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Environmental Protection Agency

Emission of chemical substances from products made of exotic wood

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Danish Technological Institute

Survey of Chemical Substances in Consumer Products, No. **49** 2004

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Preface

This project ”Emission of chemical compounds from products made of exotic wood” was carried through for the Danish Environmental Protection Agency under the programme “Survey of chemical compounds in consumer products” in the period May-November 2003.

The target group for this report is authorities, manufacturers, importers and consumers of products made of exotic wood that will obtain information about environmental and health aspects in relation to products made of exotic wood.

The purpose of the project is to analyse the emission of chemical compounds and to determine whether there are health risks by consumer products made of exotic wood, when used at home. The first priority is given to the emission of volatile organic compounds to the air and less to ingredients and compounds, which can be emitted from the products by migration into artificial saliva. The emitted compounds have been evaluated in relation to LCI-values and indoor-relevant time-values, and it has been evaluated whether the wood species examined could cause allergic reactions.

The project has been divided into 3 phases:

1. Survey of the products made of exotic wood species on the Danish market
2. Measurement of emissions of volatile organic compounds (VOCs)
3. Evaluation of emissions and constituents

The following project group carried out the project:

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The Danish Technological Institute Timber and Chemical Department carried out the experimental part (phase 2) of the project.

Summary and Conclusions

The purpose of this project is to analyse the emission of chemical compounds and to determine whether there are health risks connected with consumer products made of exotic wood when used at home.

The main stress has been laid on the emission of volatile chemical compounds to the indoor air and to a less extent to the ingredients and compounds emitted from the products by migration into artificial saliva. The emitted compounds have been evaluated in relation to LCI-values and indoor-relevant time-values. It was also evaluated, whether the examined wood species can cause allergic reactions.

It should be remarked that the results presented in the report solely concerns the products examined, the results should, therefore, be considered as being based on random sampling. The results are thus not representative of the respective wood species or of exotic wood in its entirety.

The experimental part includes an examination of 10 selected products made of exotic wood. The products partly represent the product groups, which have been found on the market, and partly, wood species, which are widely used for these product groups. The 10 products have been listed in Table 1.

Table 1 Selected Products

Specimen no.	Wood species	Botanical name	Product	Surface treatment, if any
1	Rubber tree	*Hevea brasiliensis*	Dining table	Lacquer**
2	Ramin	*Gonystylus bankanus*	Venetian blind	Stain
3	Sheesham	*Dalbergia latifolia*	Bed table	Wax
4	Teak	*Tectona grandis*	Tray	
5	Jatoba	*Hymenaea courbaril*	Floor	Oil
6	Merbau	*Intsia bijuga*	Floor	Oil
7	Khaya mahomanganesey	*Khaya ivorensis*	Kitchen table	Oil *
8	Iroko	*Chlorophora excelsa*	Kitchen table	Oil *
9	Cherry wood, American	*Prunus serutina*	Kitchen table	Oil *
10	Belalu	*Albiz(z)ia falcata*	Figure	Ink

* The products, which normally are oil treated, but which in this examination form part as untreated
** The distributor informs that this product is wax treated. It has been evaluated to be lacquered

The products have what regards the majority been examined with the surface treatment, which normally occur with the consumer. What regards oil treated products, products have been bought – when possible – without oil treatment. This does not represent a typical situation of use, but it does, however, give a better picture of which chemical compounds are emitted from the wood itself. Notoriously, oil treatment emits a number of compounds, which might mask the emission from the wood itself.

On basis of the results from the initial qualitative screening of the emission from the 10 products, 5 products were chosen for a further quantitative analysis of the emission in climate chamber. The selection of the 5 products was based on the following criteria:

- Products, which are used on the largest surfaces
- Products, which emit the most
- Products, which are mostly used
- The type of the emission from the product

The 5 products are listed in Table 2.

Table 2 Products selected for quantitative analysis of emissions

Specimen no.	Wood species	Botanical name	Product	Surface treatment
1	Rubber tree	*Hevea brasiliensis*	Dining table	Lacquer
2	Ramin	*Gonystylus bankanus*	Blind	Stain
3	Sheesham	*Dalbergia latifolia*	Bed table	Wax
6	Merbau	*Intsia bijuga*	Floor	Oil
8	Iroko	*Chlorophora excelsa*	Kitchen table	

Only minor amounts of chemical compounds were found in the examined products of exotic wood (with and without surface treatment) by the climate chamber measurements.

Totally 25 individual compounds were demonstrated by the climate chamber measurements, out of which more of the individual compounds could be retrieved in a lot of the products. A part of these compounds origins predominantly from the surface treatments of the products in question.

The assessment of possible comfort and health effects from emission of compounds from products made of exotic wood includes exposure via inhalation, contact and migration into artificial saliva. The assessment is based on toxicological principles and literature data. At assessment a typical scenario from a home forms the basis.

The impact of exotic wood products on the indoor climate was partly assessed by an S-value, which is a sum of concentrations in the indoor climate divided by the "lowest concentration of interest for the indoor climate" (LCI), and partly by an indoor-relevant time-value based on odour and irritation thresholds. The lower the S-value the more acceptable the emission from the exotic wood and/or its surface treatment. For S-values below 1 no harmful health effects are expected.

The measurements stated draw a picture indicating that emission of individual compounds only to a very limited extent takes place from the examined exotic wood species or their surface treatments. None of the products will at the stated emission concentrations cause health problems.

Rubber tree is the only product among the examined ones, which has an S-value that in the measuring period exceeds 1. The individual compounds important in relation to the calculated S-value are formaldehyde and acrolein. It is deemed less likely that they are constituents of the rubber tree itself. There is on the contrary every probability that they origin from the surface treatment.

Products made of rubber tree and belalu were subjected to an analysis for the emission of chemical compounds by migration into artificial saliva. The analyses showed that none of the compounds emitted by migration form part in concentrations, which exceed the calculated TDI-values (Tolerable Daily Intake). However, compounds occur in both the examined products, which have been entered on the list of The Danish Working Environment Service of allergy or hypersensitivity causing compounds in the working environment – including vanillin and anhydride and phtalacidanhydride. The emitted compounds origin most probably from the surface treatment. The problem is of course of greatest importance in case the products are used for storage of food (salad bowls, chopping boards, kitchen table tops etc.), or if they are used for purposes, in which they will get into close contact with the skin for a long time e.g. musical instruments and trinkets.

Further analyses were carried out to demonstrate content of allergen proteins in the rubber tree. No content of allergen proteins could be demonstrated.

As rubber tree degrades very fast, this wood species is always treated with fungicide. Samples of the rubber tree were, therefore, subjected to analyses to demonstrate residues of relevant active compounds (including numerous elements). The analyses demonstrated content of boron, which indicates that the rubber tree has been treated with a boron fungicide. Taking the content of boron into consideration it would be inadvisable to use ***Hevea brasiliensis*** without surface treatment, in case the wood has been treated with a boron fungicide.

On basis of the examined consumer products of exotic wood forming part of the project, the following can be concluded:

LCI-values laid down for emitted compounds are predominantly based on irritation and only in individual cases on the health effects of the compounds.

The products (with and without surface treatment) of the wood species Ramin, Sheesham, Merbau and Iroko emit only to a limited extent compounds to the indoor air. The indoor-relevant time-value is for all these products less than 3 days. S-values are less or equal to 0.2.

The product made of rubber tree (with surface treatment) was the examined product, which has the most extensive emission. The indoor-relevant time-value for the product is higher than 28 days and the S-value is 0.6 (after 28 days).

The surface treatment of the examined product is not suitable for products in contact with food due to the emission of chemical compounds by migration into artificial saliva.

The content of boron in the wood of the product examined is so high that it cannot be recommended that the product be used without surface treatment.

Among the 5 examined wood species Ramin should be considered to be more irritating to the skin and airways than the other 4 wood species. Allergic reactions in the airways can be seen by inhalation of dust from Iroko and Ramin. Allergic contact dermatitis can, especially, be seen from Iroko and Sheesham and, presumably, to a lesser extent from Ramin. Some of the contact allergens have been identified, i.e. chlorophorin, R- and S-4 methoxydalbergione and 1,4 quinone latinone.

With the proviso that we have only examined one product of rubber tree, the products made of this wood species do not seem to present risks for persons, who are allergic to natural rubber latex.

1 Introduction

1.1 Wood Species

Approximately 12,000 truly large wood species are identified; out of which approx. 1,000 are used industrially. Europe is very poor in species, and in Denmark there are only approx. 20-30 wild species, which are used industrially. For comparison there are in Brazil and Java approx. 3,000 species.

1.2 Composition of Wood

Wood consists mainly of carbon (C), oxygen (O), hydrogen (H) and nitrogen (N) and inorganic sub-compounds. The elements form cellulose, hemicellulose and lignin, which are the main ingredients of the cell walls.

Cellulose, which consists of polymers of glucose anhydrides, constitutes 40-50% of the cell wall. The cellulose molecule forms chains, in which the number of internodes of a chain (the polymerisation degree) in average is 10,000.

Hemicellulose consists primarily of chains of pentosanes and hexosanes. Hemicellulose constitutes 25-30% of the cell wall and contributes to stabilise the cellulose structure.

Lignin, which is amorphous constitutes 20-35% of the wood, and contributes like hemicellulose to strengthen the cellulose structure.

Together with the main components of the wood wood contains numerous other organic and inorganic compounds. Content and composition of these compounds vary from species to species; like the variation within same species and within the individual tree can be extensive. The compounds contribute to the resistance to biological degradation.

Among the compounds there are terpenes and resins, which primarily are composed of abetin, sylvinite, sapin and pimaric acid. Often complex nitrogen containing compounds named alkaloids are present. These can be very toxic. The odour of the wood origins a.o. from the ethereal oils, which are emitted from the wood during drying.

1.3 The Use and Import of Wood

There are approx. 2,000 wood industrial companies in Denmark (Straarup, 2002). The furniture industry constitutes approx. 1,000. The primary wood industry, which is the part of the industry that buys and processes raw wood, is sawmills, parquet factories, packing factories etc. Furniture factories, workmen, manufacturers of construction parts, glulam manufacturers and manufacturers of panels belong to the secondary industry.

The wood applied origins partly from the Danish forestry and partly from import. The annual consumption of wood and wood products in Denmark is 3-4 times larger than the annual felling in Denmark. Thus some wood and wood products should be imported to cover the consumption.

Statistics Denmark makes estimates of the import to Denmark of all kinds of timber and all types of wood. The category "wood and products made of wood" all consist of wood products, which are categorised under chapter 44 in Statistics Denmark's Foreign Trade distributed on products and tasks (Statistics Denmark, 2002). The category covers timber, doors, windows, boxes, and kitchen fittings, but not furniture, which is summed up under "Miscellaneous goods", chapter 94 "furniture".

The category "timber" is a part amount of the imported woods, which is not processed to anything but round timber, sawn timber, veneer or plywood. In 2001 timber constituted approx. 2/3 of Denmark's total import of wood, when evaluated according to value. It should be noted that tropical timber the same year only constituted approx. 3% of the imported volume, and that the import of all types of tropical wood constituted approx. 6% of the total import of all types of wood.

What the designation "tropical wood" covers, will be elaborated in the following paragraph.

As for the timber it is to a great extent transported to Denmark by ships in regular traffic. A lot of these ships sail depending on type and container content, not longer north than Holland or Germany, where the cargo will be reloaded. At the re-loading the content of the cargo will be recorded by the customs authorities of the country in question. This means that when a ship unloads tropical wood in a European port to go on to Denmark, the cargo will be recorded as originating from the European country in question and not the country of origin. This is the primary reason why large parts of the Danish import of tropical wood seem to origin from countries such as Germany and Holland. This practice makes it at the same time hard to trace the country of origin of the timber.

The use of different wood species indoors is in excess of completely mechanical properties also due to the colour of the wood. E.g. the use of wood for floorings, furniture and kitchen fittings is to a high extent dependent on changing fashions. In some periods dark wood is fashionable, while it in other periods is the light wood that "sells".

1.4 Exotic Wood

Tropical wood, exotic wood and overseas wood are some of the designations that are used for wood species imported from far away. In this project we will use the designation exotic wood, as we not only describe tropical or overseas wood species.

Statistics Denmark uses the designation "tropical wood" and in Appendix A, a list is given of the wood species, which Statistics Denmark includes under this designation.

Of the more than 500 of the most known exotic wood species there is in Table 3 stated the most common exotic wood species imported to Denmark (Straarup, 2002; Kopp, 2003). The mentioned wood species are all used indoors and some also outdoors e.g. in connection with water construction and external cladding. Of these wood species the following can be mentioned: Azobé, Purpleheart and Western Red Cedar (Thuja).

The original designations of the trees are often of popular origin and on the language of the individual country. Simultaneously, many of the names are just trade names covering more wood species, which in some cases have very different appearance and properties. It is, therefore, necessary to use the botanical name in order unambiguously to identify a given wood species. In Table 3 and in the following the trade name has been applied in connection with the botanical name.

Unambiguous identification of the wood species is also essential by statistical survey of their health effect on human beings. Unfortunately, such a safe identification is not always available. Information in the literature should therefore be taken with reservations (Mitchell and Rook, 1976).

For more of the wood species mentioned in Tables 3, 4, and 7 there is from literature knowledge of health symptoms due to contact with the wood and/or wood dust. These wood species are listed in Table 9.

Table 3 Trade name, botanical name, origin and typical indoor use of the most common exotic wood species imported to Denmark (Straarup, 2002; Kopp, 2003; Morsing, 2003)

Trade name	Botanical name	Origin	Application
Balsa	*Ochroma pyramidale*	South America	Insulation, model-making
Bilinga	*Nauclea diderrichii*	Africa	Furniture, floorings
Blue gum	*Eucalyptus globulus*	Australia	Floorings
Dibetoú	*Lovoa klaineana*	Africa	Furniture
Rubber tree (Hevea)	*Hevea brasiliensis*	Asia	Furniture, floorings, kitchen fittings
Ilomba	*Pycnanthus angolensis*	Africa	Furniture
Imbuia	*Phoebe porosa*	South America	Furniture
Ipé	*Tabebuia ipé*	South America	Furniture, floorings
Iroko	*Chlorophora excelsa*	Africa	Cabinet-making
Jatoba	*Hymenaea courbaril*	South America	Furniture, floorings
Jelutong	*Dyera costulata*	Asia	Cabinet-making
Kapur	*Dryoubalanops lanceolata*	Asia	Building material
Karri	*Eucalyptus diversicolor*	Australia	Floorings (furniture)
Kempas	*Koompassia malaccensis*	Asia	Floorings
Keruing	*Dipterocarpus warburgii*	Asia	Furniture, floorings
Limba	*Terminalia superba*	Africa	Furniture
Louro preto	*Cordi spp.*	South America	Furniture, articles
Mahogany, African	*Khaya ivorensis*	Africa	Furniture, floorings
Mahogany, American	*Swietenia spp.*	South America	Furniture, doors, windows
Mansonia	*Mansonia altissima*	Africa	Cabinet-making
Massaranduba	*Manilkara bidentata*	South America	Furniture
Meranti	*Shorea spp.*	Asia	Floorings, doors, windows
Merbau	*Intsia bijuga*	Asia	Furniture, floorings
Nyatoh	*Palaquium spp.*	Asia	Furniture, floorings
Obeche	*Triplochiton scleroxylon*	Africa	Furniture
Okumé	*Aucoumea klaineana*	Africa	Veneer, laminates
Ramin	*Gonystylus bankanus*	Asia	Furniture, frames, articles
Sapelli	*Entandophragma cylindricum*	Africa	Furniture

Trade name	Botanical name	Origin	Application
Sipo	*Entandrophragma utile*	Africa	Furniture, doors, windows
Tasmanian oak	*Eucalyptus spp.*	Australia	Floorings
Teak	*Tectona grandis*	Asia	Furniture, floorings, windows
Tiama	*Entandophragma angolense*	Africa	Replacement for mahogany
Virola	*Virola surinamensis*	South America	Furniture, constructions
Wengé	*Millettia laurentii*	Africa	Furniture, floorings

In excess of these exotic wood species cherry is also used indoors. Products made of cherry are, therefore, included in this project. Cherry is imported from different countries. In Table 4 cherry is mentioned with different origin.

Table 4 Trade name, botanical name, origin and typical application for cherry

Trade name	Botanical name	Origin	Use
Cherry	*Prunus serutina*	North America	Furniture, floorings
Scandinavian cherry	*Prunus avium*	Scandinavia	Furniture, floorings
Oriental cherry			Furniture, floorings

1.5 Sustainable Forest Management

Formerly, exotic wood species were primary used within very specific areas. There were less wood species on the market, which then seemed clearer. An increased concern for environmental problems and sustainability by the consumers, scarcity of wood species and more focus on the tropical rain forests have, however, changed the demand and the trade with exotic wood (Morsing, 2003).

Certification of exotic wood have had the effect that there now are numerous wood species, which have not formerly been on the Danish market. As importer and manufacturer it is today very important to run an environmental policy, which signals that the company in question contributes to sustainable exploitation of the exotic wood.

Now an environmental guideline for tropical wood is available (the Danish Environmental Protection Agency, 2003).

Close to a fourth of the exotic wood imported to Denmark is sold to the public sector. This sector has, therefore, a great influence on the demand. All public institutions were as per 1st June 2001 by the Folketing (the Danish Parliament) encouraged to ensure that all wood applied is legally and sustainably grown (Parliamentary Resolution B197). FSC (Forest Stewardship Council) is at the same time acknowledged as an example of a guarantee that wood with this certificate meets the requirements made by the Folketing.

The purpose of the certification of forestry is to ensure that the forests are operated sustainably and thereby maintained for the future generations. The idea was created in the end of the 1980's and was seriously developed, when FSC was founded in 1994. At present there are some national and international certification schemes, which can be hard to distinguish from each other.

Examples of international certification schemes:

- FSC (Forest Stewardship Council)
- PEFC (Pan European Certification System)

Examples of national certification schemes:

- SFI (USA)
- CSA (Canada)
- LEI (Indonesia)
- MTCC (Malaysia)

It falls outside the scope of this report to describe these certification schemes closer, like a potential certification does not form part of the subsequent selection of products in this project.

1.6 Surface Treatment

I many cases the products made of wood are surface treated. This surface treatment can have an aesthetic function giving the product more constancy towards use and wear, dirt and/or discoloration/bleaching of sunlight. This surface treatment can in excess also ease the cleaning and the resistance of the products to it.

A potential surface treatment can contribute to reduce the emission of chemical compounds from the wood itself, but the surface itself can at the same time imply emission of (other) compounds.
As described formerly the selection of wood species is partly conditioned by the aesthetic guidelines, which the changing fashion dictates. Same conditions are valid for a potential surface treatment, the type and colour of which are partly dependent on the architectonic and design trends.

Typical surface treatments for different product categories are listed in Table 5 below.

Table 5 Typical surface treatments for different product categories

Product category	Surface treatment
Floorings	Lacquer, oil, lye
Kitchen table tops	Oil, soap, lacquer, lye, stain
Furniture (interior furnishings for kitchen and bath)	Lacquer, wax, stain, lye
Articles for everyday use	Lacquer/paint, lye, oil, stain, wax
Art articles	Stain, lacquer/paint, oil, wax

In Asian countries acid-hardening lacquers are greatly used, which emit formaldehyde. Lacquered products imported from Asia will, therefore, often be treated with acid-hardening lacquer.

2 Survey of Products Made of Exotic Wood on the Danish Market

To get an overview of, which exotic wood species and products presently are on the Danish market, a market survey has been carried out.

The market survey is based on information from Statistics Denmark and on contact with numerous importers, distributors and manufacturers of floorings, furniture, kitchen fittings and articles for everyday use, art and ornaments.

Importers, distributors and manufacturers have been chosen on basis of the project group's knowledge of the market and recommendations from the companies contacted as well as Internet searching.

Information about amount and value of articles made of wood, which in 2002 were imported to Denmark, has been obtained from Statistics Denmark. The imported amounts are in the statement stated in different groups. In the statements from the Danish foreign trade there is a differentiation between "tropical wood" and "other wood". Appendix A states, which wood species are included in "tropical wood".

Unfortunately, Statistics Denmark does not distinguish between different wood species, but only between "tropical wood" and "other wood" and which product categories are in question. Far the main part of the Danish import of exotic wood (stated in amount) is constituted of timber. This product category is outside the scope of this project. Table 6 below states the Danish import of the remainder product categories of "tropical wood" in 2002 (Statistics Denmark, 2002).

Table 6 Danish import of "tropical wood" stated according to product category (2002 figures)

Category	Amount [kg]	Value [DKK]
Frames for paintings, photos, mirrors etc.	41,849	1,758,838
Windows, glass doors and frames for these	602,550	24,955,369
Doors and door frames, doorsteps	156,621	3,794,288
Dinner service and kitchen fittings	254,863	11,871,483
Boxes, chests, fittings (excl. furniture)	84,749	4,798,922
Statuettes and other decorative articles	101,362	3,901,290
Totally	1,241,994	51,080,190

Statistics Denmark's Foreign Trade distributed on articles and tasks states in chapter 94 "Miscellaneous articles" the import of furniture. The statement does not distinguish between furniture of different wood species, but only between furniture of wood, plastic and of other materials.

Thus it is impossible via the statistical surveys to find information, about which wood species are imported. It is likewise impossible to find information about which wood species are primarily used for different products. Information about these matters has therefore been retrieved by contact with importers, manufacturers and distributors of products made of exotic wood. Information about specific products has been obtained from (Johansen, Jensen, Lorentzen, Rubæk, Bendtsen, Møller, Andersen, Konge, Frederiksen, Gottlieb, Indo Art, IQI, IKEA 2003). This information is stated in Table 7. The table also states the companies' information about potential surface treatment.

When available, information has been retrieved information about imported amount and country of origin (Johansen, Lorentzen, Bendtsen, Andersen, Konge, Frederiksen, Indo Art, 2003). This information is stated in Table 8.

Table 7 Information about products made of exotic wood

Importer/manufacturer/-distributor	Product	Wood species	Surface treatment, if any
Tarkett Sommer A/S	Floorings	Merbau, Cherry	Oil* Lacquer*
Faxe Design A/S	Floorings	Merbau, Cherry	Oil**
SPEKVA A/S	Kitchen table tops	Bubinga, Iroko, Jatoba, Khaya Mahogany, Merbau, Sipo, Teak, Walnut, Cherry, Scandinavian Cherry, Oriental Cherry	Oil, soap, lacquer, stain
	Bathroom furniture	Cherry, Sipo, Teak	Oil, soap, lacquer, stain
IKEA A/S	Bed	Rubber tree	Lacquer
Trip Trap Denmark a/s	Floorings	Teak, Merbau, Jatoba, Keruing, Wengé, Ipé	Untreated or oil
	Articles	Teak	Untreated
HTH Køkkener a/s	Cabinet doors	Karri (omitted), Cherry, Massaranduba, Mahogany	Lacquer
BIVA Møbler A/S	Dining table	Rubber tree	Wax
Rustic Møbler A/S	Furniture	Sheesham, Mahogany	Stain, wax
Inbodan A/S	Furniture	Sheesham, Rubber tree, Cherry	Wax, lacquer, stain
Asian House	Articles/art	Unknown ("monkey pot wood")	Stain
Ejnar Debel A/S	Articles (blinds)	Ramin	Stain, lye, lacquer***
International Quality Import	Art	belalu (Batai)	
Indo Art Aps	Art, articles	belalu (Batai)	Lacquer

* The product is indoor climate labelled, ** The oil is indoor climate labelled, *** Surface treatment acc. to manufacturer without content of e.g. azo-pigments

Articles for everyday use are kitchen utensils, service and cutlery, trays, napkin holders, hall racks, blinds etc.

Table 8 List of informed amount and origin for import of products made of exotic wood

Importer/manufacturer/ Distributor	Wood species	Amount per year	Origin
BIVA Møbler A/S	Rubber tree	approx. 600 pcs.	Malaysia
Rustic Furniture A/S	Sheesham	approx. 95% of turnover	India
	Mahogany	approx. 500 m^3	Indonesia
Inbodan A/S	Sheesham	600-700 m^3	India
Asian House	-	-	Thailand
Indo Art Aps	belalu (Batai)	10 m^3	Indonesia
HTH Køkkener A/S	Mahogany	30 m^3	South America

	Cherry	-	North America
	Massaranduba	60 m³	South America
Ejnar Debel A/S	Ramin	approx. 30,000 units	China

3 Materials

3.1 Allergic Symptoms caused by the Content and the Emission of Chemical Compounds from Exotic Wood Species

From the literature numerous wood species are known, which can cause different symptoms in humans. In far the most cases the symptoms reported have, however, occurred in connection with processing of the wood, e.g. sawing or sanding. Exposure during processing is often many times larger than by general use of the products. Exposure can in this connection take place by inhalation of the compounds emitted, inhalation of dust and by skin contact with wood and wood dust.

Quite comprehensive surveys are available with identification of a number of compounds, which can cause allergy (Hausen, 1981; Woods and Calnan, 1976; Turjanmaa et al., 2002). These compounds have almost all of them a large molecular weight, and only in rare cases these compounds are expected to emit from the wood and usually it is expected that it is impossible to demonstrate these compounds by headspace analysis.

Far the most frequent reason for health effects by processing of wood is due to unspecified, irritative reactions caused by wood dust, which both can cause irritation of skin and the mucous membranes of the airways. These symptoms can in most cases be avoided by use of gloves, safety clothing and exhaust. Persons, who have developed allergy, will in future react to even very low exposure, and exhaust, usual safety clothing etc. will often not be adequate.

When the wood gives rise to allergic reactions it is either due to direct contact to intact wood through contact of the finished product, or – almost always – exposure to wood dust, which is produced during processing. The wood dust will of course contain the same proteins and chemical compounds as the wood itself, but due to the size of the particle, these compounds will be air borne and thereby the persons processing the wood will be exposed to dust both on the skin and in the mucous membranes – also even though they avoid direct contact with the wood specimens.

No information is available as to how frequent different wood species cause biological reactions in woodmen, sawmill workers, and persons processing the wood or users. Most literature information concerns individual cases.

Real epidemics are described in connection with new wood species with unknown allergen potential have substituted well-known wood species such as Pao Ferro (Conde-Salazar et al., 1980; Hausen, 1982).

Patients with eczema caused by wood dust often at the same time have respiratory symptoms (Estlander et al., 2001). A Danish examination (Schlünssen et al., 2002) of 2423 workers in the wood industry concludes that wood dust seems to be able to cause airways symptoms predominantly on irritative basis in spite of a relatively low exposure. Correspondingly, chronic bronchitis is described as a frequent pulmonary disease in wood workers exposed to wood dust. (Enarson and Chan-Yeung, 1990).

In numerous cases the reaction is not due to allergens from the wood itself, but from mould etc. growing on the wood as e.g. described by Halpin et al. (1994), or caused by Frunallaria (lichen species), which grows on the bark (De Corres, 1984). Contact eczema can also be caused by compounds added to wood preservatives or in connection with surface treatment, glue or the similar (Wilkinson, 1979; Stoke, 1979; Johnson et al., 1983; Liden, 1990).

The symptoms of this survey have been divided into symptoms from the airways (1+2), symptoms from skin (3+4+5) and general symptoms (6) (Woods, 1976; Hausen, 1981; Hausen, 2000):

1. Respiratory symptoms with asthma and hay fever (rhino-conjunctivitis) and chronic bronchitis.
2. Other specific respiratory symptoms with effect on the general condition such as allergic pneumonia (allergic alveolitis) (Bendtzen et al., 2000), organic dust toxic syndrome (Seifert et al., 2003).
3. Irritation or urticaria by direct skin contact (contact urticaria).
4. Eczema. An eczema reaction consists of tiny vesicles in the skin, redness of the skin, peeling, cracks, callosity and pruritus. The reaction occurs when in direct contact with the causing agent. The eczema is, therefore, designated ”contact eczema”. Both irritative and allergic contact eczema is known, see below.
5. A special form of plant reaction, closely related to contact eczema is the ”Erythema like - multiform reaction”, where larger vesicles may occur on the skin at the spot of contact (Goh, 1992).
6. Other reactions, especially cancer and general reactions (due to toxic compounds in the wood) (Hausen, 1981; Woods, 1976; Wills, 1982).

Biological mechanisms:

The cause of skin and respiratory reactions can be:

Irritative	By irritation an unspecified effect of skin or mucous membranes.
Biological/toxic	Symptoms produced by biologically active compounds such as alkaloids (Woods, 1976).
Allergic	Allergic reactions are well described biological mechanisms, which have the common feature that a human being after repeated exposure to a particular compound develops a specific, hyper sensitive resistance of an immunological character to this compound. At exposure later to the compound an allergic reaction is produced. The amount of the compound to produce an allergic reaction in a person, who is allergic, is often less than the amount to induce allergy. Allergy is life long.

There are different allergic mechanisms (Bendtzen, 2000):

a. Exposure to protein (albumen) results in an antibody reaction with symptoms consisting of asthma, urticaria and hay fever and in rare cases allergic shock (anaphylactic shock). Not all symptoms should necessarily be present. The asthma, urticaria and hay fever occur immediately after exposure to the allergen (minutes) and the reaction diminishes in a few hours. Skin contact to the allergen protein can in some cases cause localised urticaria (contact urticaria) only at the contact spot, but it can also develop into generalised urticaria, asthma etc. (reactions of this kind are designated the allergic immediate reaction, type-I reaction or mediated by IgE-antibody). Localised urticaria can also be produced without immunological processes by irritation.

b. In certain cases exposure to proteins causes formation of an antibody of the IgG-type. The formation of specific IgG-antibodies can result in allergic pneumonia (alveolitis), which occurs as symptoms of pneumonia up to 1 day after exposure to the allergen.

c. Exposure to numerous chemical compounds can result in an allergic contact eczema. Eczema is not developed until 1-3 days after exposure and it will not diminish until weeks after the exposure has stopped. Eczema never develops into asthma. This type of allergic reaction is designated ”mediated allergic reaction” or ”delayed cutaneous hypersensitivity reaction” or type-IV reaction.

In Table 9 reported symptoms caused by the wood species mentioned in Tables 3, 4 and 7 are stated. It should be noted that the products mentioned in Tables 3, 4 and 7 could be surface treated, which can encapsulate the components of the wood. In stead the surface treatment can be determining for the emission of compounds.

Table 9 Symptoms caused by exotic wood species (Hausen, 1981)

Trade name	Botanical name	Symptoms (due to dust)	Component
Bubinga	*Guibourtia tessmannii*	Sensitising	
Blue Gum	*Eucalyptus and other* eucalyptus species)	Sensitising	Eucalyptus oil
Dibetoú	*Lovoa klaineana*	Asthma?	
Ilomba	*Pycnanthus angolensis*	Nausea, vomit	
Imbuia	*Phoebe porosa*	Sensitising, palpitation, nausea, diarrhoea, headache	Alkaloid
Ipé	*Tabebuia ipé*	Sensitising	Desoxylapachol a.o.
Iroko	*Chlorophora excelsa*	Sensitising, asthma, alveolitis	Chlorophorin
Limba	*Terminalia superba*	Splinters cause sores. Epistaxis, skin sensitising, asthma, urticaria	2,6 dimethoxy-1,4-benzoquinon? (2,6-dmbq)
Mahogany, African	*Khaya ivorensis*	May be skin sensitising, asthma, alveolitis	Meliacin (not sensitising)
Mahogany, American	*Swietenia spp.*	Sensitising, asthma, allergic alveolitis, cancer?	Meliacin (not sensitising)
Mansonia	*Mansonia altissima*	Sensitising (frequently), asthma, cancer? epistaxis, headache, cardiac arrhythmia	Chinon? (Mansonon A-Sensitising) Glycosides
Meranti	*Shorea species*	May be sensitising	
Obeche	*Triplochiton scleroxylon*	Asthma, urticaria	
Okumé	*Aucoumea klaineana*	Sensitising, asthma?	
Ramin	*Gonystylus bankanus*	Asthma, allergic alveolitis, skin irriation (splinters), sensitising	2,6 dmbq?
Sapelli	*Entandophragma cylindricum*	May be sensitising	

Trade name	Botanical name	Symptoms (due to dust)	Component
Sheesham	*Dalbergia latifolia*	Sensitising	R-4-methoxy dalber-gione and other chinones
Tasmanian oak	*Eucalyptus spp.*	Sensitising	Eucalyptus oil
Teak	*Tectona grandis*	Asthma, Sensitising	Desoxylapachol
Tiama	*Etandophragma angolense*	Sensitising	
Wengé	*Millettia laurentii*	Stomach cramp, healing problems (splinters), sensitising	2,6-dmbq and other chinones

Some of the wood species mentioned in Table 9 are in Denmark used for kitchen table tops and could in this connection get into direct contact with food. It has, however, been impossible to retrieve information about potential problems in this context. A project on application of wood in the food industry (NIF, 1998) for e.g. chopping boards or pallets only comprised "non-exotic" wood species and thus it does not inform about wood species covered by this project.

Allergen proteins are well-known in the sap from rubber tree ***Hevea brasiliensis,*** and is extensively described in the literature in connection with rubber products made of natural rubber latex from this wood species (Turjanmaa et al., 2002), but there are no publications about asthma in persons processing wood or reactions caused by contamination of food by contact with products made of wood from ***Hevea brasiliensis***.

3.2 Selection of Products

The experimental part of this project comprises an examination of 10 selected products made of exotic wood. The products partly represent product groups, which in the market survey were found on the market, and partly wood species, which extensively are used for these product groups.

The selected products/wood species can, however, only be considered as representative examples, and they are thereby not covering for all consumer products made of exotic wood on the Danish market in 2003.

The selected products are listed in Table 10.

Table 10 Selected products

Specimen no.	Wood species	Botanical name	Product	Potential surface treatment
1	Rubber tree	*Hevea brasiliensis*	Dining table	Lacquer**
2	Ramin	*Gonystylus bankanus*	Venetian blind	Stain
3	Sheesham	*Dalbergia latifolia*	Bed table	Wax
4	Teak	*Tectona grandis*	Tray	
5	Jatoba	*Hymenaea courbaril*	Floor	Oil
6	Merbau	*Intsia bijuga*	Floor	Oil
7	Khaya mahogany	*Khaya ivorensis*	Kitchen table top	Oil*
8	Iroko	*Chlorophora excelsa*	Kitchen table top	Oil*
9	Cherry, American	*Prunus serutina*	Kitchen table top	Oil*
10	Belalu	*Albiz(z)ia falcata*	Figure	Ink

* Products, which are normally oil treated, but which in this survey, form part as untreated

** The distributor has informed this product to have been wax treated. It has, however, been evaluated to be lacquered.

The products have as for the majority been examined with the surface treatment, with which they normally appear with the consumer. As for normally oil treated products, when possible products have been bought, which have not been oil treated. This does not represent a typical use situation, but on the contrary it gives a better picture of the chemical compounds emitted from the wood itself. Notoriously, an oil treatment emits numerous compounds, which might conceal the emission from the wood itself.

On basis of the results from an initial qualitative screening (described in paragraph 4.1) of the emission from the 10 products listed in Table 10, 5 products were selected for further quantitative analysis of the emission. The 5 selected products are listed in Table 11.

Table 11 Products selected for quantitative analysis of the emission

Specimen no.	Wood species	Botanical name	Product	Surface treatment
1	Rubber tree	*Hevea brasiliensis*	Dining table	Lacquer
2	Ramin	*Gonystylus bankanus*	Venetian blind	Stain
3	Sheesham	*Dalbergia latifolia*	Bed table	Wax
6	Merbau	*Intsia bijuga*	Floor	Oil
8	Iroko	*Chlorophora excelsa*	Kitchen table top	

The selection of these 5 products is based on the following criteria:
- products, which are used on large surfaces
- products, which emit the most
- products, which are most widely used
- the type of emission from the product

The knowledge of the amount used by the individual wood species is limited. The primary criteria for the selection have, therefore, been products, which form part with a large surface in a typical home and/or has a ”high” emission.

The quantitative analysis of emission is described in paragraph 4.2.

3.3 Determination of Wood Species

For two of the selected products made of exotic wood, the distributor/importer has only been able to inform the trade name of the wood species. As the trade name can be geographically determined and vary from area to area, it is necessary to know the botanical name to identify the wood species unambiguously.

Below the determination of the botanical names of the two wood species are listed. Regular descriptions of wood species are for all 10 selected wood species listed in Appendix B (Danish Technological Institute, 2003).

3.3.1 Sheesham

Among the selected products there is a bed table made of the wood species sheesham. The bed table is part of a series of furniture, distributed via Idé Møbler.

At purchase of the table with the distributor the wood species had different designations in the catalogue, product descriptions and price tags e.g. sesame, shesam, sheesam.

Neither the distributor nor the importer could inform the botanical name of the wood species but referred solely to the trade name.

On basis of samples taken from the purchased piece of furniture the wood species has subsequently been tried determined via a literature study. The major part of the wood used in the piece of furniture in question is sapwood, which makes a unique determination of species impossible. It is either ***Dalbergia latifolia*** or ***D. sissoo***. These two wood species can only be determined by difference in colour and not by microscopic characters. As the wood material in question primarily consists of juvenile wood, the colour is less characteristic. It is, therefore, impossible with certainty to determine the wood species, but there is every probability that it is ***Dalbergia latifolia*** (Venås, 2003). This identification is used with the above-mentioned reservations throughout this report.

3.3.2 Belalu

A figure cut of an Indonesian wood species named belalu forms part of the project. The importer, who personally is in charge of the purchase of the figures in the country of origin, can only inform the Indonesian name, belalu, of the wood species.

From the name belalu there is every probability that it is the wood species with the botanical name ***Albiz(z)ia falcata***, which in Danish, English and German is named batai (Venås, 2003). This corresponds to the literature description of the appearance and structure of the wood and to its application for woodcarving with a low degree of detailing. In the present report it is, therefore, assumed that it is ***Albiz(z)ia falcata***.

4 Method

As described in paragraph 3.2 ten products were selected for initial qualitative screening of the emission of chemical compounds. Of these 10 products 5 were selected for further quantitative analysis.

In excess of analyses of the emission of chemical compounds to the air, samples of belalu, ***Albiz(z)ia falcata***, have been analysed for the emission of chemical compounds by migration into artificial saliva and samples of rubber tree, ***Hevea brasiliensis***, have been analysed for the emission of chemical compounds by migration into artificial saliva, content of latex allergens and fungicide. Description of these analyses has been treated later in this chapter.

4.1 Initial Qualitative Screening

The qualitative screening is carried out at 40°C, where samples of the product to be examined, are placed in a glass and heated to 40°C for 4 hours. An air sample of 1 ml is taken with a gastight syringe and analysed by capillary column gas chromatography combined with mass spectrometric detection (GC-MS).

The components are identified by comparison of the respective mass spectres with mass spectres from NIST 98 library. The percentage part of the total VOC content is stated as area percentage of the spectre assuming that all detected components have the same response to the same amount. The detection limit is on this theory 5-10 ng/g test material. The degree of accuracy of the relative area percentages constitutes 10-15%.

Brief results of the static headspace analysis are stated in paragraph 5.1. Results in detail are stated in Appendix C.

4.2 Quantitative Determination of the Emission in Climate Chamber

The quantitative determination was carried though by climate chamber measurement according to ENV 13419-1 Building Products. Determination of the emission of volatile organic compounds. Part 1: Emission test chamber method (CEN, 2001).

4.2.1 Preparation of Test Specimens

The test specimens were prepared in size in relation to the chamber volume to obtain the desired material load. A relation of n/L = 1 between air change (n) and material load (L) is used.

4.2.2 Test Conditions

Climate chamber	225 l polished stainless steel
Temperature	23 ± 0.5°C
Relative humidity	45 ± 3% RH
Air change in climate chamber	1 ± 0.05 h^{-1}
Air velocity	0.15 ± 0.05 m/s.

Material load	0.225 m^2
n/L	1

The test specimens were placed in the climate chamber during the entire testing period.

4.2.3 Measuring Method

The general principle of emission measurements in climate chambers is that the test specimen to be examined is placed in a climate chamber at standard testing conditions. Gases and vapours emitted from the test specimen are mixed with the chamber air. Air samples are taken at fixed intervals and are analysed at different analysis techniques.

In the examination the measurement intervals were fixed at 3, 10 and 28 days.

4.2.4 Chemical Analysis

The emissions from the examined products were collected on Tenax TA, desorbed thermally and subsequently analysed by capillary column gas chromatography combined with mass spectrometric detection, GC-MS-SCAN (29-450 amu-screening analysis) according to ISO/DIS 16000-6.2 (2002). The components were identified by comparison of the respective mass spectres with mass spectres from the NIST 98 library.

Aldehydes were collected on dinitrophenylhydrazine (DNPH) filters and subsequently analysed by liquid chromatography with UV detection (HPLC-UV).

By the analyses quantification has been carried out in relation to the external calibration standards of the detected compound of closely related chemical compounds.

Detection limit for VOC's on Tenax	0.3-1 µg/m^3
Detection limit for aldehydes on DNPH	1.2 µg/m^3
Inaccuracy of analysis results	10-15 %

Blind values have been analysed for the empty chamber prior to testing, and unexposed tubes have been analysed together with test tubes.

4.3 Determination of Natural Rubber Latex Allergen

In the literature there are innumerable descriptions of allergy towards natural rubber latex extracted from ***Hevea brasiliensis***. Proteins cause the allergy. In the literature there are no studies described, in which the content of natural rubber latex allergens in the wood itself can cause reaction in natural rubber latex allergic persons.

The dining table made of rubber tree, which is one the selected products, is lacquered on legs and upper side of the table top. Samples of the tabletop have been analysed for content of natural rubber latex allergens in the wood itself. Most natural rubber latex allergens are water-soluble and in case they are able to penetrate the surface treatment, they may cause allergic symptoms at contact with the surface.

The tabletop consists of laminboards. Totally 3 test specimens have been sampled from different staves. The specimens have been sampled in the middle of the material by means of a metal drill, so that neither glue nor wax forms part of the bored material. The material was subsequently pulverised in a metal grinder. The sampled test material has thus not been in contact with materials, which might contain/emit natural rubber latex allergens.

The material is extracted with phosphate-buffered salt water in the relation 1 g to 5 ml buffer according to ASTM D5712. Particles have subsequently been removed by centrifuging for minimum 15 minutes at minimum 500G. The supernatants were then tested by an immunological method for each of the allergens Hev b 1, Hev b 3, Hev b 5 and Hev b 6.02 by application of specific antibodies (FIT-kit™) (FIT Biotech; Palusou et al., 2002) both undiluted as diluted 1:10, if a high allergen level was expected. The amount of allergen is stated for each allergen in μg/l. The total amount is stated as μg/g test material.

The detection limit of the analyses for the allergens Hev b 1, Hev b 3, Hev b 5 and Hev b 6.02 is given in Table 12.

Table 12 Detection limit for latex-allergens

	Hev b 1	Hev b 3	Hev b 5	Hev b 6.02
Detection limit [μg/l]	1.2	2.3	0.5	0.1

The samples were analyses by FIT Biotech Oyj Plc., Tampere, Finland. The results are stated in paragraph 5.3.

4.4 Determination of Content of Fungicide

Among the selected wood species rubber tree is especially exposed to attack of mould and insects from the wood is felled and until it has been dried. Timber of rubber tree is due to this always treated with a fungicide/insecticide to prevent these attacks.

The treatment takes place shortly after felling and cutting and prior to drying, thereby it is carried out while the wood is still wet. The treatment takes in some cases place by dipping the timber into a container with a liquid containing different active ingredients. In other cases an actual preservative treatment takes place. As the treatment is carried out while the wood is wet, the penetration of fungicide only takes place to a limited depth and will predominantly be on/in the surface.

After drying the wood is often further processed implying that the surface is planed, sanded or smoothed. This process entails that the parts of the wood, which might contain the largest amount of fungicide, are removed. It was, however, deemed relevant to perform analyses of potential content of fungicide in the wood.

Test specimens from more staves of the rubber tree in the tabletop of the dining table were sampled (specimen no. 1, Table 10). The sampling was carried out by means of a metal drill with subsequent pulverisation of the material in a metal grinder.

The sample was analysed for content of numerous organic active ingredients: tebuconazole, propiconazole, tolylfluanid, dichlofluanid, IPBC (3-iodo-2-propynyl-butyl-carbamat) and pentachlorophenol. In excess, the sample was analysed for a number of elements (silver, arsenic, boron, bismuth, cadmium, cobalt, chromium, copper, quicksilver, manganese, nickel, lead, antimony, selenium, tin, thallium, vanadium and zinc).

4.4.1 Organic Compounds

For all analyses, except for pentachlorophenol a weighed amount of test material was extracted with acetone. For analyses to determine content of pentachlorophenol a weighed out amount was extracted with dichlormethan added deuterium marked internal standard of C13-PCP by ultrasound.
The extracts were analysed with capillary gas chromatography combined with mass spectrometry (GC-MS). A double determination was carried out.

Tebuconazole, propiconazole, tolylfluanid, IPBC and pentachlorophenol were quantified in relation to standards of the respective compounds. Dichlofluanid was searched by means of the NIST 98 library.

Detection limit for the compounds is stated in Table 13. The degree of accuracy of the analysis results is approx. 10%.

Table 13 Detection limit for organic components

Component	CAS no.	Detection limit [μg/g]
IPBC	55406-53-6	0.5
Tolylfluanid	731-27-1	0.5
Tebuconazole	80443-41-0	0.35
Propiconazole	60207-90-1	0.35
Dichlofluanid	1085-98-9	0.5
Pentachlorophenol	87-86-5	0.1

The result of the analyses is stated in paragraph 5.4.

4.4.2 Elements

The test material was destroyed by nitric acid in telflon cylinders by microwave heating. Subsequently, the extracts were analysed for content of the elements by ICP-MS and ICP-AES (for boron).

For the analysis for boron the sample was spiked with boron and re-analysed. The retrieval was 104%.

The detection limits for the compounds are stated in Table 14. The degree of accuracy is stated together with the results in paragraph 5.4.1.2.

Table 14 Detection limit for elements

Component	Detection limit [mg/kg]	Component	Detection limit [mg/kg]
Argent (Ag)	0.5	Manganese (Mn)	0.5
Arsenic (As)	0.5	Nickel (Ni)	0.5
Boron (B)	10	Lead (Pb)	0.05
Bismuth(Bi)	0.5	Antimony (Sb)	0.5
Cadmium (Cd)	0.05	Selenium (Se)	0.5
Cobalt (Co)	0.5	Tin (Sn)	0.5
Chromium (Cr)	0.5	Thallium (Tl)	0.05
Copper (Cu)	0.5	Vanadium (V)	0.5
Quicksilver (Hg)	0.05	Zinc (Zn)	1

4.5 Determination of the Emission of Compounds by Migration into artificial saliva

Two products were analysed for emission of chemical compounds by migration into artificial saliva: Lacquered dining table made of rubber tree (Specimen no. 1) and ink treated figure made of belalu (Specimen no. 10). The determinations were carried out by assessing the intake of compounds, which might happen by children sucking and biting at the products.

For the analyses the surface of the test specimens were scraped and pulverised, then 1 g test material was firstly added internal standards and subsequently 25 ml simulated saliva (DIN 53160-1). The sample was then placed in an incubator at 37°C; it was initially shaken for 1 hour and was then left for 1 hour.

The samples were centrifuged and the saliva simulant were extracted by “solid phase extraction” SPE (IST Isolute, C18/ENV). The SPE-tubes were dried by a flow of nitrogen and were eluted with dichlormethan. The dichlormethane evaporated to 250 µl and was analysed by GC-MS (SCAN).

4.6 Evaluation of the Allergic Potential of the Wood Species

As a part of the assessment of all 5 wood species sampled for climate chamber analyses, a literature survey was carried out to evaluate the tendency of the wood species to cause allergic reactions from skin or airways.

The literature studies are based on information from numerous textbooks (Woods, 1976; Mitchell, 1979; Hausen, 1981; Lovell, 1993; Bendtzen, 2000; Hausen 2000; Krant and Cohen, 2000) and a systematic survey of ”Contact Dermatitis” and searching on Medline.

4.7 Principles for Evaluation of Chemical Compounds

4.7.1 Lowest Concentration of Interest to the Indoor Climate

Health effects caused by the indoor environment are normally very unspecified and may comprise symptoms such as headache, fatigue, mucous membrane irritation and dry skin. In excess malaise caused by odour may occur. These symptoms do not necessarily imply critical health effects, but can be of decisive importance to the general well being when staying indoors.

When evaluating, whether a chemical compound or a product consisting of numerous chemical compounds can constitute a health risk, it would be natural to evaluate the result of epidemiological examinations on the reaction of humans to the exposure in question. These examinations are, unfortunately, rare and they in many cases impossible to carry out. It is, therefore, necessary to use other methods to be able to carry out a toxicological evaluation of compounds emitted from e.g. exotic wood.

In a former examination of emission from wood and wood-based materials, furniture and interior furnishings a method for health evaluation (Jensen et al., 2001) is described. This method has been applied in this project.

The main principles of the health evaluation appear from Figure 1.

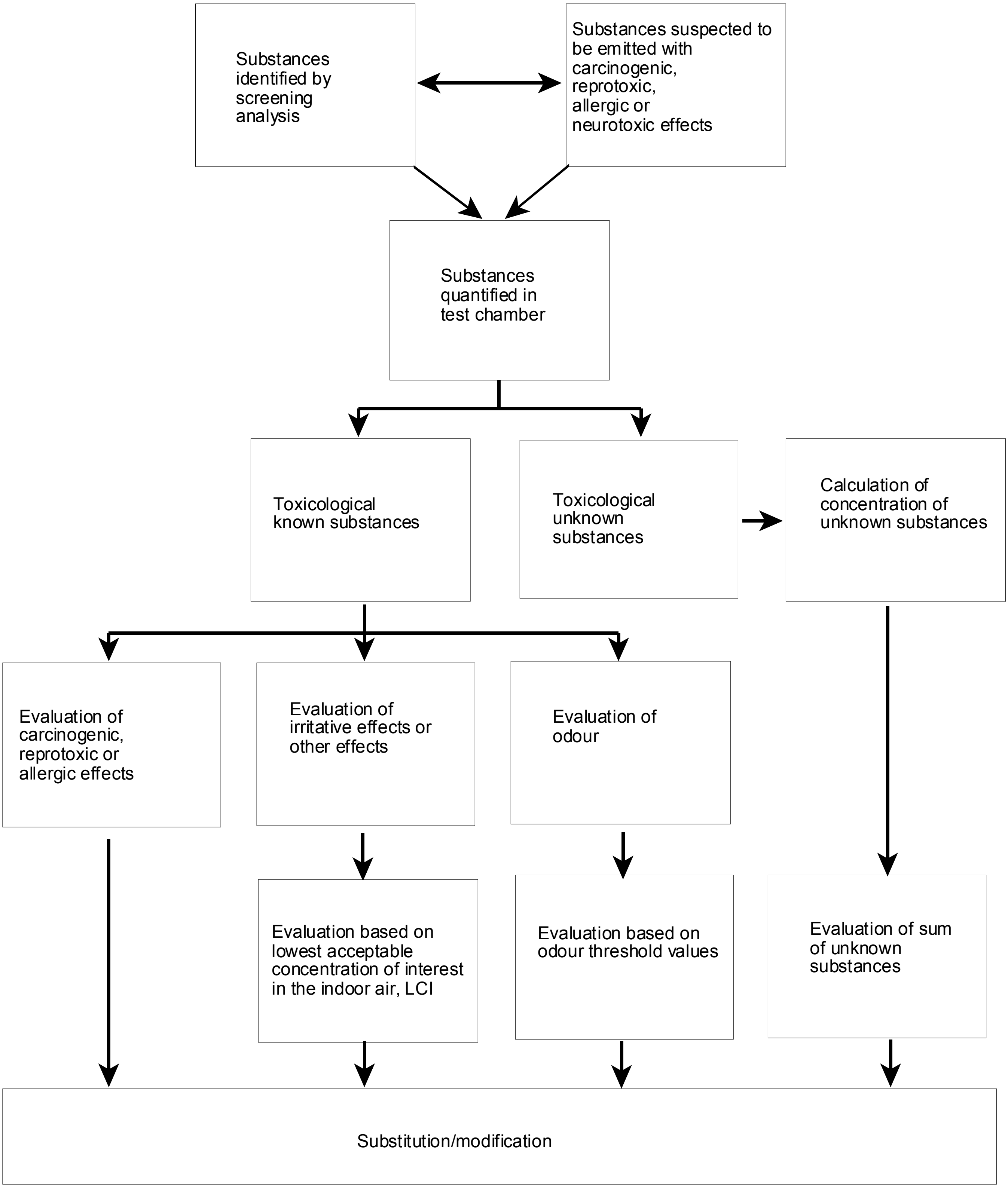

Figure 1 Fundamental principles of health evaluation of emissions

The evaluation of the individual compounds found in the emissions by the climate chamber measurements have, when possible, included the following: Toxicological effects (cancer, allergy, congenital malformations, nervous system effects and other health effects) and irritation and odour. As a superior principle the emission of carcinogenic compounds, allergens and feto-toxic

compounds from the products examined are considered as undesirable, and it is recommended to avoid import of these articles.
For all compounds an assessment for 1) effects, where no observed effect level is expected (NOEL) expected, 2) effects, where no NOEL effect level is present (e.g. carcinogenic compounds), 3) sensory irritation and odour have been carried out. The principles of this stipulation are thoroughly described in the Guidelines for Air Emission Regulation (The Danish Environmental Protection Agency, 1990).

Information about individual compounds has been retrieved by searching in the databases TOXLINE, RTECS, NIOSHtic, and Medline, and by application of existing criteria documents.

The Danish Environmental Protection Agency has carried out toxicological evaluation of chemical compounds related to air pollution, in drinking water and by soil pollution. The toxicological principles, which the Danish Environmental Protection Agency has used, were in accordance with the principles used in this project in the cases, where the assessment of the Danish Environmental Protection Agency was carried out on basis of the effects of a compound and not on basis of odour. In the cases where a toxicological assessment by the Danish Environmental Protection Agency of a chemical compound with a fixed B-value was available (The Danish Environmental Protection Agency, 1990, 1996) this was used. If the assessed value (LCI-value) deviates from this, it has been stated in the individual compound assessment.

As part of a former report on emission of wood and wood-based materials (The Danish Environmental Protection Agency, 1999) a toxicological assessment was carried out on a part of the measured compounds in this project. For these compounds the former assessment and fixed LCI-value applied, as according to our knowledge, there are no new data on the compounds that might affect the assessment.

4.7.2 Determination of LCI- and S-Values

LCI-values (Lowest Concentration of Interest) are a term, which was introduced in the report on emission from wood and wood-based materials (The Danish Environmental Protection Agency, 1999). We have defined the LCI-value as the lowest concentration of a certain compound, which not – according to our present knowledge – at permanent exposure to the indoor air would imply risk of hazardous effects to the human beings. LCI-values are considered as a quality criterion to the indoor air and not as fixed limit values.

There was only limited information about a lot of the chemical compounds and their effects, which emitted from the exotic wood products or from the surface treatment of the products, the LCI-value determination is, therefore, for a part of the compounds determined on basis of poor knowledge of the effects. This has implied that it has been necessary to work with considerable safety margins when determining the LCI-value.

For most of the emissions irritation was the effect, which was decisive for the determination of the LCI-values. More severe effects were for most compounds not found until concentrations were reached, which were way over the level, which implied irritation.

In more cases LCI-values were determined on basis of analogous considerations. In case data were missing for the compounds, and where the most essential effect was assessed to be irritation, the LCI-values were fixed on basis of reduction of the respiratory frequency by 50% in mice (RD_{50}-value).

The values converted into LCI-values by introduction of a safety factor of 10 to protect especially sensible communities and by calculating with an influence of 24 hours 7 days per week (Nielsen et al., 1997).

One of the limitations of the LCI-values is that they very often are concluded from limited knowledge about the individual compounds. The LIC-values can, therefore, only be used by comparison of materials with a uniform emission profile and with uniform determination of the LCI-values. They can, therefore, only be used as an initial indication of potential comfort and health effects in the indoor environment.

In this report the evaluation for all compounds is according to the same principles except for formaldehyde. Formaldehyde follows WHO's recommendations for an indoor environment value, which is essentially less restrictively determined than for the other individual compounds.

Concentrations of the compounds, which were measured in the climate chamber, were calculated by means of conversion factor so that they became relevant in relation to the indoor environment. The calculation appears from formula 1, where C_m [mg/m^3] is the calculated equilibrium concentration in the indoor environment, n is the air change in the indoor environment [times per hour]; V is the volume of the actual room [m^3], R_s is the specific emission rate [$mg \times h^{-1} \times m^2$] determined by climate chamber tests and A is the area of the specimen in the actual room in m^2.

$$C_m = R \times A / n \times V \qquad (1)$$

The calculations were carried out by application of a volume, V, corresponding to a standard room of 17.4 m^3 c.f. DS/INF 90 (1994). For all products a material load of 0.4 m^2/m^3 was used, which corresponds to e.g. a table and 6 chairs or a floor area.

For all compounds identified by the climate chamber measurements a calculation for day 3, 10 and 23 was carried out. The concentration in the standard room, c, for the compound in question was divided by the fixed LCI-value. An S-value was calculated by adding the contribution of c_i/LCI_i for all individual compounds (formula 2).

$$S = \sum c_i / LCI_i \qquad (2)$$

In principle this should be done for compounds with comparable effects. For the majority of LCI-values in question the irritative effect was decisive. On basis of this and as the other compounds at the same time only contributed very poorly to the total S-value, we have taken the liberty to make a total addition for all compounds.

The S-values can be used for a quick comparison of emission from the different wood species to select the products, which emit the least. The lower the S-value the more acceptable the emission from the exotic wood and/or its surface treatment. By S-values below 1 no health effects are expected.

4.7.3 Indoor-Relevant Time-Values

The indoor-relevant time-value for a product or material is an expression of the time, which passes until the concentration of all individual, emitted compounds have dropped to 50% for the odour and irritation thresholds of the products. All concentrations have been converted into indoor-relevant concentrations by using standard room conditions, cf. the definition in 4.7.2.

For the majority of the products examined this loading is, however, to be considered as worst-case.

Regarding irritation it is estimated that the effect from more compounds is more extensive than the irritative contribution for the individual compound. In case of more compounds with irritative effects, requirements for the sum of irritative compounds in the emission are made (formula 3).

$$\sum c_i / CL_i \qquad (3)$$

C_i/CL_i states the concentration of the i'th compound in relation to the acceptable concentration of the i'th compound, CL_i, in the indoor climate. CL is calculated as 50% of the irritation threshold for the individual compound.

The sum is determined by adding the contribution of the indoor-relevant concentration divided by the CL-value for all individual compounds with irritative effect in the emission (formula 3).

The indoor-relevant time-value is normally based on both chemical determination and sensory evaluation of the emission. In this project the indoor-relevant time-value of a product is, however, solely based on chemical measurements of the emission in the climate chamber.

The indoor-relevant time-value stated in days, which should be as low as possible, is a direct expression of how long time passes from installation of a product until the emission from the product no longer is expected to cause odour or irritation of mucous membranes in eyes, nose and upper airways.

Application of indoor-relevant time-values enables - like LCI-values - indoor-related comparison of materials and products.

The most extensive limitation is that threshold values for odour and irritation only are available for a limited number of compounds, and that there are distinct deviations between the published threshold values. Odour does not signify that the emission causes health effects, just like no odour do not imply that the emission does not cause health effects.

Indoor-relevant time-values form the basis of indoor climate labelling of building products, furniture and interior furnishings (Danish Society of Indoor Climate, 2003).

5 Results

Results of the qualitative screenings are stated overall in paragraph 5.1 and results in detail in Appendix C. Results of the quantitative climate chamber measurements are stated over all in paragraph 5.2 and results in detail in Appendices D and E.

In consideration of the health and comfort assessments, concentrations measured in climate chamber were converted to concentrations, to which persons are exposed in the indoor air in a typical room scenario.

The measured emissions can not be considered as covering for the examined type of material or as generally representative of emissions from exotic wood, but can be used as an indication of the emission from the examined types of products. The actual measurement results are exclusively valid for the analysed products.

5.1 Qualitative Screening

By the initial screening by headspace-analysis of the 10 selected products 74 different chemical compounds were identified cf. the result tables, Appendix C. In Table 15 the total amount of emitted compounds from the individual compounds and their mutual order of priority (stated according to total amount – 10 states the largest total amount) are stated.

Table 15 Total amount of emitted compounds by headspace

Specimen no.	Wood species	Botanical name	Total [µg/kg]	Total listed in order of priority
1	Rubber tree	*Hevea brasiliensis*	2938	9
2	Ramin	*Gonystylus bankanus*	929	6
3	Sheesham	*Dalbergia latifolia*	819	5
4	Teak	*Tectona grandis*	110	4
5	Jatoba	*Hymenaea courbaril*	959	7
6	Merbau	*Intsia bijuga*	6445	10
7	Khaya Mahogany	*Khaya ivorensis*	10	2
8	Iroko	*Chlorophora excelsa*	1739	8
9	Cherry, American	*Prunus serutina*	67	3
10	Belalu (Batai)	*Albiz(z)ia falcata*	< 15	1

If the only total amount of the emitted compounds by headspace is considered, it appears that the surface treated wood species merbau and rubber tree emit the largest amount of chemical compounds.

The compounds emitting from the individual products are listed in Table 16. The CAS no. of the compounds and their classification are stated in Appendix C.

Table 16 Emitted compounds by headspace-analyse

Specimen no.	Wood species	Botanical name	Emitted compounds
1	Rubber tree	*Hevea brasiliensis*	Acetone, 2-Butoxyethanol, Butylacetate, Butylbenzene, 1-ethyl-3,5-dimethyl-benzene, Cyclohexane (could be),

			Decan, Decanal, Dodecan, Acetic acid, Ethylbenzene, 1-Ethyl-4-methylbenzene (4-Ethyltoluene, Heptan (and isomers), Hexanal, 2-Methyl-1-propanol, 1-Methyl-3-propylbenzene, Methylcyclohexane, 4-Methyl-decan, 2-Methylheptan, 3-Methylheptan, 2-Methylhexane, 3-Methylhexane, MIBK, Octan, 2,10-Pentadecen-1-ol (could be), Pentan, 1,14-Tetradecandiol (could be), Tetracapric acid, Toluene, 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, Undecan, Undecanal, m-Xylen, o-Xylen, p-Xylen
2	Ramin	*Gonystylus bankanus*	Acetone, Aliphatic Hydrocarbons, Butanal, Butane, Butylacetate, Decanal, 4.4-Dimethyl-2-oxedanon, 1.2-Dimethylcyclohexanee, 2.5-Dimethylheptan, 2.4-Dimethylhexane, Dodecan, Acetic acid, Ethanol, Ethylbenzene, 3-Ethyl-2-methylhexane, Heptan (and isomers), 2-Methyl-1-propanol, 2-Methylheptan, 3-Methylhexane, MIBK, Octan, Toluene, m-Xylen, o-Xylen, p-Xylen
3	Sheesham	*Dalbergia latifolia*	Acetone, Bicylo(3.2.1),3-methyl-4-methylen-oct-2-en, Butane, Butylacetate, Decanal, 4.4-Dimethyl-2-oxedanon, 1.2-Dimethylcyclohexanee, 2.5-Dimethylheptan, 2.4-Dimethylhexane, Acetic acid, Ethanol, Ethylbenzene, 1-Ethyl-2-methylbenzene, 1-Ethyl-3-methylbenzene, 1-Ethyl-4-methylbenzene (4-Ethyltoluene, Heptan (and isomers), Hexanal, 2-Methyl-1-butane (could be), 3-Methyl-1-propen, 2-Methyl-2-propenal (could be), Methylcyclohexane, Propylbenzene, 2-Methylheptan, 3-Methylheptan, 2-Methylhexane, 3-Methylhexane, 3-Methyloktan, Octan, α-Pinene, Propylbenzene, Toluene, 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,2,5-Trimethylbenzene, o-Xylen, Xylenes unspec.
4	Teak	*Tectona grandis*	Acetone, Acetic acid, Hexanal, 2-Pentynal
5	Jatoba	*Mymenaea courbaril*	Acetaldehyde, Acetone, Aldehyde, 1-ethyl-3,5-dimethyl-benzene, Acetic acid, Hexanal, 4-Methyl-1-hexen, 3-Methyl-2-Butanon, 5-Methylhexanal, Pentanal
6	Merbau	*Intsia bijuga*	Aliphatic Hydrocarbons, Bromomethane, Cyclododecan, Acetic acid, Ethanol, Hexanal, Octan, Pentane, Pentanal
7	Khaya Mahogany	*Khaya ivorensis*	Acetaldehyde, Acetic acid, Hexanal
8	Iroko	*Chlorophora excelsa*	Acetone, Acetic acid, Hexanal, Nonadienal, Propion acid
9	Cherry, American	*Prunus serutina*	Acetic acid, Acetic acid methylester, Ethanol
10	belalu (Batai)	*Albiz(z)ia falcata*	Bis (2-ethylhexyl) Phtalat, Decanal, Acetic acid, Heptanal, Hexacapric acid, Hexanal, Octanal, Tetracapric acid

5.2 Quantitative Climate Chamber Measurement

Out of the 10 selected products from headspace, 5 were selected for climate chamber measurement. By the quantitative climate chamber measurements of the emissions from the 5 products, 25 different chemical compounds were quantified. The emission from the individual products is stated in Table 17. The concentrations of the compounds, CAS no. and their classification is stated in Appendices D and E.

The most important compounds are distributed in the products examined as stated in tables 22-26 in paragraph 6.1.

Table 17 Distribution of the emitted compounds in climate chamber

Specimen no.	Wood species	Botanical name	Emitted compounds
1	Rubber tree	*Hevea brasiliensis*	Formaldehyde, Acetaldehyde, Acrolein, Propanal, Hexanal, Nonanal, Decanal, MEK (2-butanon), Acetone, 2-Methyl-1-propanol, Butane, 3-Methylhexane, Methylcyclohexane, Toluene, Xylenes/ethylbenzene, Butylacetate, 2-Butoxyethanol
2	Ramin	*Gonystylus*	Formaldehyde, Acetaldehyde, Butanal, Hexanal, Nonanal,

		bankanus	Decanal, MEK (2-butanon), Acetone, 2-Methyl-1-propanol, Butane, 3-Methylhexane, 1,2-butandiol
3	Sheesham	*Dalbergia latifolia*	Formaldehyde, Acetaldehyde, Propoanal, Butanal, Hexanal, Acetone, 2-Methyl-1-propanol, Butane, 1-Methoxy-2-butane, 3-Methylhexane, Methylcyclohexane, Toluene, Butylacetate, α-pinene
6	Merbau	*Intsia bijuga*	Formaldehyde, Acetaldehyde, Propanal, Pentanal, Hexanal, Benzaldehyde, Decanal, MEK (2-butanon), Acetone, 2-Methyl-1-propanol, Butane, 2-Ethyl-1-hexanol, 3-Methylhexane, Butylacetate, Tridekan
8	Iroko	*Chlorophora excelsa*	Formaldehyde, Acetaldehyde, Hexanal, MEK (2-butanon), Acetone, 3-Methylhexane, α-pinene

Except for iroko, specimen no. 8, all specimens are surface treated with wax, stain, oil or lacquer.

Very low indoor-relevant concentrations were found for ramin, sheesham, merbau and iroko. The emissions origin primarily from the surface treatment and include mainly alcohols and glycolethers and –esters. For iroko, which was not surface treated, the emission origins from the wood itself.

The emissions from rubber tree origins primarily from the lacquer and include mainly aldehydes, aromatic hydrocarbons, alcohols and glycolethers and –esters.

5.3 Determination of Content of Natural Rubber Latex Allergens in Rubber tree

Analysis of the content of natural rubber latex allergens in three specimens sampled from three different staves of the tabletop of test specimen no. 1 was carried out. The specimens were sampled in the wood itself, i.e. without surface treatment. Analysis was carried out for the proteins Hev b 1, Hev b 3, Hev b 5 and Hev b 6.02.

No content of proteins was traced in the three samples.

5.4 Determination of Content of Fungicide in Rubber tree

5.4.1.1 Organic Components

Results of analyses for content of organic active ingredients: Tebuconazole, propiconazole, tolylfluanid, dichlofluanid, IPBC (3-iodo-2-propynyl-butyl-carbamat) and pentachlorphenol are shown in Table 18.

For none of the compounds concentrations above the detection limit could be demonstrated

Table 18 Content of organic components

Component	CAS no.	Content [μg/g]
IPBC	55406-53-6	<0.5
Tolylfluanid	731-27-1	<0.5
Tebuconazole	80443-41-0	<0.35
Propiconazole	60207-90-1	<0.35
Dichlofluanid	1085-98-9	<0.5
Pentachlorphenol	87-86-5	<0.1

5.4.1.2 Elements

Results of analyses for content of inorganic components are stated in Table 19. Content of boron, manganese and zinc were traced in the sample. The content of copper varies greatly, which indicates inhomogeneity of the test material. The copper may not origin from the wood itself, but has been added as pollution during the pulverisation of the test material.

The high content of boron indicates that the rubber tree has been treated with a boron fungicide.

Table 19 Content of elements

Component	Content [mg/kg]	Component	Content [mg/kg]
Silver (Ag)	<0.5	Manganese (Mn)	21.3 ±0.6
Arsenic (As)	<0.5	Nickel (Ni)	<0.5
Boron (B)	801 ± 7	Lead (Pb)	1.25 ± 0.15
Bismuth(Bi)	<0.5	Antimony (Sb)	<0.5
Cadmium (Cd)	0.128 ± 0.002	Selenium (Se)	<0.5
Cobalt (Co)	<0.5	Tin (Sn)	<0.5
Chromium (Cr)	<0.5	Thallium (Tl)	<0.05
Copper (Cu)	2.7; 9.9	Vanadium (V)	<0.5
Quicksilver (Hg)	<0.05	Zinc (Zn)	15.1 ± 1.3

5.5 Analysis for Migration into artificial saliva

Results of analysis for migration into artificial saliva from lacquered tabletop made of rubber tree (***Hevea brasiliensis***) and ink treated figure made of belalu (***Albiz(z)ia falcata***) are stated in Tables 20 and 21. A complete list of the compounds found appears from Appendix F.

Table 20 Compounds migrated from lacquered tabletop (Specimen no. 1)

Compound	CAS no.	Concentration [μg/g]
2-butoxy-ethanol	111-76-2	171
Hexanoic acid	142-62-1	3.1
2-(2-ethoxy)-ethanol	111-90-0	0.8
2-ethyl-1-hexanol	104-76-7	2.3
1-methyl-2-pyrrolidinon	872-50-4	4.0
Phtalat acid anhydride	85-44-9	52
n-capric acid	334-48-5	0.8
Vanillin (isovanillin)	121-33-5 (621-59-0)	3.0
Benzaldehyde	100-52-7	1.2
Phthalic acid monobutyl ester	131-70-4	11.3
Tricaprylin	538-23-8	3.3

Table 21 Compounds migrated from ink treated figure (Specimen no. 10)

Compound	CAS no.	Concentration [μg/g]
2-Butanon (MEK)	78-93-3	0.4
1-methoxy-2-propyl acetate	108-65-6	0.6
2-butoxy ethanol	111-76-2	5.5
Butyrolacton	96-48-0	0.2
Benzaldehyde	100-52-7	0.1
2-ethyl-1-hexanol	104-76-7	0.9
1-methyl-2-pyrrolidinon	872-50-4	41
2-phenoxy-ethanol	122-99-6	3.1
2-(2-butoxyethoxy)-ethanol acetate	124-17-4	1.3
Vanillin (isovanillin)	121-33-5 (621-59-0)	0.7
Diethyl phtalate	84-66-2	0.6
2,3,5-trimethoxy-benzaldehyde	86-81-7	0.6
4-hydroxy-3,5-dimethoxy benzaldehyde	134-96-3	1.7
N-butyl-benzenesulfonamid	3622-84-2	1.7

5.6 Results from Literature Survey

Due to differences in the immunological mechanisms, the allergic reactions have been evaluated for asthma and urticaria respectively (IgE-antibody-mediated), allergy and for contact eczema (cell mediated allergy) separately.

5.6.1 Allergic Respiratory Symptoms and Allergic General Reactions

5.6.1.1 Hevea Brasiliensis, Rubber tree

In the literature there is no information available about allergic respiratory symptoms caused by exposure to wood dust from ***Hevea brasiliensis***.

There are no publications on allergic reactions caused by e.g. food, which has been in contact with items made of ***Hevea brasiliensis***.

Latex from ***Hevea brasiliensis*** contains numerous allergen proteins, there is no information about the incidence of latex allergens in wood or wood dust.

The allergen proteins have been characterised and the major-allergens were designated Hev b 1, Hev b 3, Hev b 5, and Hev b 6.02. Between 3 and 17% of the public health staff are estimated to be sensitised that means that they could develop allergic reactions by exposure to allergen proteins from the latex sap (Turjanmaa et al., 2002).

At analysis of wood from ***Hevea brasiliensis*** no allergen proteins could be demonstrated.

5.6.1.2 Chlorophora Excelsa, Iroko

Synonyms: Kambala, African teak, moreira, moule morus excelsa, swamp mahogany, rock elm

Numerous publications on respiratory symptoms, incl. allergic alveolitis exist. Potential allergen caused by allergy asthma has, however, not been identified (see paragraph 3.1).

Hausen (1981) lists 6 references, in which iroko has been described as cause of lung symptoms, may be on irritative basis, may be on allergic basis. Iroko has been stated as cause of allergic alveolitis. De Zotti (1996) has in an examination of 7 patients stated iroko as one among more cause of asthma. Azofra and Olaguibel (1989) describe a patient occupational asthma, but without documentation that allergic mechanisms are involved.

5.6.1.3 Dalbergia Latifolia, Sheesham

Synonyms: Indian rosewood, East Indian rosewood, Bombay blackwood, palissandre d'Asie, Asian rosewood.

Dalbergia is a large group of wood species coming from all over the world. Many different species have been described, which can often be difficult to separate. In addition, pao ferro (***Machaerium scleroxylum***) can be difficult to distinguish from dalbergia-species.

No asthma-symptoms or rhinitis seem to be described. Incidence of urticaria and Quincke-oedema quoted by e.g. Woods (1976) can be an indication of allergic reaction of type 1 caused by air borne allergens of protein character (see paragraph 3.1), there are, however, no recent descriptions of it and potential allergen has not been identified.

5.6.1.4 Gonystylus Bankanus, Ramin

Synonyms: Malawis, melawis

Hausen (1981) describes in 3 reports asthma, caused by ramin, which may be allergically caused (e.g. Howie et al., 1976). In excess a case of Hinojosa et al. (1986) is described, in which an antibody-mediated reaction seems to exist. Hausen (1981) states ramin to cause allergic alveolitis. There is, however, no published information about the identification of allergen protein in the wood dust from ramin, even though the incidence of allergic lung symptoms and contact urticaria could indicate this.

5.6.1.5 Intsia Bijuga, Merbau

Not mentioned by Hausen (1981) or Mitchell (1979).

5.6.2 Allergic Skin Symptoms

5.6.2.1 Hevea Brasiliensis, Rubber tree

There were no published information in the screened literature about contact allergic eczema or contact urticaria (see paragraph 3.1) to the wood of ***Hevea brasiliensis***, as no contact allergens in the wood was described. Natural rubber latex products made of the sap have on the contrary caused contact eczema (Sommer et al., 2002).

In some of these cases it was an undeclared content of natural rubber latex sap of the well-known allergen accelerators etc., but allergy towards the latex sap has also been described without such hidden amounts of accelerators have been demonstrated. It is possible that real contact allergens may occur in the sap as known from other species of plants e.g. sesquiterpenes.

In most of the cases, in which contact allergy has been demonstrated towards the latex-sap, it was an IgE-mediated allergy towards natural rubber latex proteins (see above), and it was symptoms in an ” intermediate phase” between type-1 and type-4 allergy, designated ”protein-contact dermatitis” (Janssens et al., 1995).

In an article from 2003 the use of Glycidyl-methacrylate is described to change the timber to increase its strength (Devi et al., 2003). Glycidyl-methacrylate is as other derivates of methacrylate described as allergen (Lepoittevin and LeCoz, 2000). It is unknown, whether the described method has been used in practice.

5.6.2.2 Chlorophora Excelsa, Iroko

Synonyms: Kambala, African teak, moreira, moule, morus excelsa, swamp mahogany, rock elm.

The wood contains chlorophorin, which has shown to be a moderately strong allergen (Hausen, 1981). The allergen consists of two components, maybe isomers and only one of them is allergen. Contact urticaria has not been described.

Mitchell (1979) refers to an epidemic in Breslau in 1910 in persons, who processed the wood. In excess, Mitchell has listed 20 later publications on sensitisation. In newer literature there are more case descriptions (Hinnen et al., 1995; Stingeni et al., 1998).

5.6.2.3 Dalbergia Latifolia, Sheesham

In Dalbergia species more contact allergens are isolated, from strong to weaker allergens. Ranked in order of degressive allergenicity (Hausen, 1981): R-3,4-dimethoxydalbergion, R- and S-4-methoxydalbergion, S-4,4-dimethoxydalbergion, S-4'-hydroxy-4-methoxydalbergion.

Thus ***Dalbergia latifolia*** contains semi-strong R- and S-4-methoxydalbergion and1,4 quinone latinon (Hausen, 1981), and there are numerous publications on allergic contact eczema. Woods (1976) cites publication, in which ***Dalbergia latifolia*** is described as the cause of urticaria in cabinetmakers.

The wood has especially been used for musical instruments, and cases have been decribed of contact eczema towards the chin support of violins, the mouthpiece of flutes and handles of a knife (Hausen, 1981; Mitchell, 1979). Woods (1976) refers to a case of air borne contact eczema in a person, who lived next to a factory that processed ***Dalbergia latifolia***. Other cases of contact eczema have likewise been described about workers processing the wood (Gallo et al., 1996).

Dalbergia nigra is described as the cause of UPPE, a very aggressive, but also of rare occurrence skin reaction probably based on allergy. There is no information that ***Dalbergia latifolia*** could cause a corresponding reaction. There is no information that ***Dalbergia laifolia*** could cause a corresponding reaction.

5.6.2.4 Gonystylus Bankanus, Ramin

Synonyms: Malawis, melawis

Both allergic contact eczema and unusually strong skin irritation have been described. Thus Mitchell (1979) and Hausen (1981) describe that the wood contains some very sharp fibres that can cause irritative inconvenience, in case that they are not removed. These fibres can also cause eye irritation. Reference is only made to isolated cases of contact urticaria, which may also be caused by the irritating sharp fibres.

Two references both report a case of air borne allergic contact eczema (Beck and Roberts, 1982; Bruynzeel and Dehaan, 1987). Hausen (1981) describes a case of eczema, in which the allergen is not safely identified, it states, however, that it may be 2,6 dimethoxy-1,4-benzoquinon. Bruynzeel and Dehaan refuse that this compound could be the cause.

Ramin is in excess mentioned to cause urticaria and eczema by both Mitchell (1979), Hausen (1981) and Woods (1976).

5.6.2.5 Intsia Bijuga, Merbau

Neither Hausen (1981) nor Mitchell (1979) mentions the wood species.

6 Assessment of Emissions

The assessment of potential comfort and health effects from emissions from compounds from products made of exotic wood comprises exposure to inhalation, contact and migration into artificial saliva. The assessment is based on toxicological principles and data from the literature. At the assessment the basis is a typical scenario from the home.

The impact of exotic wood products to the indoor air was assessed by:
A sum of concentrations in the indoor environment, c, divided by "the lowest concentration of interest" (LCI) and an indoor-relevant time-value based on odour and irritation thresholds, see the definition in paragraph 4.7.1.

The assessments of the wood products examined appear from Tables 22-26 and from the summary in Table 27. Results in detail for the quantified individual compounds appear from Appendix C.

6.1 Results

6.1.1 Compounds Emitted to the Air

Table 22 Lacquered dining table, rubber tree (*Hevea brasiliensis*)

Essential individual compounds			Comfort and health assessment					Indoor-relevant time-value [days]
Type of compound	Name of compound	CAS no.	Critical type of effect	LCI [µg/m³]	c/LCI 3 days	c/LCI 10 days	c/LCI 28 days	
Aldehydes	Formaldehyde	50-00-0	Irritation	100	0,58	0,42	0,33	< 3 days on basis of irritation
	Acrolein	107-02-8	Irritation	3	nd	0,67	nd	
Alcohols	2-Methyl-1-propanol	78-83-1	Neurotox	400	0,11	0,06	0,04	< 3 days on basis of odour
	Butane	71-36-3	Irritation	200	0,01	<0,01	<0,01	< 3 days on basis of odour
Hydrocarbons Aromatic	Toluene	108-88-3	Neurotox	400	0,19	0,12	0,07	< 3 days on basis of odour
	Xylenessethylbenzene		Irritation	500	0,14	0,07	0,04	
Glycols	2-Butoxyethanol	111-76-2	Irritation	490	0,11	0,04	0,03	> 28 days on basis of odour
Ketones	Acetone	67-64-1	Irritation	400	0,03	0,03	0,04	< 3 days on basis of odour
Summary: S-values (∑c/LCI) and indoor-relevant time-value					1,2	1,4	0,6	> 28 days on basis of odour

Table 23 Stained Venetian blind, ramin (*Gonystylus bankanus*)

Essential individual compounds			Comfort and health assessment					Indoor-relevant time-value [days]
Type of compound	Name of compound	CAS no.	Critical type of effect	LCI [µg/m³]	c/LCI 3 days	c/LCI 10 days	c/LCI 28 days	
Aldehydes	Formaldehyde	50-00-0	Irritation	100	<0,01	0,03	0,02	< 3 days on basis of irritation
Alcohol's	2-Methyl-1-propanol	78-83-1	Neurotox	400	0,01	0,01	<0,01	< 3 days on basis of odour
	Butane	71-36-3	Irritation	200	0,18	0,13	0,09	< 3 days on basis of odour

Hydrocar-bons Aliphatic	3-Methylhexane	589-34-4	Neurotox	250	<0,01	<0,01	0,02	
Ketones	Acetone	67-64-1	Irritation	400	<0,01	0,05	0,03	< 3 days on basis of odour
Summary: S-values (∑c/LCI) and indoor-relevant time-value					0,2	0,2	0,2	< 3 days on basis of odour

Table 24 Waxed bed table, sheesham (*Dalbergia latifolia*)

Essential individual compounds			Comfort and health assessment					Indoor-relevant time-value [days]
Type of com-pound	Name of compound	CAS no.	Critical type of effect	LCI [µg/m³]	c/LCI 3 days	c/LCI 10 days	c/LCI 28 days	
Aldehydes	Formaldehyde	.	Irritation	100	0,05	0,04	0,04	< 3 days on basis of irritation
Alcohols	Butane	71-36-3	Irritation	200	0,08	0,06	0,05	< 3 days on basis of odour
Hydrocar-bons Aliphatic	3-Methylhexane	589-34-4	Neurotox	250	<0,01	0,01	0,02	
Hydrocar-bons Aromatic	Toluene	108-88-3	Neurotox	400	0,01	0,01	0,02	< 3 days on basis of odour
Ketones	Acetone	67-64-1	Irritation	400	0,01	0,03	0,02	< 3 days on basis of odour
Summary: S-values (∑c/LCI) and indoor-relevant time-value					0.2	0.2	0.2	< 3 days on basis of odour

Table 25 Oiled floor, merbau (*Intsia bijuga*)

Essential individual compounds			Comfort and health assessment					Indoor-relevant time-value [days]
Type of com-pound	Name of compound	CAS no.	Critical type of effect	LCI [µg/m³]	c/LCI 3 days	c/LCI 10 days	c/LCI 28 days	
Aldehydes	Formaldehyde	50-00-0	Irritation	100	<0.01	<0.01	0.03	< 3 days on basis of irritation
Alcohols	2-Methyl-1-propanol	78-83-1	Neurotox	400	0.002	0.002	0.002	< 3 days on basis of odour
	Butane	71-36-3	Irritation	200	<0.01	<0.01	0.06	< 3 days on basis of odour
Hydrocar-bons Aliphatic	3-Methylhexane	589-34-4	Neurotox	250	0.02	0.02	0.02	
Ketones	Acetone	67-64-1	Irritation	400	0.06	0.04	nd	< 3 days on basis of odour
Summary: S-values (∑c/LCI) and indoor-relevant time-value					0.1	0,1	0.1	< 3 days on basis of odour

Table 26 Kitchen table top, iroko (*Chlorophora excelsa*)

Essential individual compounds			Comfort and health assessment					Indoor-relevant time-value [days]
Type of com-pound	Name of compound	CAS no.	Critical type of effect	LCI [µg/m³]	c/LCI 3 days	c/LCI 10 days	c/LCI 28 days	
Aldehydes	Formaldehyde	50-00-0	Irritation	100	0,06	0,04	0,04	< 3 days on basis of irritation
Hydrocar-bons Aliphatic	3-Methylhexane	589-34-4	Neurotox	250	<0,01	<0,01	0,02	
Terpenes	α-pinene	80-56-8	Irritation	250	<0,01	0,02	<0,01	< 3 days on basis of odour
Ketones	Acetone	67-64-1	Irritation	400	<0,01	0,02	0,02	< 3 days on basis of odour
Summary: S-values (∑c/LCI) and indoor-relevant time-value					0,1	0,1	0,1	< 3 days on basis of odour

Table 27 Breakdown of wood materials examined on basis of S-value and indoor-relevant time-value

Classification	Product	Wood species	S-value	Indoor-relevant time-

				value [days]
Medium-emitting material	Lacquered dining table	Rubber tree (Hevea brasiliensis)	0.6	> 28
Low-emitting material	Stained blind	Ramin (Gonystylus bankanus)	0.2	< 3 days
Low-emitting material	Waxed bed table	Sheesham (Dalbergia latifolia)	0.2	< 3 days
Low-emitting material	Oiled floor	Merbau (Intsia bijuga)	0.1	< 3 days
Low-emitting material	Kitchen table top	Iroko (Chlorophora excelsa)	0.1	< 3 days

6.2 Assessment of Emissions of Individual Compounds

By the climate chamber measurements of the 5 examined wood species (with or without surface treatment) 7 individual compounds (iroko), 12 individual compounds (ramin), 14 individual compounds (sheesham), 15 individual compounds (merbau) and 17 individual compounds (rubber tree) were found in the emission. Totally 25 individual compounds were demonstrated by the climate chamber measurements. There were thus more individual compounds, which could be retrieved in more of the products. There were only very few compounds in the emissions from the examined wood species, in which it appeared that health effects of the compounds (cancer, allergy, congenital malformation and nervous system effects) had an effect in relation determination of the LCI-value.

For formaldehyde the effects cancer and irritation had an effect in relation to the total assessment of the emissions. The assessment is for formaldehyde based on recommendations from WHO and is less restrictively determined than all the other individual compounds.

Acetaldehyde has like formaldehyde two significant effects, cancer and irritation, where the irritative effect occurs at significantly higher concentrations than for formaldehyde. The risk of cancer is, furthermore, less documented.

Acrolein is assessed to have both an irritative and allergen effect.

For 2-methyl-1-propanol, 3-methylhexane and toluene the LCI-value is determined on basis of the neurotic effects of the individual compounds in question.

For the remainder individual compounds, the LCI-values are based on their irritative effects, see Table 22-26.

6.3 Assessment of the Total Emissions

The examined products were assessed health-wise by determination of the S-value on basis of LCI-values and on basis of comfort considerations by the indoor-relevant time-value. The comfort effects include odour and mucous membrane irritation.

The assessment of the examined exotic wood species and their potential surface treatment appear from the summaries in Tables 22-26. Values for emission have been measured after 3, 10 and 28 days.

The S-value appears for the individual products on basis of a loading of 0.4 m^2/m^3 corresponding to a wood-based material in a room corresponding to a floor or a table and 6 chairs.

The S-values vary for the 3-days measurement for the 5 products (iroko, ramin, sheesham, merbau and rubber tree) between 0.1 and 1.2, where rubber tree has the highest S-value. (An S-value below 1 is considered to be unproblematic). By the measurements on day 10 S-values were found, which for the 5 products varied between 0.1 and 1.4.

Rubber tree still had the highest S-value. The increase in S-value for rubber tree was based on identification of acrolein in the second sample (day 10) and not in the first (day 3). The result of the measurement is safe, it can, however, not be explained, why acrolein was not demonstrated by the first measurement. By measurements after 28 days the values had dropped further. At that time the S-values for all products - rubber tree, too – were below 1.

The stated measurements thus show a picture indicating that emission of individual compounds from the examined exotic wood species or their surface treatments only take place to a limited extent. None of the products will at the stated emission concentrations cause health effects.

Rubber tree is the only product examined which as an S-value, which in the measurement period exceeds 1. The individual compounds important in relation to the calculated S-values, are formaldehyde and acrolein. It is less probable that they are components of the rubber tree itself. There is every probability that they origin from the surface treatment.

The problems in question with the emission from the rubber tree could thus be solved by substituting the surface treatment or leave the product to emit unpacked 1 month before the customer brings it at home.

6.3.1 Compounds emitted by Migration of Artificial Saliva

The assessment of the 3 compounds occurring at the highest concentration in the two specimens and allergen compounds are listed in Tables 28 and 29. These compounds are in this case chosen on basis of an impression that it would give ”worst case” scenario. No information has been found, which describes how much of a wood product a child can consume by sucking or chewing at it.

Table 28 Chemical compounds emitted by migration into artificial saliva from a lacquered table top, *Hevea brasiliensis*

Compound	CAS no.	Concentration [µg/g]	Remarks
2-butoxy-ethanol	111-76-2	171	NOAEL= 30 mg/kg/day (corresponds to µg/g/day), safety factor, SF = 100 TDI = 0.3 mg/kg/day
Phthalic acid anhydride	85-44-9	52	Respiratory- and contact allergen. LOAEL= 1562 mg/kg/day SF = 1000 TDI = 1.5 mg/kg/day
Phthalic acid mono-butyl ester	131-70-4	11.3	TD_{Lo} = 400 mg/kg/day, SF = 1000 TDI = 0.4 mg/kg/day
Vanillin	121-33-5	3.0	Contact allergen

Table 29 Chemical compounds emitted by migration into artificial saliva from an ink treated figure, *Albiz(z)ia falcata*

Compound	CAS no.	Concentration [µg/g]	Remarks
2-butoxy ethanol	111-76-2	5.5	NOAEL= 30 mg/kg/day, SF = 100 TDI=0.3 mg/kg/day

1-methyl-2-pyrrolidinon	872-50-4	41	NOAEL = 300 mg/kg/day, SF = 100 TDI = 3 mg/kg/day
2-phenoxy-ethanol	122-99-6	3.1	TDLo = 3000 mg/kg/day, SF = 1000 TDI = 3 mg/kg/day
Vanillin	121-33-5	0.7	Contact allergen

The determination of compounds migrated into artificial saliva was carried out to assess the intake of compounds, which possibly may occur by children sucking and biting at the products. The examination was carried out by migration to 25 ml artificial saliva, as described in paragraph 4.5.

In this context the LCI-values can not be used. In stead calculations of TDI-values have been carried out. TDI (Tolerable Daily Intake) states the amount of chemical pollution, which a human being daily can consume through an entire life without constituting a health risk and the value is determined on basis of the knowledge, which is available on the toxicological properties.

On basis of the toxicological examinations the highest dose is determined, which does not cause demonstrable harmful effects in the most sensible animal species (NOAEL). The safety factor, SF, is normally 100, but in the cases, where no NOAEL is available, but only LOAEL (the lowest dose, which can cause a demonstrable harmful effect) and TD_{50} (the dose, which is toxic to 50% of a species) the factor has been determined at 1000 or higher. TDI has only been calculated for the 3 compounds occurring in the highest concentration in the 2 examined specimens.

As appears from the following calculation none of the compounds will occur in concentrations exceeding the TDI-value. In a worst case calculation it is estimated that a child weighing 10 kg, consume the entire amount of saliva from 1 gram specimen a day. For 2-butoxy-ethanol 171 µg/g specimen was found corresponding to 171 µg/10 kg body weight/day, which corresponds to 0.017 mg/kg/day. The TDI-value for 2-butoxy-ethanol is 0.3 mg/kg/day.

None of the compounds (in 1 gram test material), which occur in concentrations that exceed the calculated TDI-values, see Tables 28 and 29. On the contrary compounds occur in both the products, which are listed on the list of The Danish Working Environment Service for allergy and sensitivity producing compounds in the working environment, including vanillin and phthalic acid anhydride.

Generally, it is considered inappropriate that products emit allergy-producing compounds.

Furthermore, it is considered inappropriate that phthalates such phthalic acid monobutyl ester and diethylphthalat are emitted from the products.

The problem is, of course, of most importance, if the products are used to store food (salad bowls, chopping boards, kitchen table tops etc.) or if they are used for purposes, in which they will get into close and long contact with the skin e.g. musical instruments or trinkets.

In Denmark the use of phthalates in toys and articles for small children is limited to a maximum concentration of 0.05% (w/w). This can be used as a restrictive comparison, as infants hardly suck at exotic wood articles to the same extent as at toys.

The demonstrated concentrations of phthalates are significantly below 0.05%.

For products, which might get into contact with food, the accepted maximum concentration varies depending of the type of phthalate and is between 1 and 60 mg/kg, corresponding to 1-60 μg/g (Fabech, 2003). It must, therefore, recommended that exotic wood articles (or other articles) if used for storage or in contact with food are not surface treated with other compounds than those appearing from the Positive List of the Danish Veterinary and Food Administration (BEK 111 af 20/2 03 om materialer og genstande bestemt til kontakt med fødevarer) (***Statutory Order no. 111 of 20/2 2003 on materials and articles for contact with food)***.

6.4 Health Assessment of Elements

An overall health assessment of the demonstrated elements has been carried out. Compounds, the concentration of which is below the detection limit, have not been assessed. The assessments have been carried out as ingestion assessments, which is a restrictive method, as provisions thus are made for the use of the products i.e. food e.g. a salad bowl.

At assessment the monographs EHC (Environmental Health Criteria) and JECFA (Joint Expert Committee on Food Additives) (www.inchem.org). The different values for acceptable or tolerable intake is not directly comparable, as some have been determined as provisional or as maximum values, while others are not.

Boron (B): 801 ± 7 mg/kg: The estimated daily intake from food is 1.2 mg, from drinking water 0.2-0.6 mg/litre. The tolerable daily intake is 0.4 mg/kg body weight.

Cadmium (Cd): 0,128 ± 0,002 mg/kg: The estimated daily intake from food is 0.001-0.004 mg. A provisionally tolerable weekly intake of 7 mg/kg body weight has been determined.

Copper (Cu): 2,7; 9,9 mg/kg: The estimated daily intake from food is 2-5 mg. A provisional maximum tolerable intake is 0.05-0.5 mg/kg body weight.

Manganese (Mn): 21.3 ± 0.6 mg/kg: The estimated daily intake from food 2-9 mg, 10-50 microgram/day from drinking water1-10 mg/day is considered to be acceptable.

Lead (Pb): 1.25 ± 0.15 mg/kg: A provisional tolerable weekly intake of 50 mg/kg body weight has been laid down.

Zinc (Zn): 15.1 ± 1.3 2 mg/kg: The estimated daily intake from the food is 8,8-14,4 mg. A tolerable intake of 0.3-1 mg/kg body weight has been laid down.

The only compound exceeding the limits for tolerable daily intake is boron. Taking the content into consideration it would be critical to use ***Hevea brasiliensis*** without surface treatment, if the wood has been treated with a boron containing fungicide.

6.4.1 Assessment of Risk of Allergic Reactions

When processing wood the exposure to wood dust could cause irritative, unspecified reactions from both skin and respiratory system.

Among the 5 Selected wood species ramin must be considered to be more skin and airway irritating than the other four ones.

Allergic reactions in airways can be seen at exposure to iroko and ramin.

Allergic contact eczema can especially be seen in contact with iroko and sheesham and, presumably to a less extent to ramin.

Considering the fact that we have only one product of ***Hevea brasiliensis***, products made of this material do not seem to present risk to persons, who are allergic to natural rubber latex.

7 Concluding Discussion

7.1 Compounds found in the Emission

For the examined products made of exotic wood (with or without surface treatment) only minor amounts of chemical compounds were found in the emission at the climate chamber measurements.

Totally 25 individual compounds were demonstrated at the climate chamber measurements, out of which more of the individual compounds could be identified in more of the products. There is every probability that a part of these compounds origins from the surface treatments of the products in question.

For only very few compounds in the emissions from the wood species examined the health effects of the compounds (cancer, allergy, congenital malformation and nervous system effects and other effects) became of importance in relation to the determination of the LCI-value.

The examined products have been assessed in relation to health by determining the S-value on basis of LCI-values and on basis of comfort considerations of the indoor-relevant time-value.

The S-values vary the 3-days measurements for the 5 products (iroko, ramin, sheesham, merbau and rubber tree) between 0.1 and 1.2, where rubber tree has the highest S-value. By the measurements on day 10 S-values were found, which for the 5 products varied between 0.1 and 1.4. Rubber tree still had the highest S-value.

By the measurements on day 28 the values had dropped further. At that time the S-value for all products - rubber tree, too – was below 1 (An S-value below 1 is considered to be unproblematic).

The stated measurements thus show a picture indicating that emission of individual compounds from the examined exotic wood species or their surface treatments only to a very limited extend takes place. The obtained S-values and indoor-relevant time-values are based on a material loading, which for most of the products would be an absolute “worst case”. Nevertheless, none of the products would at the scenario stated imply health effects.

Rubber tree is the only examined product, which has an S-value, which during the measuring period exceeds 1. The individual compounds important in relation to the calculated S-value are formaldehyde and acrolein. It is less plausible that they are constituents of the rubber tree itself. There is on the contrary every probability that they origin from the surface treatment.

The results of the examination thereby shows that the examined untreated exotic wood species have the same low emission as the untreated wood species oak, beech, and ash, which were examined in Environmental Project no. 501 (The Danish Environmental Protection Agency, 1999).

The problems in question with emission from rubber tree could be solved by changing the surface treatment or by leaving the product to emit unpacked for 1 month, before release to the consumers.

The emission of chemical compounds from the products has been very low. An explanation to this could be that exotic wood species are imported from geographical area, in which the relative humidity frequently is much higher than is the case in Denmark. By a drying process a major part of the compounds is expected to emit. At the same time some of the surface treatments will contribute to encapsulate the compounds in the wood and thereby limit the emission.

7.2 Compounds found by Migration into artificial saliva

None of the compounds found occur in concentrations that exceed the calculated TDI-values. In return compounds occur in both products, which are listed on the list of the Danish Working Environment Service for allergy and sensitising compounds including vanillin and phtalacidanhydride.

It is generally assessed that it is inappropriate that allergen compounds from the products in question are emitted, it is also inappropriate that phthalates such as phtalacid monobutyl ester and diethylphtalate are emitted from the products. The problem is of most importance in case the products are used for storage of food (salad bowls, chopping boards etc.) or if they are used for purposes, in which they get in close and long contact with the skin e.g. musical instruments or trinkets.

It is, therefore, generally suggested that exotic wood products (or other products), which have not been surface treated with other compounds than those appearing from the positive list of the Ministry of the Food, Agriculture and Fisheries, if they are used for storage of food or in close contact like e.g. chopping boards and kitchen table tops. At the same time it must be recommended that rubber tree is not used without surface treatment, if the wood has been treated with boron fungicides. It will most probably be hard to obtain complete information about the products, which at the place of origin have been used as fungicide.

It should be noted that the results presented in the report solely concern the products examined and they should only be considered as based on random samplings. The results obtained are, therefore, not representative for the respective wood species or for exotic wood in full.

7.3 Risk of Allergic Reactions

Processing of wood can imply exposure to wood dust, which may cause irritative, unspecified reactions from skin and airways.

Among the 5 examined wood species ramin should be considered to be more skin and respiratory irritation than the other 4. Allergic reactions in airways can be seen by exposure to iroko and ramin. Allergic contact eczema can especially be seen from iroko and sheesham, and, probably to a less extent from ramin.

Considering the fact that we have only examined one product made of rubber tree, products made of this type do not seem to present a risk to persons, which are allergic to natural rubber latex.

7.4 Future Examinations

In this project 10 Selected products have been examined for the emission of chemical compounds, out of which only 5 have been subjected to a quantitative analysis of the emission in climate chamber. The project, therefore, only gives limited information about the emission of chemical compounds from consumer products made of exotic wood.

The project, however, demonstrated that it on basis of the examined wood species/products could be interesting to carry out further examinations of products made of rubber tree (Hevea brasiliensis) – especially when the wood species is used for toys or products getting in contact with food. This requirement is based on the results of the project concerning compounds found in the wood itself and compounds emitted from the surface by migration.

A lot of exotic wood species exist, which have not been treated in this project and which widely are used in the residences. We find that it could be interesting to analyse these wood species in a similar project.

By future analyses it is essential to test both untreated wood and wood with a surface treatment.

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