Life Cycle Comparison of Floor Covering Materials: Vinyl Covering and Laminated Parquet Covering

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ABSTRACT

Floor covering materials have an important role for building and decoration sectors. Functionality, economy and esthetical factors sustain the options for floor covering material production. Vinyl covering and laminated parquet are the most preferable floor covering materials for their economical and easy caring functions. In this study, Life Cycle Assessment (LCA) methodology was used to compare two floor covering materials; laminated parquet and vinyl covering. Functional unit was selected as 1 m^2 floor covering and the regarding data was evaluated by CML2 baseline 2000 method that included by SimaPro 7.0. Evaluation was conducted under four impact categories; abiotic depletion, global warming, human toxicity and acidification.

Keywords: Life Cycle Assessment, Laminated parquet, Vinyl covering, SimaPro 7.0

Yer Kaplama Malzemelerinin Yaşam Döngüsü Karşılaştırması: Vinil Kaplama ve Lamine Parke Kaplama

ÖZET

Yer kaplama malzemeleri yapı ve dekorasyon sektöründe önemli bir yere sahiptir. Fonksiyonellik, ekonomi ve estetik faktörler yer kaplama malzemesi üretimindeki seçenekleri belirlemektedir. Vinil yer kaplama ve lamine parke ekonomik ve kolay kullanılabilir olmaları nedeniyle en çok tercih edilen yer kaplama malzemeleridir. Bu çalışmada, lamine parke ve vinil yer kaplamasından oluşan iki yer kaplama malzemesi Yaşam Döngüsü Değerlendirmesi (LCA) yöntemi kullanılarak değerlendirilmiştir. Fonksiyonel birim olarak 1 m^2 yer kaplama seçilmiş, veriler SimaPro 7.0 yazılımı kullanılarak CML2 baseline 2000 yöntemine göre abiyotik kaynakların tükenmesi, küresel ısınma, insanlar üzerine olan toksisite ve asidifikasyon olmak üzere dört etki kategorisinde değerlendirilmiştir.

Anahtar Kelimeler: Yaşam Döngüsü Değerlendirmesi, Lamine Parke, Vinil Yer Kaplaması, SimaPro 7.0

1. INTRODUCTION (GİRİŞ)

As concern over the environmental impacts of residential house construction grows, many researchers are beginning to use life cycle assessment as a means to quantify natural resources consumption, and emissions of global greenhouse gases.

In every country, the construction industry is a major contributor to socio-economic development and also a major user of energy and natural resources. Building construction industry consumes 40% of the materials entering the global economy and generates 40–50% of the global output of greenhouse gases and the agents of acid rain. It is therefore essential to involve the building construction industry to achieve sustainable development in the society. Life cycle assessment (LCA) is a very helpful tool in this regard that not only provides an account of materials and energy involved in a product or system but also measures the associated environmental impacts (Bishop, 2000).

The objective of this study was to assess the environmental impact of laminated parquet and vinyl floorings over their entire life cycle, excluding the use phase since lack of data.

2. LIFE CYCLE ASSESSMENT (LCA) (YAŞAM DÖNGÜSÜ DEĞERLENDİRMESİ)

Life cycle assessment is a process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment: to assess the impact of those energy and materials used and releases to the environment and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity,

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encompassing, extracting and processing raw materials, manufacturing, transportation distribution, use, re-use, maintenance, recycling, and final disposal. The stages of the LCA were given in Figure 1.

LCA is a technique for assessing the potential environmental aspects associated with a product (or service) by compiling an inventory of relevant inputs and outputs, evaluating the potential environmental impacts associated with these inputs and outputs, and interpreting the results of the inventory and impact phases in relation to the objectives of the study (Asif et.al. 2007).

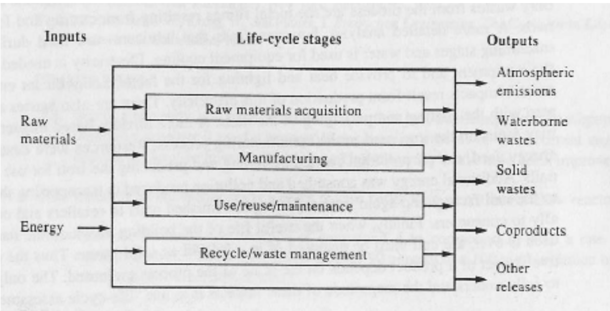

Figure 1. Stages of LCA (Bishop, 2000)

3. MATERIAL AND METHODS (MATERYAL VE METOT)

The methodology of LCA generally consists of four steps as follows.

Goal definition and scoping

This component consists of defining the purpose of the study and its scope, establishing the functional unit and establishing a procedure for quality assurance of the study.

Inventory analysis

In the inventory analysis, the systems studied and their system boundaries are defined and process flow charts are drawn. Once the system has been subdivided into its component sub-systems, the data are gathered. The data gathered comprise production, resource use, energy use, emissions to air and water, and waste generation.

Impact assessment

The impact assessment is a quantitative and/or qualitative process to characterize and assess the effects of the environmental burdens quantified in the inventory analysis. The process may be divided into three steps: classification, characterization and valuation. The results should be presented in a manner that is consistent with the objective of the study.

Improvement assessment

This is the component of an LCA in which options for reducing the environmental impacts or burdens of the system(s) under the study are identified and evaluated. Methodology for the goal definition and scoping and inventory analysis is, according to SETAC (Society of Environmental Toxicology and Chemistry), defined and understood. It is more difficult to draw up guidelines for how to translate environmental loads quantified in the inventory into measures of environmental effects, and how different types of effects are to be weighed against one another (Jönsson et al., 1997).

3.1. Goal and Scope Definition (Hedef ve Kapsam Tanımı)

The purpose of the study was to assess and compare the environmental impact from cradle to grave for vinyl and laminated parquet floor coverings. The covering of one square meter flooring chosen as the functional unit.

The functional unit chosen was the covering of one square meter of flooring for one year. The environmental impact of the use phase was omitted, as described in Section 1.

3.2. Life Cycle Inventory Analysis (Yaşam Döngüsü Envanter Analizi)

3.2.1. The life cycle of vinyl flooring (Vinil yer kaplamanın yaşam döngüsü)

The specific weight of the vinyl flooring is 1.3 kg/m^2 (Jönsson et al., 1997). Typical formula for vinyl flooring was considered as 40% PVC, 35% limestone, 20% plasticiser and 5% pigments (Günther and Langowski, 1997). Polyvinyl chloride (PVC) is one of the main constituents of vinyl flooring. It is produced from sodium chloride (NaCl) (57%) and crude oil (43%) (Plastic Portal, 2010). PVC production and environmental emissions data was gathered from ETH-ESU 96 library of SimaPro 7.0. ETH-ESU 96 was also used for dimethyl p-phthalate data that was taken account as plasticiser.

The primary energy consumption of vinyl flooring production is 116 MJ (77% of electrical energy and 23% of heat energy from fuel oil) (Jönsson et al., 1997; Blanchard and Reppe, 1998). Inventory table of raw materials for production of vinyl flooring (VF) was shown in Table 3.1.

Table 3.1. Life cycle inventory data for 1 m^2 vinyl flooring

Raw material	Amount (kg)
Limestone	0.45
Dimethyl p-phthalate (plasticizer)	0.26
Oil, crude, 42.6 MJ per kg, in ground	0.30
Sodium Chloride (NaCl)	0.24

3.2.2. The life cycle of laminated parquet flooring (Lamine parke kaplamanın yaşam döngüsü)

The specific weight of the laminated parquet flooring is 6.54 kg/m^2 (Nebel et al., 2006). Typical formula for laminated parquet flooring was considered as 95% wood and 5% adhesives (Günther and Langowski, 1997). Cutting of trees for wood chip production with a power saw. Cut wood is left in the forest to dry for one year. After transport to the saw mill, the wood is chipped. The wood chips are stored and further dried in large silos to 20% moisture. Laminated parquet flooring data was gathered from ETH-ESU 96 library. In this system, infrastructure for electric chipping equipment and energy for drying and chipping were included. Energy demand for production processes was calculated as 1,84 MJ according to data of ETH-ESU 96. Inventory table of raw materials for producing 1 m^2 of laminated parquet flooring (LPF) was shown in Table 3.2.

Table 3.2. Life cycle inventory data for 1 m^2 parquet flooring

Raw Material	Unit	Amount
Coal, 18 MJ per kg, in ground	g	6.87
Gas, natural, 35 MJ per m3, in ground	l	1.63
Gas, petroleum, 35 MJ per m3, in ground	l	2.53
Oil, crude, 42.6 MJ per kg, in ground	g	36.9
Wood, dry matter	kg	6.54

3.2.3. Electricity (Elektrik)

Electricity profile of the study was formed according to Turkey's primary energy resources. The source ratios used in electric generation in Turkey are given in the Table 3.3, according to the 2006 program of TEIAS (The Transmission System Operator of Turkiye) (Banar and Cokaygil, 2009). A medium voltage mixed electricity profile of the city has been created by using BUWAL 250 (2004) and ETH-ESU 96 (2004) data for Turkiye in collaboration with these ratios.

Table 3.3. Electrical energy sources and rates of Turkiye (calculated from 2006 program of TEIAS*) (Banar and Cokaygil, 2009).

Energy sources	Contribution of energy sources (%)
Fuel-oil	2.9
Coal	7.6
Lignite	21.8
Natural gas	44.7
Hydraulic energy	23.0
Total	100.0

TEIAS: The Transmission System Operator of Turkiye

3.2.4. Transportation (Taşıma)

It was assumed that both flooring materials were produced in Istanbul and transported to Eskisehir (330 km). BUWAL 250 library was used for 28 ton capacity truck.

3.2.5. Waste Management (Atık Yönetimi)

In this study, it was considered as flooring materials were landfilled after their useful time. For landfill data BUWAL 250 library was used.

4. LIFE CYCLE IMPACT ASSESSMENT (YAŞAM DÖNGÜSÜ ETKİ DEĞERLENDİRMESİ)

In this study, six impact categories included by the CML 2000 method were investigated: abiotic depletion, global warming, human toxicity, acidification, eutrophication, and photochemical oxidation. Characteristics of the impact categories are discussed below.

4.1. Depletion of abiotic resources (Abiyotik kaynakların tükenmesi)

This impact category indicator is related to extraction of minerals and fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels (kg antimony equivalents/kg extraction) based on concentration of reserves and rate of deaccumulation (Banar and Cokaygil, 2009).

4.2. Global warming (Küresel ısınma)

The characterization model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterization factors. Factors are expressed as Global Warming Potential for time horizon of 100 years (GWP100), in kg carbon dioxide/kg emission (Banar and Cokaygil, 2009).

4.3. Human toxicity (İnsanlar üzerine olan toksik etki)

Characterization factors, expressed as Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance, HTPs are expressed as 1,4-dichlorobenzene equivalents/kg emission (Banar and Cokaygil, 2009).

4.4. Acidification (Asidifikasyon)

The major acidifying pollutants are SO_2, NO_x, HCl and NH_3. What acidifying pollutants have in common is that they form acidifying H^+ ions. A pollutant's potential for acidification can thus be measured by its capacity to form H^+ ions. The acidification potential is defined as the number of H^+ ions produced per kg substance relative to SO_2 (Banar and Cokaygil, 2009).

5. RESULTS (BULGULAR)

The results of the characterization analysis per functional unit (1 m^2 of floor covering) for each impact category are reported in Table 5.1.

Table 5.1. Characterization Results

Impact category	Unit	VF	LPF
Abiotic depletion	kg Sb eq	**0.152**	0.00326
Global warming (GWP100)	kg CO_2 eq	**25.9**	15.7
Human toxicity	kg 1,4-DB eq	**6.49**	0.157
Acidification	kg SO_2 eq	**0.0991**	0.00274

Abiotic depletion: Crude oil has the largest effect on laminated parquet since it was used for cutting, chipping and milling processes. Natural gas and coal are the dominated factors for vinyl covering (Figure 5.1). These dominated effects are resulted from electricity usage.

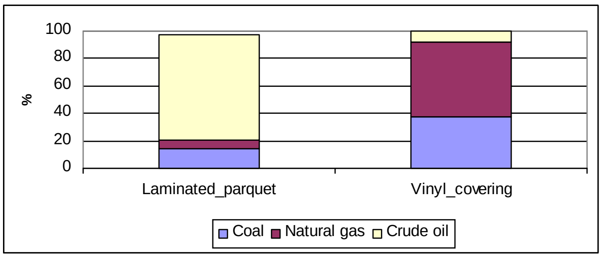

Figure 5.1. Abiotic depletion results of the flooring types

Global warming: Methane is the highest factor for laminated parquet whereas carbon dioxide is the highest for vinyl covering. It was seen that methane emissions were resulted from landfilling of laminated parquet and carbon dioxide emissions were resulted from electricity demand of vinyl flooring (Figure 5.2). And also, it should be remember the importance of weight for the emissions resulted from transportation (1 m^2 laminated parquet is 6,54 kg whereas 1 m^2 the vinyl flooring is 1,3 kg).

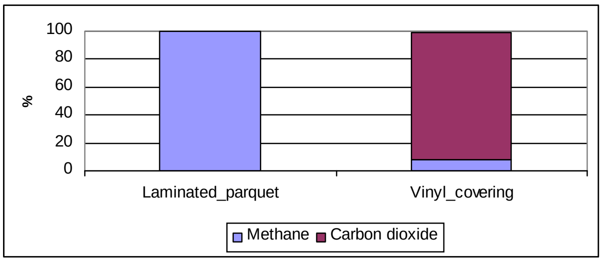

Figure 5.2. Global warming results of the flooring types

Human Toxicity: Human toxicity impact category is resulted from very kinds of substances. Figure 5.3 shows only the substances that has 10% effect individually for both of the covering materials. Landfilling of laminated parquet and vinyl production are the main reason for human toxicity effect.

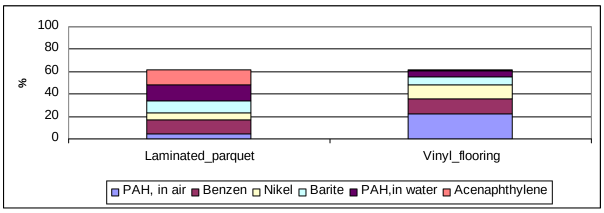

Figure 5.3. Human toxicity results of the flooring types

Acidification: Acidification impact of the covering materials are shared by nitrogen oxides and sulfur oxides. Nitrogen oxides (resulted from transportation) are the main effect for laminated parquet while sulfur oxides (resulted from electricity production) are the main effect for vinyl flooring (Figure 5.4).

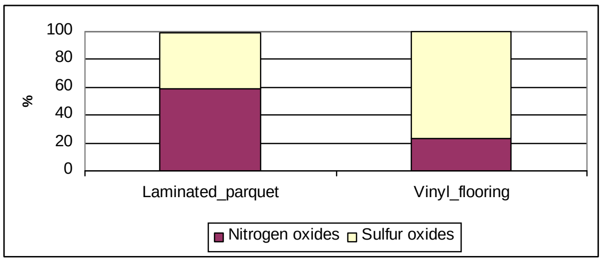

Figure 5.4. Acidification results of the flooring types

6. CONCLUSION (SONUÇ)

In this study, vinyl and laminated parquet floor covering materials were compared by CML 2 baseline 2000 method based on the LCA methodology. According to characterization results, vinyl flooring has the higher impact values than the laminated parquet has. When the results were examined on the process base, it was seen that production of vinyl flooring and landfilling of laminated parquet are the important stages of their life cycles.

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