN	100	1.00	63.0	99.0	6.2E+01
UNCOATED SHEET(L) 90.0	4.0 0.04	36.0 0.4	603.0 1.6	SKIN OIL SALIVA	15 SEC 30 SEC	10 100	0.005 1.00	0.01 0.4	0.1 95.0	1.0E-05 3.4E-01

NOTES FOR TABLE 7:

A. THIS COLUMN LISTS SPECIFIC PAPER PRODUCTS CONTAINING BK PULP. NOTE THE VARIATION IN THE PERCENT BK AMONG THE END PRODUCTS.

B. UNIT MASS BASED ON WEIGHTS OF PROTOTYPICAL SAMPLE PRODUCTS. THIS INCLUDES WT OF FILLERS, BINDERS, LAMINATIONS, ETC. IN ADDITION TO THE BK CONTENT.

C. FOR ALL PRODUCTS, ASSUME 10 PPT DIOXIN CONCENTRATION; I.E., 10 PICOGRAMS DIOXIN PER GRAM OF BK IN PRODUCT.

D. BASED ON ADL ESTIMATED VALUES AND MEASUREMENTS.

E. SEE TEXT FOR DISCUSSION ON EXTERNAL PHASE LIMITATIONS.

F. EXPOSURE TIME IS BASED ON ADL ESTIMATE OF TYPICAL PRODUCT USE

G.& H. THESE COLUMNS ACCOUNT FOR USE SITUATIONS WHERE A PRODUCT MAY NOT BE TOTALLY ENVELOPED ON ALL SIDES BY THE EXTERNAL PHASE. FOR EXAMPLE, CHEWED PAPER MAY BE COVERED WITH SALIVA ON ALL SIDES, AND THROUGH THE DEPTH OF THE PAPER ITSELF; ON THE OTHER HAND, A PAPER PLATE WITH WITH OILY FOOD MAY ONLY BE PARTIALLY COVERED WITH OIL, AND SEEPAGE COULD ALSO BE LIMITED BY THE THICKNESS OF THE PLATE. IN EFFECT, THE PARTIAL VOLUME OF PRODUCT (AREA X DEPTH) PENETRATED BY THE EXTERNAL PHASE IS DIRECTLY ANALOGOUS TO THE FRACTIONAL MASS OF PRODUCT CONTAINING DIOXIN THAT IS EXPOSED TO THE USER.

I. THE TOTAL MASS OF DIOXIN IN A GIVEN PRODUCT IS ATTENUATED USING THE VALUES ESTIMATED IN COLUMNS G AND H.

J. ADL ESTIMATE OF THE FRACTION OF TOTAL EXTERNAL PHASE VOLUME THAT IS AVAILABLE FOR DERMAL OR INGESTION INTAKE.

K. BASED ON THE TOTAL MASS OF DIOXIN IN A PRODUCT, AND THE RELATIVE REDUCTION DUE TO FRACTIONAL EXPOSURE, THE ACTUAL AMOUNT OF DIOXIN WHICH CAN RESULT IN EXPOSURE IS CALCULATED.

L. SEE TEXT DISCUSSION ON INGESTION EXPOSURE (E.G., FRAGMENT INGESTION) VS. DERMAL EXPOSURE (E.G., SKIN CONTACT WITH PAGE) FOR UNCOATED FREE SHEETS.

analysis. The product of the percent bleached Kraft, unit mass, and 10 ppt concentration, as shown in Column (C), provides the estimated dioxin mass per unit.

Based on the physical geometry, a single surface area for each product is calculated and summarized in Column (D). The specific dimensions and geometric assumptions are discussed on a per-product basis later in this section.

The characterization of a typical use situation is defined in Columns (E) through (H). The primary external phase, as shown in the Column (E), may be water or a water-based solvent, skin oil, edible oil such as hamburger or bacon grease, or body fluid such as saliva, blood or urine. As discussed in Section 3, the quantity of dioxin solubilized is not a function of the solvent type since it has been assumed that dissolution is not limited by solubility. Instead, the differences among the solvents represent the relative ease with which a pulp/paper matrix could be penetrated, so that the dioxin could become available for exposure. For example, the relative volume of skin oil that touches a sheet of paper is much less than the volume of urine that is absorbed in a diaper. Accordingly, the amount of bleached Kraft fiber penetrated by the external phase varies between the two products. Although the exact volumes of each external phase for all the scenarios have not been quantified, the differences in matrix penetration are accounted for using factors defined in Columns (E) through (H).

The exposure time, as listed in Column (F), is not used in the actual calculation scheme; however, it provides a basis for a reasonable estimate of the contact area percent and depth penetration fraction which are tabulated in the two columns immediately following. For several products and uses, it would be unrealistic to assume that an external phase contacts the entire volume of bleached Kraft fiber and saturates the entire matrix. If that were the case, then every occurrence of touching a page would result in a soggy sheet with none of its initial integrity. In fact, only a portion of the surface is contacted, and only a fraction of the depth is penetrated by the external phase in most instances. Only in a few select cases does the entire product volume (area x depth) encounter a volume of external phase. The estimated available dioxin per unit has been adjusted accordingly for each product and summarized in Column (I).

Of the total external phase that is absorbed into the matrix, there is always some fraction that remains in the web. The portion in direct contact with the user accounts for the fraction of dioxin that is potentially available. This exposure percent is listed in Column (J). For example, given the total volume of urine in a diaper, it is estimated that about five percent comes in direct contact with the infant's skin surface. On the other hand, about ninety nine percent of the water passing through a coffee filter is recovered and subsequently ingested. Assuming the dioxin has been removed from the matrix and solubilized in the external phase, a larger fraction of the dioxin mass in the water is available for exposure than the mass in the urine.

The last Column (K) contains the actual mass of dioxin that is potentially available for ingestion or dermal absorption. In summary, the total estimated dioxin mass in the product unit has been reduced first by the fractional volume of product contacted, then further attenuated by the portion of external phase exposed to the user. In the discussion that follows, the dimensions of each product and assumptions of usage are outlined.

- Uncoated Paper Plate: A sample eight-inch dinner plate weighs 16.5 gms, and the surface area of one face is 324 sq cm. The two specific use scenarios considered are (i) holding the plate, and (ii) eating a hamburger which is on the plate. Note that no cumulative effects will be considered in this analysis.

For the first situation, assume a one-inch annular ring is touched for about half an hour; therefore, skin oil encounters about 23% of the total available surface area. For typical skin oil-matrix contact scenarios, assume a one-percent penetration into the depth of the plate surface. Of the total volume of skin oil that enters the paper web, a small fraction of a percent returns to the user. This assumption has been maintained for other products where the typical use involves dermal contact/skin oil. Given this use situation, of the total dioxin mass of 148.5 pg, about 3.4×10^{-4} pg has been calculated to be available to the user.

The second scenario assumes a four-inch hamburger eaten from a paper plate. Hamburger oil covers about 16% of the top surface, and penetrates about half the depth of the plate. About one fourth of the oil that contacts the plate is removed with the burger and eaten. In this case, 3.0 pg of the total 148.5 pg has been assumed to be available for exposure.

- Disposable Diaper: Although the weight of a diaper (70 g) is high compared to other paper products, its bleached Kraft content is only 60%. The remainder is fillers, plastic lining, tape, etc. A standard absorbent diaper, when spread open, measures about 8 in wide and 16 in long. The resultant surface area is 826 sq cm. The external phase is urine, which may have contact with the diaper over several hours. About 60% of a diaper surface is generally wet, and it is reasonable to assume that the entire depth of the diaper is saturated. The extended period of use allows for repeated contact with urine; therefore, it has been estimated that the infant is exposed to about 5 percent of the volume.

Given these use conditions, an initial dioxin content of 420 pg per diaper is reduced to 13.0 pg available for exposure.

- Sanitary Tampon: This product consists primarily of bleached Kraft pulp. Its mass (including the string, but not the outer cardboard liner) is about 2.5 g. The geometry of a compressed tampon is a solid cylinder with an outer area of 16.1 sq cm. Over a period of 4 hours, blood, the external phase, is in contact with the entire outer surface and is generally absorbed through half the tampon thickness. About one-tenth of this external phase may come in contact with the inner mucous membranes. Applying these assumptions, a total mass of 23.8 pg dioxin per tampon has been reduced to 1.2 pg available for exposure.

- Dinner Napkin: This paper product has very little filler or resin content. A typical napkin, 17 in. square, weighs about 9.5 gms and has a single surface area of 1865 sq cm. For a half-hour use time, skin oils touch about 80 percent of the total surface. As with the uncoated plate, the depth penetration is estimated to be 1 percent and 0.1 percent of the skin oil remains on the skin surface of the user. For this scenario, 93.1 pg of dioxin in the product have been reduced to 7.4×10^{-4} pg available to the user.

- Paper Towel: The presence of wet strength resins reduces the bleached Kraft content slightly for this product. A typical single unit has dimensions of 11.25 in x 9.25 in, resulting in an available surface area of 671 sq cm. The potential use scenarios which have been postulated to illustrate the range of results are: (1) wiping up a spill, (2) drying hands, and (3) using the towel for bacon grease absorption during microwave cooking.

  The first use situation involves skin contact for a short period of time. Essentially, an entire surface is touched, and depth penetration is 1 percent, as assumed earlier. Less than 1 percent of the skin oil re-contacts the user; thus 30.4 pg in the product has been reduced to 3.0×10^{-4} pg available for the user.

The second scenario postulates water as the external phase. Although the use duration is short, the total area and depth are saturated with water. Since the function of the product is to dry, a fraction of a percent of water returns to the user. In this case, 3.0×10^{-2} pg of dioxin have been assumed to be potentially available.

The third use situation involves edible oils, namely bacon grease, as the external phase. In the three-minute cooking time, the entire paper towel is saturated with the grease and about 1 percent remains on the bacon strips to be eaten. For this example, the dioxin mass calculated to be available is the highest of the three scenarios: 0.30 pg from the initial 30.4 pg.

- Coffee Filter: Of the seven selected products, this is the only example of 100 percent bleached Kraft content. A medium-sized filter, 11 3/8 in x 12 in, with a surface area of 881 sq cm, weighs about 6.3 gms. In a five-minute period of use, hot water literally acts as an extracting solvent, contacting 100 percent of the area and depth of the filter. The bulk of the water is recovered as coffee, and only about 1 percent is retained on the wet filter. For this product, 62 of the total 63 pg have been assumed to be available for exposure.

- Uncoated Sheet: This product, which contains about 90 percent bleached Kraft, can have two very different use situations. The first involves routine touching or handling of sheets/pages; the second scenario involves chewing of paper fragments which may be followed by ingestion or expectoration.

A typical sheet, 8.5 in x 11 in, has a surface area of about 603 sq cm. For reading/writing applications, skin oil touches the sheet for about 15 sec, and generally is in contact with about 10 percent of the area. Due to the momentary nature of use, the assumed depth penetration is less than 1 percent. Accordingly, the 36 pg of dioxin in the sheet of paper has been reduced to 1.0 x 10^{-5} pg available for user exposure.

A fractional piece of a sheet of paper used for a spitball, on the other hand, constitutes a potential ingestion exposure. A half-inch square piece of paper weighing 0.04 gm has a single surface area of 1.6 sq cm. Given 30 seconds in the mouth, the wad of paper is totally surrounded on all sides by saliva, the external phase. Of the total external phase contacting the paper mass, a major fraction, about 95 percent may be ingested - the remainder leaves with the paper. Thus, the total mass of dioxin, 0.4 pg have been slightly reduced to 0.34 pg available for user exposure.

4.0 RISK ASSESSMENT

The process of risk assessment for exposure to dioxin contained in bleached Kraft paper products involves estimating average lifetime daily exposure to dioxin, the efficiency of the exposure route in absorbing dioxin, the estimated seventy-year lifetime use pattern of the product and the average weight of the product user to calculate the average lifetime daily dose per kilogram of body weight (U.S. EPA, 1984a, Eschenroeder, et al., 1986).

The dose is translated into risk by applying a potency factor or unit risk multiplier which yields an estimate of the increased lifetime cancer risk due to the particular exposure scenario.

4.1 Characterization of Product Uses, Users and Lifetime Exposures

For each type of paper product scenarios have been quantified and are outlined in Table 8. Column B in Table 8 was previously generated in

TABLE 8

ESTIMATES OF INCREASED LIFETIME CANCER RISK BASED ON DIOXIN EXPOSURE FROM SPECIFIC USE OF PAPER PRODUCTS CONTAINING BLEACHED KRAFT (BK)

UNIT OF PAPER PRODUCT (A)	DIOXIN MASS INGESTED OR CONTACTED (MG/UNIT) (B)	ABSORPTION EFFICIENCY (PERCENT) (C)	DIOXIN DOSE PER UNIT (MG) (D)	NO. OF UNITS USED PER DAY (E)	DIOXIN DOSE PER DAY (MG/DAY) (F)	AVG. WEIGHT OF TYPICAL USER (KG) (G)	DIOXIN DOSE DURING USE (MG/KG/DAY) (H)	AVG. NO. OF YRS USED OVER PERSON'S LIFETIME (YRS) (I)	LIFETIME DIOXIN EXPOSURE TO USER (MG/KG/DAY) (J)	INCREASED LIFETIME CANCER RISK (K)
UNCOATED PAPER PLATE	3.0E-09	50	1.5E-09	1	1.5E-09	70	2.1E-11	70	2.1E-11	6.6E-06
DISPOSABLE DIAPER	1.3E-08	1.5	1.9E-10	6	1.1E-09	10.2	1.1E-10	3	4.8E-12	1.5E-06
SANITARY TAMPON	1.2E-09	50	5.9E-10	1	5.9E-10	60	9.8E-12	40	5.6E-12	1.8E-06
DINNER NAPKIN	7.4E-13	1.5	1.1E-14	3	3.4E-14	70	4.8E-16	70	4.8E-16	1.5E-10
PAPER TOWEL	3.0E-10	50	1.5E-10	2	3.0E-10	70	4.3E-12	70	4.3E-12	1.4E-06
COFFEE FILTER	6.2E-08	50	3.1E-08	1	3.1E-08	70	4.5E-10	50	3.2E-10	1.0E-04
UNCOATED SHEET	1.0E-14 3.4E-10	1.5 50	1.5E-16 1.7E-10	1000 5	1.5E-13 8.6E-10	60 34.8	2.5E-15 2.5E-11	50 9	1.8E-15 3.2E-12	5.6E-10 9.8E-07

NOTES & ASSUMPTIONS FOR TABLE 8:

A. FOR ASSUMPTIONS ON PROTOTYPICAL PAPER PRODUCT DIMENSIONS & WEIGHTS, SEE SECTION 3.3.1. ALSO, VARIATION IN BLEACH KRAFT CONTENT AMONG THE INDIVIDUAL PRODUCTS IS ACCOUNTED FOR IN THIS ANALYSIS.

B. THIS VALUE IS EQUIVALENT TO THE "DIOXIN MASS AVAILABLE FOR EXPOSURE," AS LISTED IN TABLE 7. UNITS HAVE BEEN CONVERTED FROM PICO-GM TO MG.

C. THE ABSORPTION EFFICIENCY REFERS TO THE AMOUNT OF DIOXIN THAT IS ACTUALLY ABSORBED VIA THE SKIN, MUCOUS MEMBRANES, OR DIGESTIVE SYSTEM. FOR THIS ANALYSIS, THE FOLLOWING VALUES HAVE BEEN USED:

EXTERNAL CONTACT	1.5 PER CENT
INTERNAL CONTACT	50 PER CENT
INGESTION	50 PER CENT

D. THE DIOXIN DOSE PER UNIT OF PRODUCT REFLECTS THE REDUCTION DUE TO THE ABSORPTION EFFICIENCY.

E. THE NUMBER OF UNITS USED PER DAY ASSUMES A TYPICAL USER OF THAT PRODUCT.

F. THE DIOXIN DOSE PER DAY = DOSE/UNIT X NO.OF UNITS USED/DAY

I. ASSUMING A 70-YEAR LIFETIME DOSE WOULD NOT BE APPROPRIATE FOR USER GROUPS WITHIN SPECIFIC AGE BRACKETS, E.G. INFANTS USING DISPOSABLE DIAPERS. THUS, THIS COLUMN CORRECTS FOR THE FRACTIONAL LIFETIME USE OF A GIVEN PAPER PRODUCT.

H. THE DIOXIN DOSE DURING THE USE PERIOD IS THE DAILY DOSE (MG/DAY) DIVIDED BY THE AVERAGE WEIGHT OF THE USER(KG).

G. THE AVERAGE WEIGHT OF THE TYPICAL USER IS INPUT ON THE FOLLOWING BASIS:

ADULT MALE	70 KG
ADULT FEMALE	60 KG
CHILD UNDER 18	3.14 + (3.52 X MEDIAN AGE)

J. THE LIFETIME DAILY EXPOSURE IN MG-DIOXIN/KG/DAY IS AVERAGED OVER 70 YRS. THE VALUE IS A PRODUCT OF COLUMNS H & I DIVIDED BY 70 YEARS.

K. THE INCREASED LIFETIME RISK IS THE PRODUCT OF THE LIFETIME EXPOSURE AND THE NUMBER OF EXCESS CANCERS PER UNIT OF EXPOSURE, WHICH IS THE UNIT RISK : 1.56 X 10E5 / (MG/KG/DAY)

Table 7 and indicates the mass of dioxin (converted from pg to mg) which is ingested or contacted. The following sections address each product and discuss how this dioxin exposure estimate has been translated into an average lifetime daily dose.

4.1.1 Uncoated Paper Plate

This potential exposure scenario for use of uncoated paper plates involves ingestion of dioxin in food oils. It has been assumed that 50 percent of the ingested dioxin is absorbed by this route (McConnell, et al., 1984), that one uncoated paper plate is used each day and that the duration of paper plate use lasts for a 70 year lifetime. It has also been assumed that the user has an average adult male weight of 70 kilograms and that the average lifetime daily dose is equal to the dose per day during use. As shown in Column J of Table 8, a lifetime dioxin dose for use of uncoated paper plates of 2.1×10^{-11} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.1.2. Disposable Diaper

This potential exposure scenario for use of disposable diapers involves skin contact with dioxin in urine. It has been assumed that 1.5 percent of the contacted dioxin is absorbed by this route (Poiger and Schlatter, 1980), that six disposable diapers are used each day and that the duration of diaper use lasts for three years. It has also been assumed that the user has an average weight of 10.2 kilograms and that the average lifetime daily dose is equal to the dose per day during use multiplied by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin dose for use of disposable diapers of 4.8×10^{-12} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.1.3 Sanitary Tampon

This potential exposure scenario for use of sanitary tampons involves mucous membrane contact with dioxin in blood. It has been assumed that 50 percent of the contacted dioxin is absorbed by this route (ADL estimate). It has also been assumed that thirty sanitary tampons are used each month, representing an annual daily use of one tampon per day; the duration of sanitary tampon use has been assumed to be 40 years. The user has an assumed average weight of 60 kilograms and the average lifetime daily dose is equal to the dose per day during use multiplied by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin exposure for use of sanitary tampons of 5.6×10^{-12} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.1.4 Dinner Napkin

This potential exposure scenario for use of dinner napkins involves skin contact with dioxin in skin oil. It has been assumed that 1.5 percent of the contacted dioxin is absorbed by this route (Poiger and Schlatter, 1980), that three dinner napkins are used each day and that the duration of napkin use lasts for 70 years. It has also been assumed that the user has an average weight of 70 kilograms and that the average lifetime daily dose is equal to the dose per day during use multiplied by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin exposure for users of dinner napkins of 4.8×10^{-16} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.1.5 Paper Towel

This potential exposure scenario for use of paper towels in microwave cooking involves ingestion of dioxin in food oils. It has been assumed that 50 percent of the contacted dioxin is absorbed by this route (McConnell, et al., 1984), that two paper towels are used each day and that the duration of towel use lasts for 70 years. It has also been assumed that the user has an average weight of 70 kilograms and that the average lifetime daily dose is equal to the dose per day during use multiplied by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin exposure for users of paper towels of 4.3 x 10^{-12} milligrams per kilogram body weight per day (mg/kg/day) has ben estimated.

4.1.6 Coffee Filter

This potential exposure scenario for use of coffee filters involves ingestion of dioxin in coffee. It has been assumed that 50 percent of the contacted dioxin is absorbed by this route (McConnell, et al., 1984), that one coffee filter is used each day and that the duration of coffee filter use lasts for 50 years. It has also been assumed that the user has an average weight of 70 kilograms and that the average lifetime daily dose is equal to the dose per day during use multipled by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin exposure for users of coffee filters of 3.2 x 10^{-10} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.1.7 Uncoated Sheet (Contact)

This potential exposure scenario for use of uncoated sheet involves skin contact with dioxin in skin oil. It has been assumed that 1.5 percent of the contacted dioxin is absorbed by this route (Poiger & Schlatter, 1980), that 1000 uncoated sheets are used each day and that the duration of this intensive use of uncoated sheet lasts for 50 years. It has also been assumed that the user has an average weight of 60 kilograms and that the average lifetime daily dose is equal to the dose per day during use multilplied by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin exposure for intensive use of uncoated sheet of 1.8 x 10^{-15} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.1.8 Uncoated Sheet (Ingestion)

This potential exposure scenario for use of uncoated sheet involves ingestion of dioxin in saliva or in the paper itself.. It has been assumed that 50 percent of the contacted dioxin is absorbed by this route (McConnell, et. al., 1984), that five fragments of uncoated sheet are used in this manner, each day, and that the duration of this type of paper use lasts for 9 years. It has also been assumed that the user has an average weight of 34.8 kilograms and that the average lifetime daily dose is equal to the dose per day during use multiplied by the fraction of a 70 year lifetime during which the product is used. As shown in Column J of Table 8, a lifetime dioxin exposure for this type of use of uncoated sheet of 3.2×10^{-12} milligrams per kilogram body weight per day (mg/kg/day) has been estimated.

4.2 Risk Estimation

The U.S. Environmental Protection Agency (EPA) has calculated an upper 95% confidence limit of the carcinogenic potency of 2,3,7,8-TCDD which is equal to 1.6×10^5 per mg/kg/day of exposure (USEPA, 1984a, 1985).

Since this potency factor is based upon the administered dose, it is multiplied by 2 to give a potency of 3.1×10^5 per mg/kg/day of absorbed dose (U.S. EPA, 1984b, Eschenroeder, et al., 1986). The EPA has also developed procedures for estimating risks associated with mixtures of specific isomers of dioxins and furans; however, for this risk calculation it has been assumed that all of the contaminants are equivalent to 2,3,7,8-TCDD (USEPA, 1987).

The upper 95% confidence limit of excess cancer risk resulting from the dioxin dose is calculated by multiplying the absorbed potency factor of 3.1×10^5 $(mg/kg/day)^{-1}$ by the average daily lifetime dose expressed as mg/kg/day to yield a unitless expression of individual excess risk. When multiplied by the size of a user population, this individual risk yields the expected number of excess cancers which will result over the lifetime of the population as a result of the exposure. An estimate of the annual number of excess cancers to be expected in the population can be obtained by dividing by the 70 year average lifetime.

Column K of Table 8 provides the estimated lifetime cancer risks for an individual product user. Demographic data can be used to evaluate population-based risks (e.g., user population data in Table 3).

Overall, these individual risk estimates range from 1.5×10^{-10} for dinner napkins to 1.0×10^{-4} for coffee filters. Coffee filters are the only product category which results in a risk greater than the conventional benchmark of 10^{-5}. Using 10^{-6} as the cut-off, four other products are included: uncoated paper plates, disposable diapers, sanitary tampons and paper towels.

5.0 DISCUSSION

In this section the assumptions underlying the analysis have been summarized and the results and their implications have been discussed. Recommendations for additional work which may reduce some of the uncertainty associated with this preliminary study have also been provided.

5.1 Uncertainties and Assumptions

Throughout this study assumptions have been made. In some cases EPA reports or scientific literature have been used to support these assumptions. Where such support was lacking or unavailable, estimates have been made using past experience and judgment. For example, in the absence of data, important assumptions have been made about:

- potential levels of dioxin contamination,
- the surface area of product contacted,
- the depth of penetration of the external phase,
- the availability of dioxin to the external phase,
- the extent of absorption or ingestion of external phase, and
- the duration and frequency of product use.

Accepting the assumption that consumers may be exposed to dioxin through use of paper products, a rationale by which such exposure could occur has been developed. The scenarios are reasonable and are in accord with current understanding of the chemical and physical behavior of dioxin; however, there is insufficient information to estimate the magnitude of the uncertainty.

In addition to the uncertainty inherent in the evaluation of the potential for exposure, there also exists substantial uncertainty in the calculation of carcinogenic potency factors. The final uncertainty associated with this analysis would thus be the product of the uncertainty in the exposure estimates and the uncertainty in the risk factor.

5.2 Implications of the Results

The results presented in Table 8 imply that under certain circumstances bleached Kraft product users may be exposed to dioxin and, under the definition of zero threshold risk and using the assumptions outlined in this report, will have a calculable lifetime risk of cancer.

Although the risks calculated in this study are relatively low, ranging approximately from 10^{-4} to 10^{-10}, they are totally dependent on the assumptions of the exposure scenarios. In the actual population of product users, there may be groups who use products more or less intensively than has been assumed and, thus, have higher or lower risks. Furthermore, the combined risk from using several bleached Kraft paper products has not been considered.

Potential contamination of consumer paper products with dioxin raises questions about the impact of that contamination on emissions from municipal solid waste (MSW) incinerators. A complete summary of the literature on dioxin emissions from incinerators, dioxin content in waste feed streams and generation of dioxin during the combustion process is beyond the scope of this exposure and risk assessment. However, several observations can be made, and these have been outlined below.

During the 1970's and 1980's, dioxins and furans were identified in precipitator fly ash samples from MSW incinerators in the U.S., Canada, Europe and Asia. The mechanism of formation of dioxins and furans has been studied extensively, but the relationship between dioxin/furan emissions and the type of waste incinerated is still controversial. There are essentially no data to confirm that dioxins/furans in the waste feed materials result in dioxin/furan emissions. Generation of dioxins/furans as products of incomplete combustion appears to be more closely correlated with facility operating conditions and with the availability of precursors such as organochlorine compounds and possibly inorganic chlorine.

Paper is a major fraction of the waste streams of typical MSW incinerators. Domalski, et al. (1986) reported that paper represented approximately 50% of the mass of the MSW at a Brooklyn, New York facility during one week in early 1984; 42.5% was unbleached paper and 4.6% was bleached paper. At a Baltimore County, Maryland, facility, approximately 60% of the waste stream during a week in early 1983 was classified as paper materials. The amounts of chlorine contributed by MSW components at the two facilities were also determined. The major amounts of chlorine in MSW were contained in the paper and plastic fractions.

The paper fractions contained approximately one-quarter to one-half of the weekly average total chlorine content (0.45 - 0.89% mass). One-third to two-thirds of the total chlorine content in paper was determined to be water-soluble chlorine which is more likely to represent inorganic materials. On the other hand, greater than 90% of the chlorine in the plastic fraction was water-insoluble chlorine compounds.

Although paper is a major portion of typical MSW feed streams and may represent a source of chlorine, there is no evidence linking increased paper content in MSW to increased dioxin emissions from an MSW incinerator or documenting that dioxin in a waste stream would be likely to survive the combustion process.

Another important implication of the results is that they may be used as a basis for regulation or legal action, or they may unduly alarm the public. It cannot be stated too strongly that these results have been based on numerous assumptions and are intended to guide EPA planning for data collection and relevant research studies. The following section identifies some areas where additional research may help to resolve some of the uncertainty surrounding this subject.

5.3 Recommendations

In order to resolve some of the uncertainty regarding the potential for exposure to dioxin in bleached Kraft paper products, several areas where information is particularly lacking or where there are significant uncertainties have been identified. For example, additional data are needed on how dioxin may be generated in the bleached Kraft process, on the relative levels of dioxin in bleached and semi-bleached Kraft product and on the dioxin content of consumer products.

There are some fundamental questions regarding the physical distribution of dioxin contamination in the paper matrix. For example, is dioxin incorporated or bonded into the paper matrix, is it adsorbed to the surface of the matrix, or is it free within the paper as has been assumed in foregoing analysis?

Another fundamental area of uncertainty concerns the migration of chemicals at very low (ppt) concentrations. Dioxin at 10 ppt may have such a low migration rate that exposures, under normal scenarios, will not occur. Finally, it has been assumed that conventional coatings act as a barrier and prevent exposure. One could also hypothesize mechanisms by which the dioxin would be concentrated in the coating.

Another area which is important for accurate risk assessment is determination of usage patterns for consumers of paper products. Marketing data, consumer surveys, and focus groups could be used to develop a better understanding of the extent of exposure, in terms of both frequency and duration, and of the nature of any high risk user populations such as children or users of multiple types of bleached Kraft products.

REFERENCES

1. Adams. W. and K.M. Blaine. 1986. A water solubility determination of 2,3,7,8-TCDD. Chemosphere 15 (9-12): 1397-1400.

2. American Paper Institute. 1986. Statistics of Paper, Paperboard and Word Pulp Data Thru 1985. New York.

3. Domalski, E.S.; K.L. Churney; A.E. Ledford, Jr. and S.S. Bruce. 1986. Monitoring the fate of chlorine from MSW sampling through combustion. Part I: Analysis of the waste stream for chlorine. Chemosphere 15(9-12): 1339-1354.

4. Eschenroeder, A., R.J. Jaeger, J.J. Ospital and C.P. Doyle. 1986. Health risk analysis of human exposures to soil amended with sewage sludge contaminated with polychlorinated dibenzodioxins and dibenzofurans. Vet. and Human Tox. 28(5): 435 - 442.

5. Falandysz, J. and Z. Ganowiak. 1982. Sources of contamination of food with polychlorinated biphenyls (PCB). (Polish) Bromatologia i Chemia Toksykologiczna 15 (3), 161-166.

6. Freeman, R.A. and J.M. Schroy. 1986. Modeling the transport of 2,3,7,8-TCDD and other low volatility chemicals in soils. Environ. Prog. 5(1): 28-33.

7. Freeman, R.A. and J.M. Schroy. 1985. Environmental mobility of TCDD. Chemosphere 14 (6/7): 873-876.

8. Hotchkiss, J.H. and A.J. Vecchio. 1983. Analysis of direct contact paper and paperboard food packaging for N-nitrosomorpholine and morpholine. J. Food Sci. 48: 240-242.

REFERENCES

9. Iaccarino, T., L. Croci, S. Gizzarelli, A. Ferrara, G. DeFelip and M. Morgantini. 1982. Precise definition of microbial tests on migration of antiseptics from food wrapping paper. (Italian) Bullettino dei Chimici dell'Unione Italiana dei Laboratori Provinciali 33 (S6), pp 629-637.

10. Mackay, D, S. Paterson and B. Cheung. 1985. Evaluating the environmental fate of chemicals. The fugacity-level III approach as applied to 2,3,7,8-TCDD. Chemosphere 14 (6/7): 859-863.

11. Marple, L., B. Berridge and L.Throop. 1986. Measurement of the Water-octanol partition coefficient of 2,3,7,8-tetrachloro-diBenzo-p-dioxin. Environ. Sci. Technol. 20(4): 397-399.

12. McConnell, E., G. Lucier, R. Rumbaugh, et al. 1984. Dioxin in soil: Bioavailability after ingestion by rats and guinea pigs. Science. March 9.

13. National Center for Health Statistics. 1986. Aging in the Eighties, Prevalence and Impact of Urinary Problems in Individuals Age 65 Years and Over. Advance Data from Vital and Health Statistics. No. 121. DHHS Pub. No. (PHS) 86 - 1250.

14. Podoll, R.T., H.M. Jaben and T. Mill. 1986. Tetrachlorodibenzo-dioxin: rates of volatilization and photolysis in the environment. Environ. Sci. Technol. 20(5): 490-492.

15. Poiger, H. and C. Schlatter. 1980. Influence of solvents and adsorbents on dermal and intestinal absorption of TCDD. Food Cosmet. Toxicol. 18(5): 477-481.

16. Predicast Forecast: Paper, Paperboard and Pulp. 1985. p. B-183 thru B-192.

REFERENCES

17. Schroy, J.M., F.D. Hileman and S.C. Cheng. 1985. Physical/chemical properties of 2,3,7,8-TCDD. Chemosphere 14 (6/7): 877-880.

18. Sen, N.P. and P.A. Baddoo. 1986. Origin of N-nitrosomorpholine contamination in margarine. J. Food Sci., 51 (1): 216-217.

19. Stanovick, R.P., S.I. Shahied and E. Missaghi. 1973. Determination of polychlorinated biphenyl (Aroclor 1242) migration into food types. Bulletin of Envir. Contam. and Tox. 10 (2): 101-107.

20. Till, D.E., D.J. Ehntholt, A.D. Schwope, K.R. Sidman, R.H. Whelan and R.C. Reid. 1983. A study of indirect food additive migration. Arthur D. Little, Inc. report to Department of Health and Human Services, Public Health Service, Food and Drug Administration; FDA Contract No. 223-77-2360. July, 1983.

21. U.S. Bureau of the Census. 1987. Statistical Abstract of the United States.

22. U.S. Department of Commerce. 1987. Paper and Allied Products, U.S. Industrial Outlook, p. 5-1 thru 5-24.

23. U.S. Department of Commerce, Bureau of the Census. 1985. Current Industrial Reports: Pulp, Paper and Board, MA 26A (85)-1.

24. U.S. Environmental Protection Agency. 1987. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and - Dibenzo Furans (CDDs and CDFs). EPA/625/3-87/ 012.

REFERENCES

25. U.S. Environmental Protection Agency. 1985. Health Risk Assessment Approach for 2,3,7,8-TCDD. EPA/600-8-85/013.

26. U.S. Environmental Protection Agency. 1984a. Ambient Water Quality Criteria Document for 2,3,7,8-TCDD. EPA 440/5-84-007.

27. U.S. Environmental Protection Agency. 1984b. Risk Analysis of TCDD Contaminated Soil. EPA-600/8-84-031.

28. Voss, et. al. 1980. Chlorinated Organics in Kraft Bleachery Effluent. Proceedings Third International Congress on Industrial Waste Water and Wastes, Stockholm, Sweden, February, 1980.

29. Whitfield, F.B., C.R. Tindale, K.J. Shaw and G. Stanley. 1984. Contamination of cocoa powder bichlorophenols and chloroanisoles adsorbed from packaging materials. Chemistry and Industry, 5 Nov 1984: 772-774.