





ID: WOOD

Clustering knowledge, Innovation and Design in the SEE Wood Sector

n.1 Thematic Dossier Furniture

WP5: Transnational knowledge clustering www.idwood.eu

Foreword
Furniture industry : standards, safety, performance (A. Giavon, F. Bulian) Introduction
1. European consumer requirements (clear and embedded)
2. Genesis EN standards and other deliverables
 3. Assessing safety by means of EN. 3.1 Mechanical safety requirements 3.1.2 European Legislation and Standards 3.2 Chemical Safety 3.2.1 Wood 3.2.2 Wood based panels 3.2.3 Covering materials 3.2.4 Coating materials 3.2.5 Other materials
 4. Assessing performance by means of EN
5. Present practice and perspective of these themes in the area studied
Innovations: applications of new materials in furniture (M. Petrič) Introduction
1. Applications of Nanoparticles in Furniture and Other Wooden Products UsedIndoors.24
2. Self healing polymers
3. New Wood Based Materials for Production of Furniture

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foreword

With a surplus of quality forest resources and a strong tradition in woodworking, the SEE area has yet to take advantage of the significant potentials in the wood sector. The development dynamics of the sector have not been homogeneous, and the area is characterized by a dual spatial pattern - some of the territories have managed to develop their potential to excellence levels, whilst others are still struggling to fine tune the right support approach to the sector. Considerable disparities in terms of innovation and technological capacity hamper trade and investment flows.

The main objective of the **ID:WOOD Project** is to foster the innovation and competitiveness of SMEs in the wood manufacturing sector in the SEE area by networking and sharing technical and organizational know how in order to enable local support organizations (wood clusters, wood technology centres and RDAs) to address the organizational and technical deficits in the production sector. Pooling the experiences and know how of territories which have reached levels of excellence in the wood sector, and promoting cooperation between support organizations and local knowledge poles (universities and design centres) should accelerate the catching up process in terms of innovation capacity and human resources development.

A transnational network of wood sector support centres/experts which has been set up within the framework of the ID:WOOD Project is bestowing a synergic approach in order to promote the sharing, integration and transfer of the necessary know how. This approach should not promote simply cooperation, but also the complementarities and synergies between the territories in order to prevent any unnecessary overlapping of initiatives and investments in support structures which do not appear to be very rational in times of increasing budget constraints.

The present **Thematic Dossier** is part of a series of 5 technical dossiers produced by the wood sector experts involved in the ID:WOOD Project: 3 dossiers are each dedicated to one of the sub-sections of the wood sector (Sawmill, Construction Material, Furniture), 1 is dedicated to organizational aspects of the sector (Clustering), and 1 is dedicated to the transnational technical assistance provided to partners and SMEs by international experts. The aim of the dossiers is to provide partners, stakeholders and SMEs with an insight into some of the relevant technical aspects for the sector, and to strengthen the knowledge flow between the different reference centres, the stakeholders and the SMEs.

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Furniture industry: standards, safety, performance



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Introduction

The scope of this "furniture" dossier within the ID:WOOD Project is to depict the European scenario in which furniture is positioned from the technical, normative and legislative points of view, and how these factors, amongst others, are driving the sector towards the future. This is with respect to the current situation of the countries studied in order to try to propose a useful approach to the market (European or otherwise) to the related relevant companies.

It is understood that there are no magic solutions to the various problems, only a possible change of perspective on all of these issues.

Anyway, there are also a lot of chances and challenges for the countries involved in the ID:WOOD Project. In fact, there is a considerable richness in raw material (i.e. :), but the potential development is still hindered by many problems of a varying nature (technology, knowledge, education, information exchange both within the countries and amongst them etc.).

The topics of this dossier focus mainly on the technical aspects, from all perspectives, that the furniture industry has to face nowadays, i.e. consumer needs, standards, laws, and all of the interconnections among all these different aspects.



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1. EUROPEAN CONSUMER REQUIREMENTS (CLEAR AND EMBEDDED)

Furniture has a history almost as long as that of mankind. It has always been one of the centres of human expression, both from the point of view of work (that is, as a handicraft product first and then as an industrial product), and as an object of artistic expression. In both cases, examples are both numerous and widely known.

For these "historical-cultural" reasons, furniture has become a subject so intimately linked with human kind that it has become a reality inseparable from our daily lives. Let's just try to think about the diversity of our reactions when faced with a furnished room (even if only with a chair), and when faced with an unfurnished room.

In the second case, most of the time we will use the term 'empty', i.e. lacking the content to which we attribute a greater importance than the container itself. In other words, more closely to the terminology which we are used to, and we can say that furniture is a consumer product. This approach has also been taken by the lawmakers of Europe.

It must be stressed absolutely that this categorization is by no means a reduction of the importance of or a trivialization of furniture, but is a point of view which defines a specific perspective which is essential in order to understand the current scenario, and therefore to design and if possible predict the future.

There is no doubt that over the last decades, the overall awareness of consumers of furniture has increased to such a large extent that, as desired and outlined by the EU Council in the eighties, it has completely changed the scenario in which furniture is now positioned from both normative and legislative points of view.

It is widely known and accepted that we, as consumers, have a certain number of expectations when buying a piece of furniture.

Without running the risk of "creeping into" the various psychological aspects of this complex matter, we can summarize them in two main categories:

- those which are related to the use of the furniture by the user without any major unexpected risks
- those which are related to the function of the furniture.

We call the former the safety of the furniture, and the latter the performance of the furniture.

We will now more fully explain these concepts by means of some examples.

It is unlikely that the user thinks that a chair may overturn or collapse under his/her body weight. This is not expected to happen, even after use over a certain period of time. The same expectation also applies to other pieces of furniture like, for example, a cabinet: the experience of a cabinet tipping over whilst opening the doors is one of the most frightening experiences we can have, and it is certainly unexpected.

When we move onto children's furniture, the expectations are even more rooted in the concept of safety because of its use by a category of people who deserve a high level of protection.

Moving onto something more "invisible" or "less visible" than the above and looking at what may be called "chemical risks", we face another "parallel universe".

Formaldehyde emission has been an issue in this respect, and still is when considering the increasing number of cases (in Europe and probably everywhere) of allergic reactions. On top of this, information on VOC emissions is also increasing in popularity, with request for it coming from organizations like big retailers and consumers associations, and everyone in between.

2. GENESIS OF EN STANDARDS AND OTHER DELIVERABLES

Despite its long history, it was only in the fifties that documents first started to contain a description of test methods on furniture and its parts. More or less at the same time, during this decade and in the early sixties, we can find examples of documented test methods developed by large furniture companies such as Steelcase in the U.S. and IKEA in Sweden.

As we said previously, the interaction between human beings and furniture is very intimate, and this makes the dynamics of these interactions (the scientific method) extremely complex, dense and infused with not only predictable known phenomena, but also with infrequent and less well known phenomena which must be taken into account.

Until the late eighties, all European countries involved in the production of furniture developed a large number of separate national standards concerning furniture (testing and various requirements) and its supply chain.



Then the TC 207 was established within CEN and now, after 25 years of activity, almost all types of furniture are in one way or another covered by the relevant standards.

Now, it's worth giving a brief description of the types of documents that CEN produces about products.

For the purposes of this document, those relevant to furniture deliverables are the following:

European Standard (EN)

standard adopted by CEN/CENELEC and carrying with it an obligation of implementation as an identical national standard and withdrawal of conflicting national standards

Technical Specification (TS)

document adopted by CEN/CENELEC for which there is the future possibility of agreement on a European Standard, but for which at present

- 1. the required support for approval as a European Standard cannot be obtained,
- 2. there is doubt as to whether consensus has been achieved,
- 3. the subject matter is still under technical development, or
- 4. there is another reason precluding immediate publication as a European Standard.

Technical Report (TR)

document adopted by CEN/CENELEC containing informative material which is not suitable for publication as a European Standard or as a Technical Specification

Obviously, the EN is the most demanding deliverable issued by CEN, especially because of its binding status in the EU (it has also the status of a national standard), but we want to underline that TS and TR already existed, and have to be taken into account because of their "advanced front line" position in what is a fast developing "state of the art". In the case of furniture, there are few of these documents, but all are worthy of careful reading.

European standards on furniture have to be seen and considered as a very often invaluable tool to the proper design of products taking into account all the needs from the user's point of view and from those deriving from the producer's side. All of this is in an equilibrium which allows production/buying processes at a reasonable effort and price. It is well know, from the experiences of the most advanced furniture companies (both large and small), that when using standards (even if they are not perfect) at a design level and merging them with the imagination of the designer, results can be quickly achieved in terms of market feedback. This has been the case since the early beginnings of the "technical standards era" and is still so to a large extent (in order of magnitude) today.

As we will see later, within the complex scenario of European legislation (starting from the New Approach Principle in the eighties), there are also other meanings and uses of standards, but the use outlined above should be, in our opinion, the main one in terms of "quality" and also from the point of view of a sustainable approach (as an example, see the Work program of CEN/TC 350).

As shown in annex 1 (published list of CEN deliverables), all end uses of furniture are widely covered by EN standards (or other deliverables) ranging from terminology, dimensions, test methods and safety to performance.

3. ASSESSING SAFETY BY MEANS OF EN

The safety of furniture has always been an important issue for the most advanced standardization bodies. Since the mid-seventies, safety has been quoted in numerous national standards (e.g. DIN BS, NF, UNI, etc.) in many European countries. To a certain extent, the same increasing focus on this matter can also be found in the USA (e.g. ASTM and ANSI), even if there were and still are quite a few differences between the two sides of the Atlantic.

Obviously, there were also many differences amongst countries within Europe, but as far as furniture is concerned, the very complex and sometimes rather difficult process of drafting EN standards started in 1989 with the setting up of CEN/TC207 "Furniture". Since the very early beginnings, a strong recommendation from



CEN has been to give safety the highest priority. It was very soon realized that this assigned task was far from easy for many reasons, but certainly one of the most objective reasons was the lack of accessibility of data on incidents.

There is no doubt that every kind of scientific process needs to start from experimental data and, as a consequence, the lack of this makes the job very difficult and uncertain. As might be remembered, the internet did not exist in the late eighties, so case data was limited only to paperwork which was frequently forgotten on dusty shelves or in the library of some "pioneer" consumer group. For example, in the mid-nineties, the Italian Institute of Statistics (ISTAT) published a booklet concerning incidents in the domestic environment which had been reported during the previous decade. Its analysis contained details from those years, but unfortunately it was never updated. At this time, other papers reporting data of incidents could be found in the UK (e.g. glass in furniture studies) and in the USA with publications issued by the CPSC (Consumer Product Safety Commission). Anyway, the production of safety standards continued, ranging from children's furniture to domestic and office furniture. Then, the internet started to connect people and to spread information about incidents throughout the world.

On top of this epochal change in disseminating information, the DIRECTIVE 2001/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 3rd December 2001 on general product safety (also known as GPSD) was published in 2001, and hence the safety of all consumer products became an obligation under law. After that, in February 2004, the RAPEX website was launched and once again the scenario of consumer products, including furniture, was radically changed.

Roughly twenty years after the USA, Europe also has its own organized system to monitor products and related incidents. Since then, nothing has been the same, and things have started to evolve at an unexpected rate. Nowadays, this "connected world" and its tools allow us to know almost everything about what happens relating to incidents unless the disclosure of information is stopped by the authorities, as in the case of fatalities. Nevertheless, even in these cases, the raw data is public and more and more often this has an enormous impact on both the standardization work and the legislative work.

As previously said, the complex system involving multiple relationships - products–consumers, producers– standards, and laws - is rapidly evolving and as a consequence, it is essential to set down some markers in order to produce and use safe products, namely furniture, which is still a well known hallmark of Europe.

3.1 Mechanical safety requirements

When dealing with the safety requirements of furniture (excluding chemical aspects), it is a widely shared experience amongst all countries that have dealt with the matter that the mandatory topics to take into consideration are the following:

- general design requirements (i.e. the shape of corners and edges)
- holes, gaps and openings
- shear and squeeze points between moving parts
- stability
- strength
- durability

All types of furniture, despite its end use (i.e domestic, office, contract etc.), has a safety standard that covers the above mentioned list, even if the individual elements carry a different "weight".



In order to clarify the meaning and importance of the elements in the list, a table with the relative hazard is shown below:

Table 1

N°	Торіс	Type of hazard	
1	Edges and corners	Cuts	
2	Holes, gaps and openings	Entrapment of body parts (limbs, head, neck), asphyxia	
3	Shear and squeeze points	Pinching of body parts, entrapment of limbs	
4	Protruding parts	Entrapment, snagging, asphyxia	
5	Stability	Overturning of the furniture, falling, body crushing, positional asphyxia	
6	Strength	Sudden structural failure under foreseeable high load, falls, cuts, bruises, entrapment	
7	Durability	Structural failure due to normal loads applied many times, falls, cuts, bruises, entrapment	

The data shown below, in all its crudeness, and the author's experience, indicates that children's cabinets are the type of furniture that is most frequently involved in accidents, especially in domestic areas. The main causes are related to elements number 2 and 5, entrapment of body parts and stability.

3.1.1 European Safety Standards

All types of furniture now have their own safety requirements and related test methods within European standards. Seating, tables, cabinets (named storage units) and children's furniture are fully covered by EN standards. A complete list can be found on the CEN website [7] or via the National Standards Bodies databases under the key code "furniture".

It is useful to give some examples of how these documents work in order to better understand their usefulness and how they can be an invaluable support in the production of mechanically safe furniture.

In all of the safety standards, one of the first sentences in each sounds like this: "Edges and protruding parts accessible during normal use shall be rounded or chamfered and free of burrs and sharp edges."

This is a subjective evaluation that many times in the past was very controversial. Figure 1 shows two edges, one sharp and the other rounded. The statement may seem obvious, but every furniture manufacturer knows the consequences in terms of processes and costs in moving from one type to another. Endless discussions with producers about this topic are part of the everyday experience of the author.

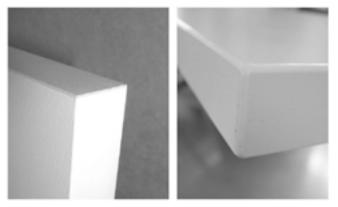


Fig. 1

As described above, another crucial safety requirement is the one concerning gaps and openings. From the data described in the previous clause, it is evident that serious incidents involving children relate to suffocation/ strangulation or limb entrapment. The work carried out on this aspect of furniture (for both children and adults)

is one of the long term issues, and it is still undergoing constant improvement and evolution in Europe and also in the USA. Various measuring probes, simulating parts of the body like fingers, arms, head, torso etc., are used (with or without force) in order to verify, according to a pass/fail criteria, the gaps in furniture. Figures 2, 3 and 4 clearly show the measurement procedure. It is absolutely necessary and advisable to consider these dimensional requirements at the design stage of furniture; changing a particular design which does not meet these requirements on an existing production without doubt leads to modifications which can be very complicated and sometimes almost impossible.









Fig. 3

Fig. 4

It is quite clear that stability is perhaps the main issue for the safety of cabinets, especially in the domestic environment. This matter has a long story within the area of standardization (within Europe and also outside of Europe). Seating and tables are provided with well-established test methods for stability. In contrast, methods are constantly evolving and improving in the case of cabinets. The incidents reported previously, which happened in Denmark and Italy, clearly show that the job is not yet complete. Figures 5 and 6 illustrate how this requirement is verified in a lab.

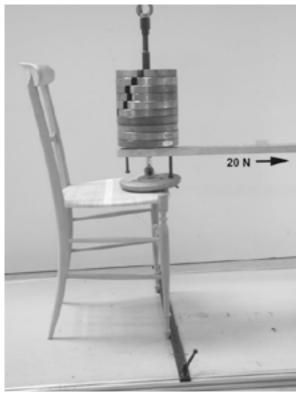






Fig. 6

Strength and durability are usually tested together even if, as shown in table 1, they cover two quite different interactions with the furniture. The European approach is to apply a certain sequence consisting of static and fatigue testing on the very same furniture sample. This requirement (and the relative test methods) is the oldest within standardization, and is therefore the one which is best consolidated. Figure 7 shows a fatigue test for chairs.

Instructions for use, including the necessary warnings, have become a fundamental requirement of which a critical analysis by standardization, furniture manufacturers and ultimately by consumers is still necessary. As described below, the relevant legislation has placed particular emphasis on this point.

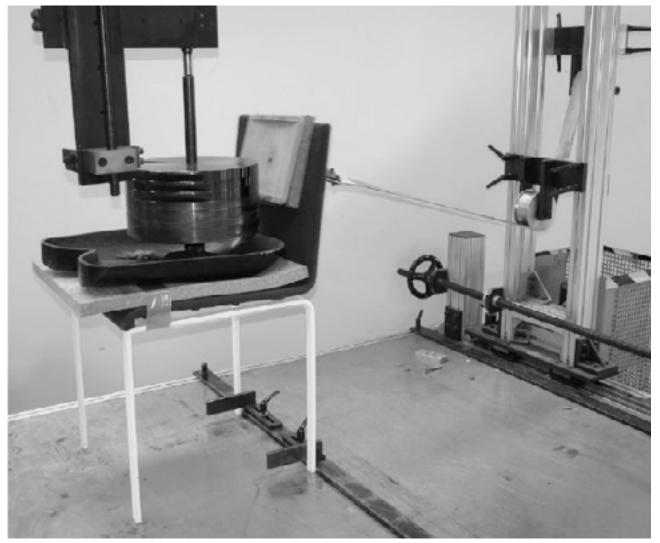


Fig. 7

The contents of instructions for use has been debated for quite a long time within CEN working groups, and enormous progress has been made. How to make instructions clear to the consumer is still a topic of discussion.

3.1.2 European Legislation and Standards

Furniture (with very few exceptions, i.e. low voltage devices fitted internally) is not covered by any "vertical" European Directive but, as a consumer product, is regulated by the General Product Safety Directive [8]. Article 3 clearly explains the relationship between the law and standards, either in the case of these which were published in the OJEU (paragraph 2), or in the case of standards not in that list.

Art. 4 (1)(a) of the Directive [8] was amended by:

M1 Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008,

and

M2 Regulation (EC) No 596/2009 of the European Parliament and of the Council of 18 June 2009

and states the following:

"(a) the requirements intended to ensure that products which conform to those standards satisfy the general safety requirement shall be determined by the Commission. Those measures, designed to amend non-essential elements of this Directive by supplementing it, shall be adopted in accordance with the regulatory procedure with scrutiny referred to in Article 15(4)". This means that it is up to the Commission to decide (publishing their



Decisions in the OJEU) which products shall have a mandate to the relevant TC in order to draft the standard quoted in article 3. This is a relatively new attitude from the Commission which started, for our products, after the results of the study on child-related products in 2006. Following a priority list in 2010, the Commission Decision (2010/376/EU) on the safety requirements for products within children's sleeping environments was published and consequently, in 2011, a mandate on mattresses was given to CEN/TC207. This year, a similar mandate on children's seating and tables is expected. Anyway, the work has already started within WG2, and a draft mandate has been circulated within the CEN.

3.2 Chemical Safety

A wide range of materials and technologies are used by the furniture industry. Wood, wood based panels, covering materials, adhesives, coating materials, metals and plastics are the most frequently used but, within each individual category, a large variety of products exist with different compositions and properties.

Standardization and legislation on safety aspects related to possible chemical risks are continuously evolving all over the world. Many examples are already well known and have become important references for the purchasing and selling departments of every furniture manufacturer: REACH, VOC directive, Decorative paint directive, CARB (formaldehyde), Consumer Product Safety Act (USA), IKEA IOS-MAT, Toys regulations (also covering children's furniture), are only some examples of the wide range of existing references which should be considered.

3.2.1 Wood

The furniture sector is closely related to the wood products sector and, although modern industrial production has introduced other materials, this sector remains traditionally characterized by the activities of carpenters. The success of wood comes primarily from its high availability and workability, and from the positive properties granted to the finished product, such as mechanical strength and lightness.

Being a natural material, wood is very often considered "organic", safe for workers and end users. This assumption is, however, not always accurate as there is objective and substantial evidence that using solid wood requires some precautions. It is well known that certain extractives which are present in some specific wood types may be the cause of irritant dermatitis and respiratory problems of various types [1] during the processing phases. In particular, it should be taken into consideration that the wood dust of certain hardwoods has been classified as a carcinogen (Class 1) by IARC the International Agency for Research on Cancer [2].

Biodeterioration is one of the major weaknesses of this natural material, and is frequently counteracted with the use of treatments with different chemicals which exhibit a preservative function. Such substances, especially those used in past years, can very often be dangerous for humans.

The safety of wood for the end user should also consider the possible content of substances like Pentachlorophenol (PCP) and other chemicals of various natures.

PCP, first produced in the 1930s, is an organochlorine compound which is very effective in wood preservation but its use has recently declined due to its high toxicity and slow biodegradation. Contact with PCP can irritate the skin, eyes and mouth, and can also affect the liver, kidneys, blood and nervous system in the case of prolonged exposure [3]. IARC, the international agency for research on cancer, has classified PCP as possibly carcinogenic to humans (Group 2B) [4].

This substance is considered in the CE marking of building products like wood floorings and panels [5] - the presence of PCP should be declared if above a limit of 5 mg/kg.

Restrictions on PCP and other preservatives in wood used for furniture production are included in the specifications of some international retailers [6] and furniture certification schemes [7].

Radioactivity

Radioactive decay is the process by which an atomic nucleus of an unstable atom loses energy by emitting ionizing particles and radiation. There are different types of radioactive decay, depending on the specific emission produced: alpha (helium nucleus), beta (electrons or positrons) and gamma (high energy photons). The Becquerel (Bq) is the unit of radioactivity. One Bq is defined as the activity of a quantity of radioactive

material in which one nucleus decays per second.

Such emissions are called "ionizing radiations" as they carry enough energy to alter atoms and molecules producing highly reactive chemical species like radicals and ions.

Such interactions can be especially harmful in the case of living organisms particularly because they can interact with DNA, altering its complex chemical structure. A consequence of such a mechanism, the most common impact for humans when exposed to high radiation levels, is the possibility of cancer induction with a latent period of years or decades after exposure.

Nuclear accidents (e.g. Chernobyl) have consequently led to highly dangerous contaminations of air, water and soil by different radioactive isotopes, and also amongst the negative effects, forests have been strongly affected due to the absorption and persistence of such dangerous isotopes within trees.

Timber and derived products from such areas can consequently contain high levels of radioactive isotopes, which should be carefully considered.

Radioactivity concentration levels in materials below 1 Bq/g are usually not considered necessary to regulate against even if specific limits for the different isotopes have been taken into consideration [8]. Precautionary limit values and procedures for wood and related materials deriving from certain areas, particularly those affected by nuclear disasters, have been published by some international furniture retailers [6].

3.2.2 Wood based panels

The use of panels is an effective way of exploiting wood resources as it allows for the use of materials which are not directly suitable for other purposes such as sawdust, twigs and also, in some cases, recycled wood. The resin used to bind the different type of unitary elements (particles, fibres, veneers, etc.) and "recycle wood" are the main sources of concern in terms of chemical safety for such fundamental raw materials.

Formaldehyde emission

The problem of formaldehyde emission from wood based panels has been affecting the world furniture market for many years. Almost all wood based panels are made with urea-formaldehyde or similar thermosetting adhesives. Formaldehyde, as a consequence of complex chemical mechanisms (hydrolysis), may be released into the environment for long periods of time where the wood based panels have been placed. This substance is considered dangerous to human health for its possible effects on the respiratory tract in both the short and long term. Formaldehyde is an extremely volatile substance, small enough to easily penetrate the human body through the respiratory tract. Its first effect is the irritation of eyes even at very low concentrations in the air, although individual susceptibility is very broad. Because of its high solubility in water, the irritant effect of formaldehyde primarily affects the upper respiratory tract, being felt particularly in the nose and throat. In sensitive or particularly exposed people, the effects can become chronic.

In 2006, IARC, the International Agency for Research on Cancer, published a monograph [10] which stated that formaldehyde had been classified as carcinogenic to humans. This evidence explains why many countries have imposed legal restrictions on the emission of this substance, which also directly considers wood based panels as structural elements of building materials and furniture.

In many European countries, only panels classified as E1 are allowed. This classification means that formaldehyde emissions do not exceed the limit of 0.124 mg/m³ (0.1 ppm) recommended for living environments in 1996 by the World health Organisation. Compliance with the limit should be verified by a test method called the chamber method (EN 717-1) which simulates a real indoor environment.

Other countries and US states (Japan, California, China, etc.) have established similar or in some cases lower limits, but the present scenario is strongly affected by the advice of the IARC mentioned above, and possible further limitations are expected soon worldwide.

Contaminants from "recycled wood"

Particleboards are usually produced from raw material which has been derived directly from logs, twigs and sawdust. However, in addition to "virgin" wood, it is even possible to use wood recycled from the disposal of



furniture, building elements, or packaging.

Consumption of recycled wood is growing, especially in Italy where it exceeded 1.800.000 tons [9] in 2007.

The use of recycled wood can be considered a sustainable process because it follows the principle of ISO guide 82 "the needs of the present are met without compromising the ability of future generations to meet their own needs".

In any case, recycled material can contain harmful substances which have been derived from the treatment of the original wood with various type of preservatives: heavy metals, halogenated organic compounds, or polycyclic aromatic hydrocarbons (creosote) which are known for their toxic, carcinogenic, mutagenic and teratogen properties.

In 2002, EPF, the European Federation of Panel Producers, published an industrial standard [11] which was to be followed by its members in order to establish methods and limits for such harmful substances, as reported in table 1 which follows.

Element/Compound	Limit values (mg/kg recycled wood)
Arsenic	25
Cadmium	50
Chromium	25
Copper	40
Lead	90
Mercury	25
Fluorine	100
Chlorine	1000
Pentachlorophenol	5
Creosote	0,5

Table 1. EPF specification for recycled wood

In addition to the list above, the specifications of international retailers and the previously mentioned certification schemes also include other preservatives, like for example organotin compounds [6, 7]. It should be mentioned here that limitations for organotin compounds can also be imposed on other materials which are used by the furniture sector (e.g. polymeric materials like plastics or coatings) due to their possible use as catalysts in production processes.

3.2.3 Covering materials

Formaldehyde emission

Veneers derived from multilaminar wood are a type of reconstructed (or reassembled) wood. They are produced in a similar way to plywood, but in this case the veneers are superimposed and glued together with parallel grain. Such wood blocks are then sawn or sliced again to produce new veneers.

The success of these materials primarily derives from the ability to mass colour the wood sheets and consequently to produce a large variety of patterns depending on the manufacturing method adopted. Some of these techniques, which may include multiple steps, allow for the reproduction of any kind of wood species, including rare and valuable ones, using cheap and highly available trees.

The adhesive used in the bonding of veneers is normally a thermosetting urea-formaldehyde product. Formaldehyde emission from the finished multilaminar veneer is consequently an important parameter to take into account.

Formaldehyde can also be released by impregnated papers, a covering material frequently used in the furniture sector as cheap substitute for wood veneer. They consist of a base of natural cellulose (paper) which has been impregnated with thermosetting resins. The surface of the paper is also coated with a protective layer.

Impregnated papers are normally printed with the pattern and colour of the required wood species. They are



also produced as monochrome paper with the required decorative effect.

The appearance of impregnated papers has been progressively improved by modifying the production process, and has now achieved an extremely high level in the reproduction of the complex grain and texture of various wood species, including the effect of three-dimensionality which is typical of the porosity of the material reproduced. The resins used for the impregnation of papers are normally urea-formaldehyde and melamine-formaldehyde, frequently in combination with other resins (e. g. acrylics) to confer flexibility to the sheet.

The possible presence of UF resins can result in high levels of formaldehyde emission, especially in the case of large surfaces.

Official limits for formaldehyde emission from covering materials have not yet been defined, but references based on experimental studies can be found in the specifications of some furniture retailers [6].

Heavy metals

Lead and cadmium stabilizers are common additives used in the formulation of polyvinyl chloride (PVC) and other polymeric materials, especially so in the past. This plastic is broadly used as covering and edging material in the furniture sector, especially in the case of the 3D process for kitchen doors which is carried out with membrane presses.

These metals act as stabilizers, protecting PVC from chemical degradation due to heat or ultraviolet radiation. Moreover, lead pigments such as lead chromate are also used to impart the desired colour to the plastic.

Both metals are harmful to many organs and tissues. In particular, lead interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behaviour disorders [12]. Many young children typically try to eat small things that are not food (this tendency is called "pica"), but eating chips of material containing lead represents a particular hazard for children.

Moreover, inorganic lead compounds are classified by IARC as probably carcinogenic to humans (Group 2A) [13].

Limitations for Pb in plastics have been established in many countries, especially for materials which come into contact with food, and also for toys and other articles. According to EU rules (REACH), applications to use lead chromates must have been authorised by November 2013, and they can no longer be used or placed on the market after 2015.[14]

In this case, examples of limitations for furniture are also present in some standards, legal documents and in the specifications of international retailers [15, 6, 7].

Phthalates

Phthalates, esters of phtalic acid, have been the most common plasticizers used in plastics for many years, but recently their use has been strongly restricted due to safety reasons connected with REACH.

REACH (Registration, Evaluation, and Authorisation of Chemicals) is the main general European chemicals regulation. Chemical producers and importers must provide data to the European Chemicals Agency on the substances which they produce or import in order to establish the possible risks resulting from their production and use. The legislation also includes restrictions on the use of certain chemicals due to safety reasons.

Some low molecular weight phthalates, including di-butyl phthalate (DBP), bis 2-ethylhexyl phthalate (DEHP), benzyl butyl phthalate (BBP), di isobutyl phthalate (DIBP) have been considered by the European Agency in terms of their reproductive and developmental toxicity. These low phthalates were consequently included on the REACH Candidate list of Substances for Authorisation due to their EU hazardous classification [17].

The inclusion of phthalates on the "candidate list" means that any EU manufacturer or importer of an item containing more than 0.1% of these phthalates must notify the European Chemical Agency. In addition, the manufacturer or importer must provide information to all of the supply chain about the content of such substances in the item.

Possible further limitations for phthalates have already been published [14] or are expected in the future.

Consequently, REACH is strongly affecting the use of phthalates in plastics used by the furniture sector, particularly raw materials and semi-finished or finished products coming from non-EU countries.



3.2.4 Coating materials

Heavy metals

The term heavy metal, which does not have a real scientific basis, is commonly used to identify some toxic metals and semi-metals.

In the furniture sector, the heavy metals of particular concern are those defined by European standard EN 71 which specifies safety requirements for toys, the field of application of which has been extended to also include children's furniture. The presence of such elements can be primarily derived from pigments, but also from some additives used in the formulation of coating materials.

In particular, part 3 of EN 71 (the migration of certain elements) defines a test method simulating the ingestion of coating particles by children, verifying the possible dissolution of such toxic elements in the gastric fluids.

8 such metals, reported in table 2, can affect amongst other things, the central nervous system, the kidneys, the liver, the heart and other organs.

Element/Compound	Limit values (mg/kg)
Antimony	60
Arsenic	25
Barium	1000
Cadmium	75
Chromium	60
Lead	90
Mercury	60
Selenium	500

Table 2. Heavy metals	specified in EN 71-3
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Moreover, the USA Consumer Product Safety Commission has declared that paint and similar surface-coating materials for consumer use, including furniture, in which the lead content is in excess of 0.06 % of the weight of the dried paint film, are banned hazardous products [16].

Emissions of volatile organic compounds from finished products

All coating materials, including solvent based, water borne and photocuring products, always contain volatile substances as ingredients in their formulations. These compounds do not completely evaporate during the drying process, and consequently a certain amount remains trapped within the dry film. This means that all coated products slowly release volatile organic compounds into the indoor environment in which they are placed (homes, offices, schools, etc.).

Several factors influence the amount of solvents and other volatile substances present inside a coated surface, for example:

- the amount and type of solvents present in the coating materials used for the specific coating system;
- the application rate;
- the drying method and process;
- the maintenance of the plant.

Considering the variables mentioned above, the VOC emission of a particular coated element could be high even in the case of coating systems based on products with a reduced amount of solvents, such as high solids or water borne coatings.

In some specific cases, certain substances, which are characterized by strong odours such as benzaldehyde, are formed as a result of the complex chemical reactions taking place during the drying phase of photocuring products.

It should, however, be noted that solvent emissions tend to gradually but continuously decline over time.



The alarm toward such emissions, frequently referred as "indoor pollution", has particularly increased in recent years. The presence of volatile organic substances in the air of living spaces is often associated with certain diseases (e.g. allergies), or at least with a reduction in quality of life as a consequence of feelings of discomfort, this also touches the psychological aspects of human life. This subject is becoming particularly relevant to the different national bodies which are responsible for the protection of human health.

Presently, there are no legislative or regulatory documents on VOC emissions from furniture surfaces.

Limits for VOC emissions can be found only for building materials as a result of two different laws recently approved in France [19] and Germany [20].

Voluntary certifications such as the German RAL UZ 38 [7] are the only examples of limit values for finished furniture. They usually consider the highly dangerous substances (carcinogenic, teratogen and mutagenic) separately, and the overall emission of other organic compounds.

At EU level, a technical committee of CEN, the TC351, is responsible for establishing test methods and limits for harmful substances potentially released from building materials.

3.2.5 Other materials

Fabric and other flexible materials used for furniture upholstery should not contain azo-dyes as some of them can release aromatic amines which are particularly toxic for humans. The EU banned such substance in 2003 [14].

Also, foams used in furniture upholstery are considered for potentially containing dangerous monomers (isocyanates) and expanding agents (e.g. CFC).

There are also limitations for other materials (e.g. nickel in metals, chromium VI in leather, and so on) which have been specified by international retailers or voluntary certification schemes [6, 7], but it should be carefully noted that the list of chemicals considered here is in constant evolution, with the inclusion of new substances, and with revisions to the values of present limits.

4. ASSESSING PERFORMANCE BY MEANS OF EN

4.1 The mechanical performance of furniture

For those of us who have a long history in furniture, the matter of performance returns with a cyclicality of more or less every ten years.

The Italian standardization on furniture which was developed in the '80s was focused purely on the performance aspects of furniture, and its part in a system where there was room for all (price) segments, from the cheapest to the most expensive (the famous five levels of UNI). It was more or less the same in the UK (BS standards on furniture, i.e. tables, seating, cabinets) and also at ISO level.

Then, with the beginning of European Standardization (CEN), attention has for over twenty years been focused on safety and test methods. Now that this has been achieved (i.e. there is a set of dedicated technical standards) in many areas, there is a growing need for a quantitative assessment of aspects related to performance/ functionality.

We cannot go into the varied and complicated aspects of this crucial topic, neither do we have the teaching approach or the time span required during a classroom course, but starting from what has already been done, we want to briefly define the normative (eg. European Standards) framework, and then to draw some considerations to start a fruitful discussion for the industry in the area studied.

No word other than "performance" has been so debated in both the areas dedicated to Standards (UNI, ISO and CEN), and those areas outside of this area, such as those that develop in the complex relationship between conception, design, production, sales and the after sales of furniture.

After years of discussions, it has now been accepted that the term 'performance' is intended to cover the strength and durability of furniture.

In other words, what is meant by this term is the "functionality" of the furniture and its parts. As a first approximation, we should consider the performance as a further step above the minimum safety level.



However, it is also recognized that the boundary between safety and performance is not always so clear and distinct, and that sometimes the two concepts have overlapping areas.

To get an idea of the system we are considering, let's focus on the most common furniture, that is - chairs, tables and cabinets.

Aside from in the professional field where furniture is considered as equipment, in domestic and contract use, we first of all note that we have some common standards regarding the test methods.

EN standards exist for the intended use of contract furniture and for all three types of furniture, which, in addition to safety, also define the performance (i.e. strength and durability) within a system of levels (two or three) depending on the severity of use.

This approach is important as it establishes in an indirect way that, at least within the contract field of application, product differentiation may exist which, although based on the severity of use, identifies different productions and markets.

For the moment, there is not a similar situation for domestic use, despite Danish and Italian requests within CEN for a similar document (on storage units). The other European countries have not expressed a similar interest.

A huge range of possibilities is then open for defining the performance criteria for domestic furniture, critical for this sector, both in Europe (more difficult at the moment), and also at a national level (much easier). There is the example of contract furniture, and this can and should be taken into serious consideration. If we add to this the fact that the various EN standards on the hardware of furniture are also graded into two or three levels according to severity of use (and hence performance), it is clear that the "body of standards" is complete as a tool to use for this purpose.

Finally, if we add to this that the wording of the requirements (what we are willing to accept as a defect after the relevant test) is crucial to the definition of performance, then we realize that the chances of qualifying the functionality of the furniture are real and ready. Let's take a simple example: if, after a vertical load test on a door, we require that the door does not fall, we have defined a safety requirement. If, after the same test, we also require that the door continues to perform its intended function, then this is also a performance requirement.

It is therefore clear that, from the point of view of the mechanical characteristics, there is an enormous opportunity to define and measure the performance of furniture.

Given the above, there is the need for an important moment of reflection by the "furniture system" concerning the area studied.

It is now clear that the crisis which we have suffered has become a status that has given rise to a different market from the previous one. We are convinced that the furniture sector in the areas studied still has a lot to say and to hear, and still has several options available in order to gain its role in Europe. But, this goal must by necessity pass through a concept and a practice of "measure" that demonstrates that the product is different when compared to other products. A quality which has not been measured is not long lasting, and will lose the battle in the price war.

Shiny catalogues and fairs will always be there. Now is the time to give substance to the technical product, and this is the purpose of the performance standards. Safety shall be met by default, performance gives reason to the industrial effort and realizes the added value of the product.

4.2 The performance of furniture surfaces

Coating characteristics

Degradation factors affecting furniture surfaces in interior environments can be considered to be a consequence of the normal actions carried out by people during their daily lives inside houses, offices or other living spaces. They can either be accidental events, such as an object falling, or continuous stressing factors, such as surface cleaning. There are several test methods simulating degradation effects affecting coated surfaces during real use. They can be broadly sub-divided into three groups:

- mechanical tests (impact, scratch, abrasion);
- physical tests (light, climatic variations, heat);
- chemical tests (contact with liquid substances e.g. accidental spillage).



The various national and international standardization committees very often define test methods for coated surfaces by considering the final use of a particular product, but not its composition. Moreover, performance requirements are generally not directly included in the standards. The "philosophy" of some standardization committees is to prepare specific tools (technical test methods) but to leave the definition of requirements to the market.

Within the furniture industry, similar tests are applied to all types of finishes including laminates and polymeric foils, as well as to liquid coatings. It is the finished substrate combination that is tested, not the coating itself. In other cases, the test methods are integrated with other standards that define specific performance requirements.

Such standards are frequently divided into further parts establishing different performance requirements depending on both the final use (e.g. in kitchens, bathrooms, bedrooms, etc.), and on the horizontal or vertical orientation of the surface, assuming that the former tends to be more stressed than the latter.

4.2.1 Gloss

The fraction of light reflected by surfaces is called the reflectivity. The amount of reflected light depends on the nature of the substrate and on the incident angle of the rays. The way in which the rays are reflected is associated with the perception of shininess and brilliance.

The reflected light may be concentrated at angle numerically equal to the angle of the incident ray, or scattered in all directions. Between these two extremes, called "specular" and "diffuse", there are many possible intermediate distributions. The directional reflecting properties of a surface are described by the term "gloss", the definition of which is "visual impression deriving from the reflection properties of the incident light onto a surface of a coating material" according to the international standard ISO 2813.

4.2.2 Adhesion

Adequate adhesion is a fundamental requirement of good coating performance and will affect all resistance and durability properties. Adhesive performance is a measure of the forces needed to separate surfaces (and thus is normally a destructive test).

In the case of wood, the dimensional variations of the substrate, in response to humidity exchanges, play an important role in causing the coating to become strained. The internal stresses generated are often a determining factor in the origin of spontaneous detachments.

One of the most common test methods for investigating adhesion performance is described by the ISO 4624 Pull-off test for adhesion in which stress is applied perpendicularly to the coated surface. Another method is described by the international standard ISO 2409 Paint and varnishes - Cross cut test.

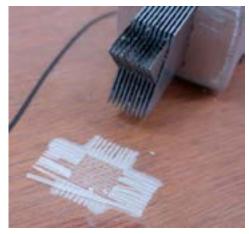


Figure 4.1 Cross-cut test

4.2.3 Hardness

Hardness can be defined as the ability of a surface to resist indentation or penetration by a solid object. In the case of coating materials, hardness also depends on the state of dryness, solvent retention and, for chemical



drying coatings, on cross-linking effectiveness. The efficiency of the drying system is therefore fundamental in achieving adequate hardness.

The hardness of a coated surface is a significant parameter in determining the behaviour of the coated product during its transportation, manufacture and use. A soft surface can be problematic and prone to marking by packaging or general handling. Common operations carried out at the end of the coating process (e.g. stacking of components) or during transportation can cause problems.

It should be specified that the overall hardness of the surface also depends to some extent on the mechanical behaviour of the substrate.

Hardness influences many different properties of the final product, such as the resistance of the surface to impacts, scratches and abrasion effects.

ISO 15184 describes a method used to assess the hardness of organic coatings using a series of pencils with leads of known hardness. Pencils are made with leads which range in hardness from 9H (very hard) to 6B (very soft). The test equipment consists of a set of 17 pencils being used manually or by means of a special holding device.



Figure 4.2 Hardness by pencil test

4.2.4 Resistance to scratching

Scratch resistance is not uniquely defined, ranging from marring for optical defects, to friction, wear, erosion, abrasion and cracking for mechanical defects (see for example EN 15186). The result is expressed, according to the cited method, with a strength which expresses the minimum load required to "scratch the surface" or to otherwise produce a scratch "visible" or of a certain size.





Figure 4.3 Resistance to scratching

4.2.5 Resistance to abrasion

Abrasion can be defined as the effect of scraping or rubbing exerted on a surface by natural or artificial means. The result depends on the ability of the surface to maintain its pattern, colour or original aspect under an abrasive action.

Most methods used to evaluate this property, such as the one described by EN 15185, are based on the principle of rotating a test material against two abrasive wheels loaded with a certain weight. The result is expressed by the number of revolutions needed to achieve a certain degree of abrasion.

4.2.6 Resistance to impact

Impact tests evaluate the effects of accidental contact damage which may occur during use. They are usually carried out by a direct evaluation of the effect of an object, sphere or dart of specified shape and hardness falling onto the tested surface from different heights.

4.2.7 Resistance to heat (wet and dry)

Tests on resistance to heat are carried out in order to evaluate the effects produced by contact of the surface under investigation with a hot object. It is a simulation of possible common actions which happen frequently within a domestic context, where the placing of a hot object (e.g. a cup of tea or a hot pot) onto a furniture surface (table) is a very common.

There are also special methods interposing a wet textile between the two surfaces. Such type of tests, called "resistance to wet heat" are usually more severe as the effects of hot water (or vapour) may lead to discolouration or halo effects. The existing test methods regarding furniture surfaces are the following:

EN 12721 Assessment of surface resistance to wet heat;

EN 12722 Assessment of surface resistance to dry heat.

4.2.8 Resistance to changing climates

Climatic variations can be the origin of different defects in coated surfaces. One effect is the dimensional movement of wood as a consequence of moisture variations. Also, the expansion and contraction of coating films in response to temperature fluctuations can be observed. Consequently, climatic variations can potentially cause tension between the two materials to become critical, especially in a case where there's an inadequate level of flexibility in the coating films.

There are several methods which aim to evaluate the effects of temperature and humidity on finished furniture elements.

The Italian standard UNI 9429 Resistance to temperature changes, for example, is based on 15 thermal cycles between + 50 ° C and - 20 ° C.

A further problem frequently observed is the colour change of coated elements when exposed to moderate temperatures (e.g. 50°C) for a long time. This phenomenon is associated with the use of certain types of additives (photoinitiators) or resins which are particularly sensitive to oxidative phenomena (e.g. oil based alkyds).

The sinking effect, being the decline or loss of the specular effect of high gloss surfaces, is accelerated by prolonged exposure to moderate temperatures (e.g. 50 °C).

4.2.9 Light fastness

Light resistance is defined as the ability of a coated surface to maintain its aspect unaltered under the action of sunlight filtered through glass. Natural substances imparting colour to wood, or the colourants added to a coating product, could be altered as a consequence of exposure to light, producing colour variations which are usually perceived as "appearance defects" by end users. Also, depending on their composition (e.g. polyurethane coatings based on aromatic isocyanates), the colour of organic coating films can be altered by the effect of photochemical processes induced by light.



Figure 4.4 Test specimen after the light fastness test.



The upper part was exposed to light, whilst the lower surface was protected as reference.

In the case of opaque paints, colour changes induced by light can only be considered as being derived from the photodegradation of the coating components (binder or colouring substances). However, the discolouration of clear coated surfaces is more complex, depending on additional factors which include:

colour change of wood substrate itself;

degree of protection of the coating film towards the substrate.

Fastness to light is assessed by means of complex devices equipped with xenon lamps. Special filters are used for reducing the IR and UV portion in order to make the irradiated spectrum similar to sunlight filtered through glass. At the end of the exposure period, the duration of which depends on the irradiation specifications, the colour change of the exposed sample is evaluated in comparison with a non-exposed reference.

Standard ISO 11341 - Paints and varnishes - Artificial weathering and exposure to artificial radiation - Exposure to filtered xenon-arc radiation describes the general principles for the artificial weathering of coating systems, both for interior and exterior use. In addition to this standard, EN 15187 specifies a test method for furniture surfaces.

4.2.10 Chemical resistance

The chemical resistance of a coated surface can be defined as its ability to maintain its appearance unaltered when subjected to the action of certain chemical agents under specific conditions.

The standard EN 12720 Resistance to cold liquids, describes a method to evaluate the effect of common products (acetone, tea, coffee, detergents, etc.).

5. PRESENT PRACTICE AND PERSPECTIVE ON THESE THEMES IN THE AREA STUDIED

The area studied in the project includes the following countries (from West to East):

Slovenia, Croatia, Hungary, Bosnia, Serbia, Bulgaria and Romania.

As can be seen, it comprises a very large area of EU and non-EU countries. From the above considerations, this is a difference that should be taken into account for the reasons below:

- the technical standardization scenario is different (see part 2 of this dossier)
- the legislative framework is radically different, e.g. GPSD in the EU, national laws in the other countries.

As far as the product (furniture) is concerned, these differences may be not crucial, but the behaviour of the respective internal markets and the request from EU countries in the case of exports will definitely be different.

From a technical point of view, all of the countries listed above seem to consider the EN standards on furniture to represent the real "state of the art" on the matter. In our opinion, this is a very important milestone in the communication procedure which is one of the targets of the ID:WOOD Project.

There are many different levels from which to approach the subject of the safety and performance of furniture (in the complete aspects described in the previous clauses), but in all cases there is a strong self-consciousness of the actual industry situation, and high market demands.



In the cases of all of these countries, the feedback from the market is that safety (including in fire), performance and the high quality of the finishing are what are being asked for, for the time being. Looking at the annex (list of European deliverables on furniture), it is very clear how the deliverables are the main tools in achieving the desired goal.

There are some examples in all of these countries of companies that have already implemented these processes because of the requirements of their foreign clients (companies and/or retailers). A system of sharing these experiences will, to a very large extent, help the entire supply chain.

In the area studied, one thing that the companies almost all have in common is a great need for knowledge from inside the companies (technicians, skilled personnel), and also from outside (current technology, standards, design demands of the market). There is no doubt that all these needs are closely interlinked, and that solving everything at a glance is wishful thinking, but it is also clear that the starting point is looking at the furniture produced and "measuring" it with the criteria described above.

There are five recognized centres in this area:

- the University of Sopron;
- the University of Zagreb;
- the University of Belgrade;
- Zeda in Zenica;
- Euroinspekt in Slavonski Brod

In a way, they are quite new within the "enlarged" Europe, and for this reason they can and should act as true catalysts in these processes. On top of this, almost all of the countries are quite rich in timber, and this will make them different from the rest of Europe. This is quite true because of the next step in the furniture scenario - that is, sustainability.

In our view, a strong and dense network of these institutions is conceivable in order to enable the furniture industry of the area to find the great knowledge and skills which will allow them all to be economically viable, and so efficient and effective.

It goes without saying that this process needs the support in the long term of the experts and labs located in the neighbouring countries.



REFERENCES

- [1] HSE (2012) Toxic woods, Woodworking Sheet No 30, Health and Safety Executive.
- [2] IARC (1995) Monographs on the Evaluation of Carcinogenic Risks to Humans Wood Dust and Formaldehyde, Volume 62, WHO.
- [3] Fisher B. (1991), Pentachlorophenol: Toxicology and Environmental Fate, Journal of Pesticides Reform Vol. 11, n°1, NCAP.
- [4] IARC (1991) Monographs on the Evaluation of Carcinogenic Risks to Humans Occupational Exposures in Insecticide Application, and Some Pesticides Volume 53, WHO.
- [5] EN 13986 (2004) Wood-Based Panels for Use in Construction. Characteristics, Evaluation of Conformity and Marking, CEN
- [6] Ikea Specification, (2011) Chemical Compounds and Substances IOS MAT 10, IKEA
- [7] RAL (2011), RAL-UZ 38 Low Emission Wood Products and Wood-Base Products, RAL gGmbH.
- [8] Euratom Council Directive 96/29 (1996), The Council of EU: http://ec.europa.eu/energy/nuclear/ radioprotection/doc/legislation/9629_en.pdf.
- [9] European Panel Federation (2009), Annual Report, EPF.
- [10] IARC (2006) Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 88, WHO.
- [11] European Panel Federation (2002), EPF Standard for Delivery Conditions of Recycled Wood, EPF.
- [12] Advisory Committee On Childhood Lead Poisoning Prevention (2012) (http://www.cdc.gov/nceh/lead/ ACCLPP/acclpp_main.htm), CDC.
- [13] IARC (2006) Monographs on the Evaluation of Carcinogenic Risks to Humans Inorganic and Organic Lead Compounds, Volume 87, WHO
- [14] COMMISSION REGULATION (EU) No 125/2012 of 14 February 2012, amending Annex XIV to Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals ('REACH')
- [15] EN 71-3,(1994) Safety of Toys. Part 3: Migration of Certain Elements, CEN.
- [16] Consumer Product Safety Commission (2008), Part 1303 Ban of Lead Containing Paint and Certain Consumer Products Bearing Lead-Containing Paint Federal Register - Volume 73, n° 245, CPSC.
- [17] ECHA (2009): Dibutyl phthalate. Priorisation and Annex XIV Background Information. 14 January 2009. http://echa.europa.eu/doc/consultations/recommendations/prioritisations/priori tisation_dbp.pdf
- [18] Bulian F., Graystone J. (2009), Wood Coatings, Theory and Practice, Elsevier.
- [19] Health-related Evaluation Procedure for Volatile Organic Compounds Emissions (2008) from Building Products, www.umweltbundesamt.de
- [20] Journal Official de la République Francaise, Arrêté du 19 avril 2011 relatif à l'étiquetage des produits de construction ou de revêtement de mur ou de sol et des peintures et vernis sur leurs émissions de polluants volatils.
- [21] http://ec.europa.eu/consumers/dyna/rapex/rapex_archives_en.cfm
- [22] EUROPEAN COMMISSION HEALTH AND CONSUMERS DIRECTORATE-GENERAL Consumer Affairs Product and Service Safety Cords and Chains in Window Coverings - a Hidden Home Hazard Information Event
- [23] http://gazzettadimantova.gelocal.it/cronaca/2011/03/22/news/travolto-in-casa-da-un-mobile-muoreun-bimbo-di-tre-anni-3747413.
- [24] http://milano.corriere.it/milano/notizie/cronaca/12_gennaio_23/como,
- [25] CPSC, 16 CFR Parts 1219-1220-1500, et al. Full-Size Baby Cribs and Non-Full-Size Baby Cribs: Safety Standards; Revocation of Requirements; Third Party Testing for Certain Children's Products; Final Rules)
- [26] Consumer Product Safety Commission Study on Instability and Tipover of Appliances, Furniture and TVs(2010-03) (http://www.cpsc.gov/library/foia/foia11/os/tipover.pdf)
- [27] http://esearch.cen.eu/esearch/extendedsearch.aspx
- [28] DIRECTIVE 2001/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 3 December 2001 on general product safety.

BIBLIOGRAPHY

[1] • Bulian F. (2012), Materials and Technologies of the Furniture Industry, Edizioni Goliardiche.



INNOVATIONS: APPLICATIONS OF NEW MATERIALS IN FURNITURE



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Introduction

A lot of new materials appear on the market literally every day with applications in various "non-wood" sectors, like for example, in the automotive industry or in the IT sector. History is repeating itself: if we look back, some materials and technologies that are nowadays regarded as the key ones in the furniture sector were first utilised in the automotive industries, or in some other branches, and only later came into the wood sector. Some typical current examples are, for instance, nanoparticles and self-healing polymers/coatings. Nanoparticles have already been well introduced into furniture production (e.g. in coatings), but their utilisation could be much wider, e.g. to provide some optical effects (photochromic, luminescent...), refreshing odours, to contribute to decreasing VOC emissions from the furniture materials, or even to clean the air of VOCs in offices, etc.

There is certainly an interest from the furniture producing factories in the region in the introduction of novel materials for new or enhanced furniture functionalities in order to increase their competitiveness on the market. There have already been some attempts to produce furniture with the new materials listed above (for instance, with surfaces with encapsulated refreshing odours, sensitive to external pressure). The other example is the utilisation of thermally treated wood in indoor furniture, for example, in kitchens and bathrooms. Some project applications (e.g. on the inclusion of nanoparticles in furniture coatings to clean the air in offices) are also of interest to the furniture sector for the previously mentioned as well as other innovations.

1. APPLICATIONS OF NANOPARTICLES IN FURNITURE AND OTHER WOODEN PRODUCTS USED INDOORS

Nanotechnology is nowadays regarded as a key technology for the 21st century. Therefore, nanoparticles can be found in various general consumer products (cosmetics, electronic devices, textiles, automotive industry products, even in food, etc.). When nanoparticles are simply added to a product in order to improve some of its selected properties, we speak of a nanomaterial of the 1st passive generation. In this case, it would be better to use the term "a product with added nanoparticles" instead of a "nanoproduct". One of the first sectors in which nanoparticles found an important application was the paint/coating industry. Paints, lacquers and other finishing products for wood based products (furniture, floorings) have been amongst the first in the 1st nanoproduct generation.

a) <u>Nanoparticles in Wood Coatings and/or Wood Surfaces or Wood Based Composites for the Improvement of</u> <u>Various Protective Properties</u>

There are plenty of examples of the utilisation of nanoparticles in wood finishes in order to enhance their mechanical properties such as strength, elasticity, hardness, resistance against impact, and the like. Hardness and resistance to scratching are usually improved with inorganic non-metallic or metallic particles (usually coated) which are dispersed in the coating formulation. Various nanoparticles can be used: nano-ceramic particles, clay, Al_2O_3 , $CaCO_3$, TiO_2 and, particularly frequently, SiO_2 .[1,2]. There are also reports of wax nano-particles in

4 Full professor in the field of Woodworking and Wood Processing Technologies; he teaches on various courses on Surface Finishing of Wood and on Materials. Current research interests: all topics related to wood finishings and wood coatings; most recently, particularly on the application of liquefied biomass for the preparation and characterisation of wood coatings (biorefineries) and the application of nanoparticles for the protection of wood; surface properties of wood, including surface energetic.

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wood coatings improving the effects of other nanoparticles in a finish in terms of both scratch resistance and hydrophobicity of surfaces.[3] The so-called nano-sols, containing colloid particles of silica, may also be utilised to improve the resistance of very soft substrates [4]. In comparison with the conventional dried films, UVcured coatings on wood usually exhibit better mechanical properties. However, these can be further improved with the addition of alumina and/or silica nanoparticles, and their rheological properties can be enhanced by nano-clay additives. [2,5] Chattopadhyay and his co-authors have reported on the dispersion of various nanoextenders, whiskers, clay, etc. into polyurethane coatings.[6] Latex nano particles can also be added to coating formulations, for instance to styrene-acrylic emulsions modified with epoxy resins. [7] Polyurethane coatings were also improved with nanoparticles by Jiang and his co-authors, [8] this time with the addition of CaCO, which, in combination with stearic acid, formed calcium stearate. Montmorillonite, silica and clay are also nanoadditives which should be considered. The effect of alumina and silica nanoparticles on the mechanical, optical, and thermal properties of UV-waterborne nanocomposite coatings was investigated by Sow et al [9], and it was shown that the scratch resistance of nanocomposite coatings was significantly improved. They therefore recommended that silica be used in the wooden furniture and kitchen cabinet manufacturing industry as a nano-reinforcer in order to efficiently protect the surfaces of wood substrates. As shown in another example, in order to solve the weakness of the undesirably low abrasion resistance of a water based wood coating film, modified surface nano-alumina was included in the water based polyacrylate wood coating. [10]

Summarised altogether, nanoparticles offer excellent possibilities for the improvement of the mechanical properties of coated furniture surfaces and flooring. However, despite the fact that flooring lacquers with nanoparticles are commercially widely available and used, this cannot be said of the furniture industry. Therefore, there are good opportunities for furniture producers to fill this gap with their high value added products, thereby enhancing their competitiveness on the market.

b) Fire Retardants Based on Nanotechnology

Grunlan [11] reported on the preparation of an eco-friendly flame retardant nanocoating for the furniture industry. Another example of the improvement of the fire retardancy of wooden products was shown by Devi and Maji [12] who prepared wood polymer nanocomposites (WPNCs) by the vacuum impregnation of wood with styrene acrylonitrile copolymer, modified TiO₂ and SiO₂ nanoparticles, and a nanoclay intercalating mixture. This treatment resulted in remarkable enhancements in wood properties such as flame retardancy, water resistance and anti-swelling efficiency. The presence of TiO₂ nanoparticles in WPNC also exhibited antibacterial activity. Similarly, nano silicon dioxide-wood fiber-high density polyethylene composites were prepared to investigate the effects of nano silicon dioxide on the relationship between flammability and the mechanical properties of the wood fiber-high density polyethylene composites.[13] It was shown that the addition of nano silicon dioxide could decrease the heat release rate, the total heat release, and the total smoke release of the wood fiber-high density polyethylene composites. The improved mechanical characteristics had a positive effect on the fire retardancy of the composites. Taghiyari showed that the treatment of wood with a 200 ppm nano-silver solution, with a size ranging from 20 to 80 nm, had improvement effects on its fire retardant properties.[14]

Looking at the examples cited previously, it is clear that nanoparticles can improve the fire retardant properties of furniture coatings as well as materials that are utilised indoors. Again, this is an opportunity for furniture producers to expand their production portfolio with innovative products.

c) Super Hydrophilic, Superhydrophobic, Self Cleaning and Antistatic Surfaces

Nanoparticles can provide the superhydrophobicity of coatings and the related self-cleaning efficacy (the well known lotus leaf effect!).[1] On the other hand, the self cleaning effect can also be achieved by the photocatalytic activity of TiO₂ nanoparticles (which is again, in the case of the treatment of glass properties achieved in combination with super hydrophobicity, based on nanoparticles [1]). Apart from self-cleaning/ hydrophobic furniture surfaces, the treatment of textile materials used in furniture with nanoparticles should also be considered: Textor and Mahltig[15] prepared hydrophobic sol-gel coatings for textiles that exhibited water repellency as well as antistatic properties. Similarly, textiles with nanotechnology based coatings yielding anti-static and water/oil repellent properties simultaneously were also prepared.[16] Antistatic and "anti-dust" coatings with doped nanoparticles of SnO₂, In₂O₃ or ZnO were also reported.[17]

d) Antibacterial Surfaces for Furniture and Flooring

Nanoparticles can also provide antibacterial properties to furniture surfaces [18], for instance melamine resin surfaces containing nanoparticles of silver, copper, platinum, and also MgO or TiO₂. Silver nanoparticles



are particularly well known for their antibacterial properties, for instance when applied in 2 K waterborne polyurethane coatings.[19]

e) The Influence of Nanoparticles on Colour and Other Optical Properties of Coatings

So-called chromogene materials have optical properties and colours that are dependent on the energy supplied to the material: light (visible or UV), electrostatic charge, heat, mechanical burden, etc. Relative to this, photochromic, electrochromic, thermochromic, mechanochromic etc. coatings are known.[1] Luminescent particles in coatings, which glow in dark, could also be interesting in terms of the production of innovative furniture. Luminescent properties can be assured by the inclusion of Eu containing nanoparticles[20,21], and also ZnO[22] and some other components.[23]

g) Decreasing of the Emission of Formaldehyde and Other Volatile Organic Compounds from Furniture

Nanoparticles provide the important possibility of a decrease in formaldehyde emissions from the wood composites which are used in furniture. For instance, the urea formaldehyde and melamine urea formaldehyde resins, which had been used to produce particleboard and plywood panels, were reinforced with various nanomaterials at different loading levels. The formaldehyde emissions of the composite panels decreased after reinforcement with nano SiO₂, nano Al₂O₃, and nano ZnO materials at proper loading levels.[24] The same effect is exhibited by nanoclay in oriented strand boards (OSB).[25] Similarly, carbon nanomaterials can also be applied to the manufacture of wood-based building materials in the solid state and paint/adhesives in the liquid state in order to reduce emissions of formaldehyde and volatile organic compounds (VOCs).[26]

2. Self healing polymers

Another example of innovative materials (coatings) in the furniture industry are self healing finishes which were introduced from the automotive sector. [27,28] When a scratch is formed on such a surface, it disappears after some exposure to UV light or heat. Several mechanisms are available to achieve such an effect. Microspheres can be included in the coating which break when a crack or scratch occurs, chemicals flow into the void thereby patching it up. Alternatively, special chemicals may be added which form cross-links in the coating when exposed to UV or heat.

3. New Wood Based Materials for the Production of Furniture

The modification of wood is a process whereby wood is exposed to increased temperatures in the absence of oxygen, or reacts with chemicals that change the chemical structure of its constituents.[29,30] Modified wood has many advantageous properties: increased dimensional stability and resistance to wood fungi and insects, lower thermal conductivity, it becomes a darker colour, its equilibrium moisture content is lower than that of non-modified wood, but it has somewhat lower mechanical properties. Thermally and also chemically modified wood is in commercial production nowadays, and is mainly used in exterior applications such as for fences, cladding, decking, etc. Indoor applications are less frequent – it is mainly used for parquet flooring. However, its previously mentioned properties offer many possibilities for the production of furniture which is to be used in more demanding conditions like in kitchens and bathroom. There have already been some attempts to produce kitchen and bathroom furniture from modified wood, including furniture like wooden wash bowls. But it is also believed that this material offers plenty of additional options for interior furniture.

Another two types of novel wood based materials that should be considered for the production of furniture and other wooden elements for indoor applications are densified [31,32] and surface densified wood[33]. Densified wood is obtained by thermo-hydro mechanical treatment what means that wood (usually of a low density like poplar for instance) is exposed to increased moisture and temperature, and simultaneously compressed. A high density wood with improved mechanical properties is thereby obtained. Surface densified wood is similar, but in this case only one surface is densified, and the bulk retains its original properties. Again, both types of materials can find applications in the production of high added value furniture, especially in wood floorings in the case of surface densified wood.



REFERENCES

- [29] M.F. Ashby, P.J., Ferreira, D.L., Schodek. (2009) Design Environments and Systems. Nanomaterials, Nanotechnologies and Design, Elsevier, Amsterdam.
- [30] V. Landry, B. Riedl, P. Blanchet. (2008) Progress in Organic Coatings, 61, 76-82.
- [31] K. Schulte, M. Gilsbach. (2005) Polymers Paint Colour Journal, 195, 64-68.
- [32] B. Mahltig, C. Swaboda, A. Roessler, H. Böttcher. (2008) Journal of Materials Chemistry, 18, 3180-3192.
- [33] S. Stojanovic, F. Bauer, H. Gläsel, R. Mehnert. (2004) Materials Science Forum, in Progress in Advanced Materials and Processes: Proceedings of the Fifth Jugoslav Materials Research Society, 473-478.
- [34] D.K. Chattopadhyay, K.V.S.N. Raju. (2007) Progress in Polymer Science 32, 352–418.
- [35] J-Q., Qu, H-Q. Chen. (2004) 24, Suppl., 109-112.
- [36] •, Y.C. Lam, K.C. Tam, D.T. Li, J. Zhang. (2006) Polymer Bulletin, 57, 575–586.
- [37] C. Sow, B. Riedl, P. Blanchet. (2011) Journal of Coatings Technology and Research, 8, 211-221.
- [38] L. Long, J. Xu, X. Wan. (2013) Journal of Polymer Engineering, 33, 767-774.
- [39] J.C. Grunlan. (2013) Advanced Coatings and Surface Technology, 26, 4(1).
- [40] R.R. Devi, T.K. Maji. (2013) Wood Science and Technology, 2013, 47, 1135-1152.
- [41] P. Mingzhu, L. Hailan, M. Changtong. (2013) Journal of Composite Materials, 47, 1471-1477.
- [42] H. R. Taghiyari. (2012) Wood Science and Technology, 46, 939–952.
- [43] T. Textor, B. Mahltig. (2010) Applied Surface Science, 256, 1668–1674.
- [44] T. Textor, B. Mahltig. (2010) Materials Technology, 25, 74-80.
- [45] F. Ott, J. Patzlaff, R. Rüger. (2006) Polymers Paint Colour Journal, 196, 28-30.
- [46] A. Kandelbauer, P. Widsten. (2009) Progress in Organic Coatings. 65, 3, 305–313.
- [47] M. Akbarian, M.E. Olya, M. Ataeefard, M. Mahdavian. (2012) Progress in Organic Coatings 75, 344–348.
- [48] H. Ziqun, H. Zhang, J. Guo, J. Wang, Y. Chen. (2013) Polymer Engineering and Science, 49, 1273.
- [49] V. Buissette, M. Moreau, T. Gacoin, T. Le Mercier, J.-P. Boilot. (2004) Organic and Nanocomposite Optical Materials. Symposium (Materials Research Society Symposium Proceedings Vol.846, 171-176), Boston, MA, USA.
- [50] V.A. Nikitenko.(1992) Journal of Applied Spectroscopy, 57, 783-798.
- [51] L.D. Carlos, R.A.S. Ferreira, V. de Zea Bermudez, S.J.L. Ribeiro. (2009) Advanced Materials, 21, 509–534.
- [52] Z. Candan, T. Akbulut. (2013) BioResources, 8, 3590-3598.
- [53] A. Salari, T. Tabarsa, A. Khazaeian, A. Saraeian. (2012). Journal of Wood Science, 58, 513-524.
- [54] J.-H. Lee, S. Kim. (2012) Energy and Buildings, 46, 56-61.
- [55] H. Fountain. (2009) New York Times, Late Edition (East Coast), 17 Mar 2009, D.3.
- [56] E. Tejada, M. Almato, B. Vega, M. Melchiors, M. Mechtel. (2010). Environmentally Friendly Self-Healing Polyurethane Systems for Wood Coatings. 7th International Woodcoatings Congress, PRA, Amsterdam 2010.
- [57] B.M. Esteves, H.M. Pereira. (2009) BioResources, 4, 370-404.
- [58] S. Kumar (1994) Wood and Fiber Science, 26, 270-280-
- [59] O. Skyba. (2009) Wood Research, 54, 1-18.
- [60] P. Navi, F. Girardet (2000) Holzforschung, 54, 287-293.
- [61] A. Kutnar, L. Rautkari, K. Laine, M. Hughes. (2012) European Journal of Wood Products, 70, 727–734



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