The Effect of Interaction among Different Indoor Materials on Perceived Air Quality

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ABSTRACT

THE EFFECT OF INTERACTION AMONG DIFFERENT INDOOR MATERIALS ON PERCEIVED AIR QUALITY

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Perceived air quality has been previously characterized by the concentration of human bioeffluent or the number of standard persons that would cause the same level of dissatisfaction as the actual pollution source. Based on previous investigations, the pollution load from the building materials may be calculated by adding the loads from individual materials and the occupants present in the building. However, further research revealed that this simplification is not an accurate approach in determining air quality and the required ventilation rate. Appropriate research is required to investigate the effects of several materials and their mutual interaction on perceived air quality and validate the predictability of perceived air exposed to different indoor materials.

In the present study, a comprehensive experimental set up has been conducted to observe the effect of three different building materials, i.e. carpet, paint and linoleum, on perceived air quality. A sensory panel perceived the quality of polluted air in three different settings consisting of individual materials, a combination of different building materials and a mixture of odors generated by single materials.

The results of this investigation show that the exposure response curve can vary from one material to another material and from human bioeffluent. The findings from this study confirm the results of previous studies which show the impact of dilution of polluted air on the perceived air quality varies between building products and human bioeffluent. The results of this experimental procedure also show that that interaction effect among building materials from perception point of view is very negligible. This is due to the fact that the acceptability level caused by combination and mixing set ups of materials were not statistically different. Further investigation shows that linear addition of Olfs can be used to estimate the quality of perceived air in the presence of any combination of these specific types of building materials.

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NOMENCLATURE

A	*Area of material* (m^2)
Acc.	*The mean acceptability vote*
C	*Perceived air quality in the test chamber (decipol)*
C_o	*Perceived air quality in the empty test room (decipol)*
G	*Total pollution load or source strength (olf)*
N	*Air exchange rate* (hr^{-1})
PD	*Percentage of dissatisfied people (%)*
Q	*Inlet air flow rate (L/s)*

CHAPTER 1

INTRODUCTION

1.1 INDOOR AIR QUALITY PROBLEMS AND HEALTH CONCERNS

Environmental issues have become one of the most important and promising areas of research and studies during the last few decades. Indoor air quality is a division of the vast number of subjects that relates environment to human life and attention has been paid to this field, since people generally spend 80% of their time in indoor environments. The term of indoor environment includes residential and public places, as well as office buildings. Quality and acceptability of indoor air has a direct and obvious effect on the performance and health of building occupants. This makes it necessary to consider the quality of air at the design stage of a building, the same way as thermal and acoustical parameters and conduct a design procedure that ensures occupants' comfort.

There exist several different compounds in indoor air, which are emitted from all indoor building materials, construction products and other indoor pollution sources, including HVAC system. These compounds, usually referred as Volatile Organic Compounds (VOCs), are considered indoor air pollutants and their existence might be health threatening for occupants. The emission of VOCs from building materials may depend on the indoor climate related parameters such as temperature, relative humidity of air (European Database on Indoor Air Pollution Sources in Buildings, 1997), age of materials, concentration of pollutants in the air (Knudsen *et al.*, 1997a; Knudsen *et al.*, 1999b), air velocity (Huang and Haghighat, 2004; Knudsen *et al.*, 1999b), number of aerosols in the air, etc (Jokl, 1995; Bluyssen and Fanger, 1991). The presence of the mentioned compounds makes the environment unpleasant for occupants, and causes health risks and serious problems, referred as Sick Building Syndrome (World Health Organization Committee, 1983). Due to these adverse effects caused by VOCs, it is vital to keep the concentration of VOCs in indoor environment at the lowest possible level. The major approaches that have been proposed to meet this objective are ventilation and source control.

1.1.1 Ventilation

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) developed a standard for required ventilation rates with respect to the number of occupants and their activities in indoor environment (ASHRAE Standard 62-2001). This standard is based on a common method of estimating the adequacy of ventilation rate in indoor space by measurement of CO_2 levels. Carbon dioxide is the most abundant human bioeffluent and its production is proportional to the body's metabolic rate (ASHRAE Standard 62-2001). Peaks in CO_2 readings in different areas of a building provide clue regarding areas with inadequate fresh air supply or overcrowding.

ASHRAE Standard 62-2001 is supposed to be able to maintain the quality of indoor air at an acceptable range. However, the problem with indoor air quality still exists since discomfort caused by many perceivable pollution sources that do not produce CO_2, such as building materials and furnishings, especially carpets and other flooring materials cannot be recognized by using CO_2 indicator. Moreover, applying the ASHRAE Standard 62-2001 requires higher air ventilation rates when the number of occupants increases. However, increased air ventilation rates would result in higher energy consumption and expensive investments in building services and ventilation equipment. It may also cause air movement that might be annoying for occupants due to local thermal discomfort.

1.1.2 Source Control

Controlling the source of emissions by avoiding and substituting polluting indoor materials, which will result in reduced emissions and minimized ventilation requirements, seems to be a more proper and logical strategy to improve indoor air quality. A key parameter to controlling the indoor air pollution sources and maintaining the quality of the air at an acceptable level is to develop and manufacture low emitting construction materials. In order to achieve this goal, manufacturers of construction products and architects need simple and affordable facilities for emission testing or a database that provides them with information about different materials. This would require knowledge of these pollution sources and the prediction of the impact of different materials on the perceived air quality during the design of a new building or renovation of an existing building. In order to achieve this goal, the level of pollution caused by different indoor materials should be assessed.

1.2 MOTIVATION OF THIS STUDY

Quality of indoor air as it has been already described has direct and obvious effects on occupants' performance and comfort. In order to control the level of pollution in indoor air, a well established framework is required to determine the effect of individual and combined materials on perceived air quality.

Several studies have been conducted to characterize the effect of VOCs emitted from building materials on the perceived air quality, both in sensory and chemical terms. Sensory assessment utilizes the human subject as the measurement tool, while chemical measurement uses analytical instruments to determine the level of VOCs. Some studies showed that chemical measurement is not capable of detecting all perceivable indoor pollutants, and sensory assessment is a better approach to solving indoor air quality problems (Fanger, 1988; Jolk, 1995; Aizlewood *et al.*, 1996). These studies mostly focused on the effect of single materials on perceived air quality, while a few studies took into account the effect of the combination of materials. The state-of-practice of considering this phenomenon is the linear addition of pollution loads caused by individual indoor sources (Fanger, 1988). However, some further research showed that this simplification is not an accurate approach for the determination of the air quality and the required ventilation rate (Bluyssen and Cornelissen, 1997; Bottcher *et al.*, 2002). Consequently, the prediction of perceived air quality in the presence of different indoor materials is still impossible, which is due to a lack of sufficient work in observing the interaction effect among different materials. Therefore, appropriate research is required with the objective to investigate the effects of several materials and the interaction among them on perceived air quality and to validate the predictability of perceived air exposed to different indoor materials.

1.3 Objectives

The main objective of this research is to investigate the shortcomings of the existing methods to predict the indoor air quality in presence of different building materials and to improve these approaches. Since sensory measurement has been proven to be the more appropriate method to characterize the emission of building materials, this study focuses on this method. In detail, three major objectives are considered for this research:

- To evaluate perceived air quality when pollution is generated by different building materials and a standard person, and to investigate any possible generalization of the exposure response curve of different building materials.
- To assess the additive assumption of pollution loads to predict the level of pollution generated by a combination of different materials.
- To study the possible existence of any interaction effect amongst the materials that may affect the level of pollution caused by different building materials.

1.4 Thesis Outline

This literature is divided into five chapters. Chapter 2 reviews the related literatur previously contributed to evaluate the perception of indoor air in the presence of different indoor building materials. Emphasis will be placed on sensory assessments. At the end of second chapter, the results and shortcomings of the conducted studies will be described. In Chapter 3 the methodology and experimental set up will be described. This will include the experimental procedure and strategy for conducting the measurement of acceptability of air quality. The results from the experimental procedure will be outlined and discussed in Chapter 4. Chapter 5 provides the conclusions of this study and recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

This chapter provides the review of related research and identifies areas in which the literature should be expanded. This chapter is divided into three main sections, which are: background, sensory assessment and additive concept, and results of literature review and needs for further studies.

2.1 BACKGROUND

Some experimental efforts have been put toward evaluating the effect of building materials on air quality in sensory and chemical terms. Since this work is mainly concerned with evaluating the perceived air quality using sensory assessment, emphasis will be placed on similar experimental studies using sensory assessment. This section will be dedicated to briefly presenting the related measurement method to assess the level of pollution caused by different indoor materials. Results from the literature review will be summarized at the end of this chapter.

2.2 SENSORY MEASUREMENT AND ADDITIVE CONCEPT

Fanger (1987) proposed a method to quantifying the acceptability of indoor air and identifying the causes of building occupants' complaints when being exposed to indoor building materials that had not been previously recognized (Fanger, 1988; Jolk, 1995; Aizlewood et al., 1996). He introduced the concept of source strength and perceived air quality by using the units of olf and decipol. In this approach the acceptability of air perceived by human beings is a combination of olfactory sense, sensitive to odors, and chemical sense, sensitive to irritants (Bluyssen and Fanger, 1991). Olf is a unit which quantifies the source strength of air pollution, while decipol is a unit which describes the perceived air quality of an air volume (Fanger, 1987). Fanger (1988) defined one Olf as the emission rate of air pollutants generated by one standard person[1] (Fanger, 1988), and one Decipol as the perceived air pollution caused by one standard person (one Olf) ventilated by 10 L/s of unpolluted air.

$$\text{Decipol} = 0.1 \text{ Olf}/(\text{L/s}) \quad (2.1)$$

Based on this classification, the perceived air pollution from any other sources is defined as the concentration of human bioeffluent or number of standard persons that would cause the same level of dissatisfaction as the actual air pollution source. Based on this approach, Fanger (1989) was able to estimate the required ventilation rate for an acceptable indoor air quality taking into account all pollution sources:

$$G = 0.1(C - C_o)Q \quad (2.2)$$

Where:

G is the total pollution load or source strength (olf)

C is the perceived indoor air quality in test room with materials (decipol)

C_o is the perceived outdoor air quality in empty test room (decipol)

Q is the outdoor air flow rate (L/s)

[1] 0.7 bath/day, daily clean underwear, and 80% use of deodorant.

The panel may consist of either trained[2] subjects who judge the quality of perceived air directly in decipol unit (Pejtersen and Mayer, 1993) or naïve subjects who perceive the quality of air on the acceptability scale. The experiments could be conducted by introducing or removing a certain pollution source into a room and asking the panel to make a judgment on the air quality at steady-state conditions. The alternative test method to assess the concentration load of pollutants and acceptability of air in the test chamber in sensory term is to lead air flow from test chamber through diffuser to sensory panels.

Fanger (1988) suggested that the greatest advantage of the new decipol units is that each component can be assessed separately, and then their total impacts on the environment can be based on the individual gained results. He also suggested that Decipol could be also a new basis for constituent mutual interaction study. Fanger (1987) believed that when two sources emitting pollutants of the same nature are in one space, it is obvious that their Olf values can be added. Moreover, even if the pollution sources are of a different nature, it is assumed that the combined effect of both sources in one space can be found by simple addition of the Olf values. It was also suggested by Jolk (1995) that the pollution load from the building materials may be calculated by adding the loads from individual materials and the occupants present in the building.

A few studies have been conducted to investigate the validity of generalizing the level of pollution generated by different building materials by defining the number of standard persons to produce the same level of pollution. Some of these studies have also evaluated

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[2] Individuals who are trained to assess the air quality directly in sensory unit, decipol, as defined by Fanger (1988) with refer to 2-propanone as the reference gas.

the accuracy of addition theory of Olf values. The Following are some of the studies previously performed by utilizing sensory assessment as the measurement method.

Bluyssen and Fanger (1991) showed that, for eleven different materials, the prediction of source strength and their effect on air quality for a combination set up[3] can be calculated by simple addition of the source strengths of single sources. These materials included five different building materials, four ventilation system materials, newspaper and cigarette butts, along with thirteen pairs of combinations of these sources and one combination of five single sources. However, the authors believed that at the time of predicting perceived air quality based on the olf and the decipol units, simple addition of different pollution sources does not necessarily apply.

In a series of experiments carried out by Knudsen *et al.* (1994), using linoleum, carpet and paint and a combination as samples, it was noticed that the curve showing the relationship between percent of dissatisfaction and concentration of pollutants were different from each other and from the corresponding curve of human bioeffluent. It was also noted that the curve for a combination of materials was less steep than the ones for paint and carpet and it was close to the average of the three curves for individual materials. Knudsen *et al.* (1994) mentioned that the findings from their study did not contradict with the addition theory of the loads from individual pollution sources to calculate the total sensory pollution load that was previously proposed by Bluyssen and Fanger (1991).

[3] Different building materials placed together inside one chamber and sensory panel assess the exhaust from this chamber.

No relationship was found by Woulda *et al.* (1997) between adding the sensory perception of the individual compounds and the measured sensory perception of combinations of materials. Woulda *et al.* (1997) used 4 materials for this investigation, including a empty chamber (Teflon walls), carpet tiles, curtain textile, and gypsum board. A combination of carpet and curtain, and a combination of carpet, curtain and gypsum board were also considered for the experimental procedure.

Knudsen *et al.* (1997a) conducted a set of experiments using 8 different indoor materials. Single materials used for this study included 5 different types of floor covering, i.e. linoleum, PVC, waterborne acrylic floor varnish on beech wood parquet, two loomed-polyamide-carpeting with rubber backings, and two sets of samples of waterborne acrylic wall paint, one applied to an aluminum sheet and another one applied to a gypsum board. In addition to the single materials, a combination of linoleum, loomed polyamide carpeting with rubber backing and waterborne acrylic wall paint applied on a gypsum board was also used for study. The authors showed that the exposure response relationship between concentration of air pollutants and perceived air quality differed between investigated materials as well as the corresponding relationship for human bioeffluent. Based on this result, the sensory pollution load will vary with the concentration of air pollutants, and the sensory pollution load for materials cannot be characterized by olf as one single number (Fanger, 1988).

Knudsen *et al.* (1997b) used six types of flooring materials and two types of sealant to determine the exposure response relationships for these building and furnishing materials.

It was shown that the measured exposure response relationships differed between the investigated materials.

Bluyssen and Cornelissen (1997) used six types of building materials, including floor cloth, three types of carpet, multiplex, linoleum, hardboard, glass wool, and newspaper, and ten paired combinations of these materials, to investigate the possibility of predicting the effect of combined materials based on the results from single materials. Bluyssen and Cornelissen (1997) added separate source strengths for ten combinations of materials. This study revealed that all of the predicted values of pollution loads of paired combinations are higher than the measured values of paired combinations. It was also shown that the exposure response relationships differed between materials and also from the corresponding relationship for human bioeffluent.

Knudsen *et al.* (1998) has demonstrated that the exposure response relationships are different for some typical building materials. The specimens used in this study included two types of tufted nylon carpet with latex foam backing, two types of linoleum, two types of polyolefin, and two types of water borne acrylic sealant. It was therefore proposed to characterize the emissions from materials by their individual exposure response relationships.

Knudsen *et al.* (1999a) studied the effect of three different building materials individually and their mixture of emissions (mixing set up[4]) on perceived air quality. These materials

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[4] Different materials placed individually in separate chambers, exhausts from these chambers are mixed in a mixing chamber. A sensory panel assessed the exhaust from the mixing chamber.

included polyamide carpet with latex foam backing, an elastic sealant of modified silicone polymers for indoor use and white acrylic wall paint applied on gypsum board, which were placed individually in test chambers. The exhausts from the three chambers were mixed in a fourth one and the assessments were carried out from the cone installed on the mixing chamber. Knudsen *et al.* (1999a) showed that the acceptability differed for different investigated materials and it decreased by adding pollutants from more acceptable materials to the least acceptable material. The acceptability vote of the mixtures was on average less than the least acceptable individual material. They suggested a calculation procedure to determine the acceptability of air for a mixture of odors from different materials. However, the interaction effect between sources was ignored due to placing each of the material samples separately in individual test chambers.

In a series of experiments performed by Haghighat *et al.* (2001), the impact of combinations of several building materials on perceived air quality was investigated. The sample tested in this study were paint, carpet and PVC for the single materials tests, and carpet and PVC, paint and PVC, and paint and carpet for the tests of combination of two materials. Based on the results obtained in this experimental investigation, the perceived air quality generally improved when two materials were combined, nevertheless the degree of improvement varied from one combination to another. In addition, the curve representing exposure response versus dilution rate was less steep for combination of materials compared to the one for single materials. This difference in slope will result in a higher ventilation rate demand to improve the acceptability level for the case of a combination of building materials compared to the case of single materials.

In another study conducted by Bottcher *et al.* (2002) three different types of materials making the air polluted above the odour threshold in a test chamber were used. These materials included carpet, a filter, and 2-propane. Each of the materials was placed separately in modified CLIMPAQ chambers. They carried out two series of tests, one by mixing the exhaust of test chambers and another one by adding the exhaust from one chamber to the other one. In the first set, the exhausts of two separate chambers with different materials supplied with unpolluted air were mixed (mixing set up). The outcome was later diluted with an equal flow rate of unpolluted air to get the same concentration as single materials. In the second set, the first chamber containing one of the samples was supplied with unpolluted air, and the exhaust from this chamber entered the second one as the inlet air. Bottcher *et al.* (2002) suggested logarithmic averaging of the exposure response relationships for the single materials to describe the relationship between concentration and perceived air quality. The authors showed that a linear averaging of the Decipol values leads to incorrect results that are too small. In the second set, different concentrations versus a median vote on perceived air quality were plotted again. The exposure response relationship of the addition of one odour to the second one is above the logarithmic addition of the single materials. Bottcher *et al.* (2002) stated that a linear addition of the Decipol-values leads to incorrect results that are very high. In this set, it was shown that a logarithmic addition leads to a very good correlation between calculation and assessment.

2.3 Results of Literature Review and Needs for Further Studies

The literature review presented in this chapter provided some basic background information for the topic of indoor air quality measurement in general and sensory measurement in detail. As it has been already discussed in the current chapter, some experiments have been conducted to evaluate the effect of indoor materials on indoor air quality by means of sensory measurement. Most of this research has shown that the sensory pollution load will vary with the concentration of air pollutants. Based on this, generalizing the sensory pollution load generated by different building materials by the number of standard people, expressed as Olf, is not the correct approach to solve indoor air quality problems. Furthermore, some of the described literatur suggested that predicting the acceptability level of air when being polluted by several different materials cannot be achieved by simple addition of acceptability level caused by each of individual materials.

Most of the previous experiments were conducted by placing single materials individually in separate test chambers. This means that the effect of a combination of different materials which is the real case in buildings was not considered and any possible existence of interaction phenomenon among building materials was ignored. The interaction among building materials may cause the compounds emitted by one material be adsorbed on other materials surfaces and be desorbed after concentration of pollutants in air drops. The sorption and desorption phenomena may have a significant impact on concentrations of indoor pollutants at both peak and long time average (Borrazo *et al.*, 1990; European Database on Indoor Air Pollution Sources in Buildings, 1997). This interaction among building materials makes the rate of pollutants in indoor places unpredictable when the calculation for the amount of pollutants is exclusively based on findings from individual materials.

There exists no database or guideline to fully evaluate the effect of existence of several different indoor materials and predict the level of pollution based on the results from individual materials. This is due to a lack of research conducted in this field. The uncertainty of the proposed calculation technique to quantify the quality of indoor air and required ventilation rate in the presence of different indoor materials and human beings requires some further researches in order to develop a methodology to determine the indoor air quality in presence of several indoor materials and occupants.

The fundamental motivation of this study is to conduct some further research and experimental observations to compare the exposure response curves of different single materials as well as combination of materials with each other. The result from a comparison between single set ups will lead to validity of theory of defining parallel curves with different intercept to predict the effect of different building materials on air acceptability. Furthermore, the theory of addition of sensory pollution loads of different single materials to predict the level of acceptability in the presence of combination of materials will be evaluated. The other objective of this research is to study the interaction effect among building materials that may affect the quality of perceived air. This will be investigated by comparing the acceptability results of combination set up and mixing set up. Obviously, the result of these investigations will be useful in achieving any possible method for predicting the quality of the air in indoor environment at the design stage of a new building or renovating an existing one.

Table 2.1 Summary of literature review: Sensory Assessment

Researchers	Sensory Test	Pollution Sources	Test Facilities & Conditions	Procedure	Objective/Purpose of experiments
Bluyssen and Fanger (1991)	A panel of five trained judges was exposed to air polluted by different materials, using 2-propane as the reference gas.	Five building materials: carpet, rubber doormat, sealant, painted metal plate, linoleum. Four ventilation materials: panel filter, rotating heat exchanger, humidifier paper, galvanized steel. Two other sources: newspaper, cigarette butts.	Ventilated jars (Decipolmeters) T=22°C	The trained panel assessed the source strength for different pollution sources and some of their combinations by placing their noises at the top of the diffusers of Decipolmeters.	To study the predictability of indoor air perception when polluted by different materials simultaneously.
Knudsen et al. (1994)	A panel consisted of 13 trained persons assessed perceived air quality directly in sensory units.	Linoleum, loomed polyamide carpet with rubber backing, water based acrylic paint applied on aluminum sheets, and a mixture of three materials.	A 1030 l glass test chamber placed inside a 28.5 m^3 stainless steel environmental chamber. Q (to the test chamber)=1.8 L/s, Q (diffusers)=0.9 L/s ACH=40 hr^{-1}, T=22°C	The sensory panel performed the assessments for five different concentrations of pollutants twice in random order.	To study exposure response curve for building materials individually and simultaneously.

Continuation…Table 2.1 Summary of literature review: Sensory Assessment

Wouda et al. (1997)	Trained panel perceived air quality directly in sensory units.	Materials: Empty chamber (Teflon walls), carpet, curtain textile, gypsum board, combination of carpet and curtain, and combination of carpet, curtain and gypsum board. Compounds: n-butanol, hexanal, p+m xylene, 2-ethoxyethylacetate, EGMBE, mesitylene, n-decane, 2-ethylhexanol, limonene, n-undecane, decanal, n-dodecane.	A 15 m^3 chamber Q=30 m^3/h; ACH= 2 hr^{-1};T=23°C; RH=45 %,	During 48 hours air loaded with the chemicals was supplied to the chamber. Sensory evaluations were made 1, 24, and 48 hours after the supply of chemical compounds had stopped.	To observe the sorption effect of chemicals on combined indoor materials in comparison to sorption effects on individual materials
Knudsen et al. (1997a)	A trained panel comprising 10 to 14 subjects who were trained to assess the air quality in comparison with five known references of 2-propane	5 types of floor covering: linoleum, PVC, waterborne acrylic floor varnish on beech wood parquet, two loomed-polyamide-carpeting with rubber backings (1 and 2). Two sets of samples of	A 1030 l glass made test chamber placed inside a 28.5 m3 environmental chamber made of stainless steel. Q to the test chamber=1.8 L/s, Q through	Sensory panel assessed twice the perceived air quality in five different concentrations of the exhaust from test chambers in random order.	To study the exposure-response relationships for number of materials to characterize the emissions from building materials in sensory terms.

Continuation…Table 2.1 Summary of literature review: Sensory Assessment

		waterborne acrylic wall paint, one applied to an aluminum sheet (1) and another one applied to a gypsum board (2). An acrylic sealant. And a mixture of linoleum, carpet 1 and wall paint 1.	diffusers=0.9 L/s T=22°C, no attempt to control the humidity of air. ACH= $40hr^{-1}$	Sensory panel assessed twice the perceived air quality in five different concentrations of the exhaust from test chambers in random order.	To study the exposure-response relationships for number of materials to characterize the emissions from building materials in sensory terms.
Knudsen et al. (1997b)	Untrained sensory panel comprising 33 to 41 performed the sensory assessments.	6 floor materials: two types of loomed polyamide carpeting with rubber backings (1 and 2), two types of linoleum (1 and 2), and two types of polyolefin (1 and 2). Two types of sealant (1 and 2).	T=23°C; RH= 45%; Air velocity= 0.1 m/s. Q to the test chamber=0.9 L/s, Q through diffusers=0.9 L/s; ACH= 1 hr^{-1}.	For each material four concentrations were assessed three times: 3 days, 10 days and 29 days after the materials were put in the test chambers.	To determine the exposure response relationships for emission from building materials and furnishing materials
Bluyssen and Cornelissen (1997)	A trained panel of 12 persons was used to perceive the quality of air.	Six single materials: floor cloth, three types of carpet, multiplex, linoleum, hardboard, glass wool, newspaper. Ten paired combinations	Decipol meters, Q=0.86 L/s; T= 22°C	The experiments were spread over 5 months, at 8 days. Single and pairs of two sources were evaluated in one day.	To investigate the possibility of addition of pollution loads from building and furnishing materials in order to evaluate the perceived air quality.

Continuation…Table 2.1 Summary of literature review: Sensory Assessment

Knudsen et al. (1998)	33 to 41 untrained subjects assessed the air in term of acceptability.	Two types of tufted nylon carpet with latex foam backing, two types of linoleum, two types of polyolefin, two types of water borne acrylic sealant.	CLIMPAQ type test chambers, T=23.0°C, RH= 45%. Q (through diffusers)=0.9 L/s	Panel members assessed the air on days 3, 10 and 29 after the samples were placed in the test chambers. 4 set of orifice plates were used to achieve different concentration of pollutants.	To determine the exposure response relationships for the emission from building products using an air dilution system
Knudsen et al. (1999a)	Untrained sensory panel of 37 and 38 subjects assessed the air quality in terms of acceptability and odor intensity.	Polyamide carpet with latex foam backing, an elastic sealant of modified silicone polymers, a white acrylic wall paint applied on gypsum board	Four CLIMPAQs, T=22.4 °C, RH= 35% and 40% for two parts of experiments. Q (through diffusers)=0.9 L/s	Two parts: First one with identical areas of materials based on a model room; second one by choosing the areas of materials somehow to get similar acceptability votes for the three materials. Exhausts from the first 3 chambers were mixed in a forth one. The panelist assessed the immediate acceptability of air from the diffuser. Stainless steel air dilution system was added to each chamber	To investigate how emissions from several building materials are perceived when they are mixed and to develop a calculation method to determine the acceptability of air with emission mixtures from different pollution sources based on knowledge of individual materials.

Continuation...Table 2.1 Summary of literature review: Sensory Assessment

Haghighat et al (2001)	Untrained panels of 29-50 subjects assessed the air quality in terms of acceptability and odor density.	Three type of single materials: carpets, PVC, waterborne wall paint. Three combinations of materials: paint and carpet, paint and PVC, PVC and carpet.	Three CLIMPAQs, T=22°C, RH= 40%. Q=0.9 L/s.	A panel assessed the air quality for five different concentrations of pollutants. Five different sets of orifices were used to achieve different concentrations of pollutants.	To observe the impact of operation of ventilation systems and combinations of several building materials on perceived air quality.
Bottcher et al. (2002)	A panel consisted of 10-12 trained judges performed the assessments directly in Decipol unit with five known references.	Carpet, filter, and 2-propane	Modified CLIMPAQ chambers. T= 20°C, RH= 23.5% and 27.5% in first and second set ups, respectively. Q=0.9 L/s.	One by mixing the exhausts of test chambers, another one by adding the exhaust from one chamber to the other one. For two different set ups, three and seven different relative concentrations were investigated, respectively.	To find a mathematical method to calculate the perceived air quality from mixing and addition of exhausts from test chambers containing materials based on the data from single materials.

CHAPTER 3

EXPERIMENTAL SET UP AND METHODOLOGY

As it has been highlighted in the literature review, there is a need to perform an experimental procedure to study the effect of materials on the quality of perceived air. This procedure has three main intentions, to evaluate the effect of single building materials on air quality; to determine the accuracy of addition of Olf values; to observe the presence of any interaction effect amongst building materials. This research work mainly focuses on the effect of building materials in single, combination and mixing set ups in sensory terms. This chapter describes the experimental procedure and methodology for this effort.

3.1 RESEARCH PLAN

Three types of set up were considered to fulfil the aim of present study. In the first set up a sensory panel assessed the quality of air polluted by emissions from three individual building materials. The results of this set up will be used to determine the effect of different building materials on perceived air quality. Olf theory considers parallel curves to human bioeffluent with different intercepts to predict the effect of different building materials on air acceptability (Fanger, 1988). Exposure response curves obtained from the first set up were used to investigate the validity of this assumption.

In the second set up (combination set up), combinations of two and three materials were considered to evaluate the accuracy of additive theory of pollution loads. For this purpose, the calculated source strength from the combination set up will be compared to the addition of source strength from the corresponding single materials from the first set up. Furthermore, in the third set up (mixing set up), sensory subjects assessed the quality of air when being polluted by mixture of emissions from two or three materials. Comparing the results from the combination and mixing set ups will lead to investigate the existence of interaction effects amongst building materials.

3.2 CHAMBER DESCRIPTION

Twenty one CLIMPAQ type test chambers (Gunnarsen *et al.*, 1994; NORDTEST method, 1998) were used for this experimental study (Figure 3.1). The main body and surface of these test chambers were made of glass except for the connections and tubing that were made of low polluting materials such as Teflon, stainless steel and aluminium. The volume of each chamber was 50.9 L. The test chambers were placed in a test room in the Indoor Climate Laboratory at the Danish Building and Research Institute (SBI), Horsholm, Denmark. Each test chamber was equipped with one internal fan for driving the supply fresh air and re-circulating air over the test specimens.

The air inlets to the CLIMPAQs and test rooms were provided by an air conditioning system supplied with outdoor air. Low concentrations of polluting gases and particles in the supply air were reduced by putting a fine filter of class EU7, a charcoal filter, and again a fine filter of class EU7 in series in the air conditioning system.

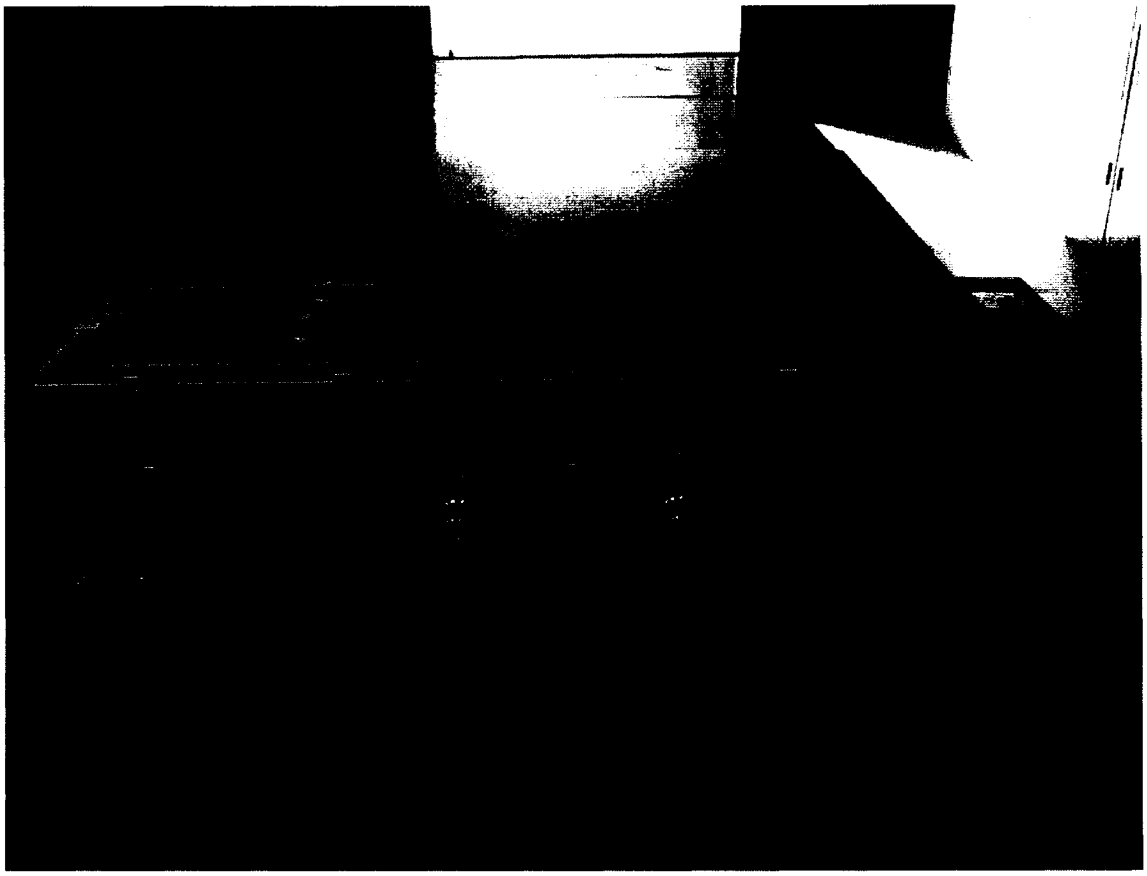


Figure 3.1. CLIMPAQ used for experimental test procedure

The exhaust air from each CLIMPAQ was led to a diffuser specially designed for sensory assessment (Bluyssen, 1990). The exposure equipment was made of stainless steel and Teflon, which are low polluting materials, in order to reduce the emission from their surfaces. The air flow rate through each diffuser was tried to be kept constant at 0.9 L/s which is the recommended airflow rate for sensory study (Bluyssen, 1990; Clausen *et al.*, 1997; Knudsen *et al.*, 1994; NORDTEST method, 1998). Table 3.1 lists the values of air flow rate through out each diffuser. The mean value of outlet airflow rate through diffusers was 0.87 L/s with the standard deviation of 0.04.

Table 3.1. Chamber calibration data

Chamber Tag	Type of Set Up	Samples	Outlet from Diffuser Using Different Sets of Orifices						
			Velocity (m/s) Using Velocity Meter	Flow Rate(L/s) Using Calibration Chart[5]	N_2O Concentration (ppm) Using Different Sets of Orifice Plates				Outlet Flow Rate(L/s) for Assessment
			Undiluted Set (1)	Undiluted Set (1)	Set 1	Set 2	Set 3	Set 4	Undiluted Set (1)
1	Mixing				738.17				
2		Linoleum, Carpet & Paint			836.13	341.75	74.40	33.49	0.84
3					747.00				
4					731.71				
6	Single	Paint	1.50	0.90	752.50	334.00	69.75	37.40	0.90
8	Single	Linoleum	1.51	0.90	742.20	291.06	74.97	37.11	0.90
9	Combination	Linoleum & Paint	1.50	0.90	798.67	273.64	55.66	25.60	0.90
11	Empty		1.50	0.90					0.90
12	Single	Carpet	1.53	0.91	858.40	254.00	51.50	25.87	0.91
13	Combination	Linoleum, Carpet & Paint	1.50	0.90	784.37	326.82	78.44	41.28	0.90
14	Mixing				916.14				
15		Linoleum & Paint			861.22	388.80	97.74	44.28	0.81
16					940.17				

[5] Appendix A

Continuation...Table 3.1. Chamber calibration data

Chamber Tag	Type of Set Up	Samples	Outlet from Diffuser Using Different Sets of Orifices						
			Velocity (m/s) Using Velocity Meter	Flow Rate(L/s) Using Calibration Chart	N_2O Concentration (ppm) Using Different Sets of Orifice Plates				Outlet Flow Rate(L/s) for Assessment
			Undiluted Set (1)	Undiluted Set (1)	Set 1	Set 2	Set 3	Set 4	Undiluted Set (1)
17	Combination	Linoleum & Carpet	1.52	0.91	727.00	264.30	59.77	28.48	0.91
18	Mixing				883.20				
19		Linoleum & Carpet			860.00	352.46	86.00	41.95	0.82
20					860.50				
21	Combination	Paint & Carpet	1.49	0.89	676.90	288.60	72.43	33.19	0.89
22	Mixing				871.32				
23		Paint & Carpet			862.00	344.80	87.96	39.18	0.81
24					877.64				
				Mean	816.26	314.57	73.51	35.26	0.87
				Standard Deviation	73.65	42.69	14.09	6.49	0.04
				Mean of Dilution Rate[6]	1.00	0.40	0.10	0.05	

[6] Appendix A

Three different types of set-up were considered for this experimental procedure, as following:

Single Set Up:

This set up considers the effect of one material at a time.

One single material was placed individually in a single test chamber. The inlet flow rate was set to 0.9 L/s in this type of set up.

Combination Set Up:

In this set up the combination effect of two or three types of materials on perceived air quality was considered.

- Two single materials were placed simultaneously inside one CLIMPAQ and the inlet air flow rate was adjusted to 0.9 L/s.
- Three building materials placed together in one chamber. The inlet flow rate of 0.9 L/s was also considered in this set up.

Mixing Set Up:

The mixtures of emissions from two or three types of materials were assessed in this type of set up. The flow rates in this set up were different from the previous set ups. The reasons for applying these flow rates will be described later in the present section.

- Two single materials placed separately in two individual test chambers, and exhausts from these two chambers were mixed in a third chamber. Inlet air flow to each of this chamber was adjusted to 0.45 L/s.

- Three single materials were placed separately in three separate test chambers. Exhausts from these three chambers were mixed in a forth chamber. The inlet air flow rate to each of these three chambers was set to 0.3 L/s.

An empty single chamber assessment was also performed to provide the acceptability level data in the absence of building materials (background level). The calibration procedure was performed carefully to adjust the intended inlet and outlet airflow in every set ups. The detail description of this procedure is included in Appendix A. Inlet air flow rate and areas of materials were considered in a way that area specific airflow rate[7] in CLIMPAQs would comply with the area specific airflow rate of a model room as defined by NORDTEST method (1998). The model room considered in NORDTEST method was a standard room[8] of 3.2 x 2.2 x 2.4 m (length, width and height, respectively) (Knudsen *et al.*, 1993; NORDTEST method, 1998).

Due to the chambers volume limitation in combination and mixing set ups, the areas of the specimens were reduced to half for two materials, and one third for three materials, compared to the areas of materials in single set up. In order to keep the desired area specific airflow rate in the CLIMPAQs constant, the supply air flow rates to the chambers were also regulated to half and one third in mixing set up for two and three materials, respectively, as it was previously mentioned in the mixing set up description.

[7] The ratio of the inlet air flow rate to the area of material samples
[8] The common size of an office in Europe

The air dilution system was installed on all set ups in order to attain different concentrations of pollutants for sensory assessment (Knudsen *et al.*, 1998). Figure 3.2 shows the dilution system installed on a single chamber. In mixing set up, this system was installed solely on the mixing chambers.

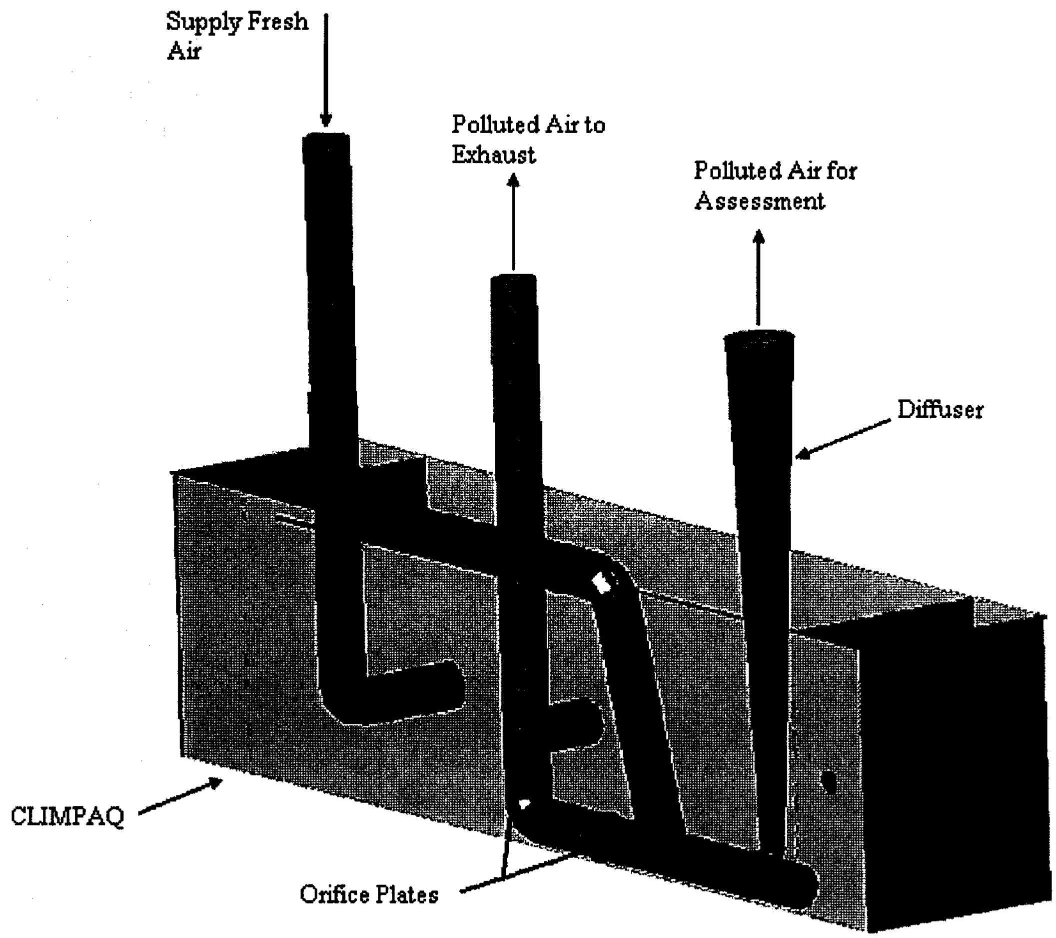


Figure 3.2. Dilution system installed on CLIMPAQ to achieve different concentrations of pollutant

The inner diameter of the dilution system was 35 mm. The system connected unpolluted fresh air to a portion of outlet air from the test chamber, while the extra amount of outlet would exhaust via a designated pipe. Different concentrations of pollutants for sensory assessment were achieved by mixing different ratios of chamber air and fresh supply air. This ratio was adjusted by varying the size of the opening in the two orifice plates, which were considered as one set. Orifice plates were made of Teflon.

Four sets of orifice plates were used for this purpose. One set provided undiluted exhaust air to the diffuser, while the other three sets were used to achieve 1/2.5, 1/10, and 1/20 of the concentration of the pollutants in the diffuser (Table 3.1). The system was calibrated using N_2O as the tracer gas. For this purpose, the concentration of the tracer gas in the diffuser and in the test chamber exhaust was measured, while N_2O was dosed at a constant rate into the test chambers.

3.3 BUILDING PRODUCTS AND SAMPLE PREPARATION

Three building materials used in this study were selected to represent major groups of building products often used in indoor places. The products used for this study included natural paint applied onto gypsum board, carpet with a textile backing and linoleum. In order to avoid the extremes of acceptability scale (Figure 3.3), the materials were selected from those types of materials that their mean of votes had not previously been shown to be "clearly acceptable" or "clearly unacceptable" (Knudsen *et al.*, 2004).

As it has been described earlier, due to the chamber volume limitation, the area of materials were reduced to half and one third in combination/mixing set ups, compared to the area of materials in single set ups. However, in order to keep the air specific flow rate constant in all different set ups (NORDTEST method, 1998), the supply airflow rates in combination/mixing set ups were also regulated to half for two materials and one third for three materials, comparing to inlet flow rate in single set up.

All the building products were brand new. All samples of materials were prepared immediately upon purchase and they were cut to the required size as provided in Table 3.2. This was performed by fixing the height of samples to 0.2 m, the maximum possible height according to chamber dimensions, and varying the length to a maximum of 0.8 m. The gypsum board pieces were painted twice on each side, 0.125 L/m^2 per time, with a painting roller. Samples were conditioned for 4 weeks in the Indoor Climate Laboratory with the air temperature of 21.9°C ±1.8 and relative humidity of 56.7% ±5.6, which is close to the normal indoor environment (23°C and 50% indicated in NORDTEST method, 1998).

After four weeks of preconditioning, samples of each of the flooring materials were stapled together, back to back, to eliminate emissions from their backsides just before being put inside CLIMPAQs. Samples of building materials were placed in the chambers fourteen days prior to the experiment. The lengths of preconditioning and conditioning periods were set to reach a steady state situation in the test chambers and to make the differences in the rate of emission from materials in two consecutive days of experiments as negligible as possible. All samples were placed vertically, in parallel with the length of the test chamber, and the emitting surfaces were parallel to the direction of the airflow. In chambers with a combination of several materials, samples were put in every other order to produce a well mixed environment. Sufficient flow of air existed between the sample plates placed inside test chambers.

Table 3.2. Supply airflow rates and test specimen areas corresponding to the model room

Type of Material	Type of Set Up	Model Room	CLIMPAQ			
		Area Specific Airflow Rate [$m^3.hr^{-1}.m^{-2}$]	Supply Airflow Rate [$L.s^{-1}$]	Area of Test Specimen [m^2]	Test Specimen	
					Number of Samples	Dimensions [m^2]
Linoleum	single set up	4.76	0.9	0.68	6	0.57x0.2
	mixing/combination set up of 2		0.45	0.34	6	0.285x0.2
	mixing/combination set up of 3		0.3	0.23	6	0.19x0.2
Paint on Gypsum Board	single set up	1.42	0.9	2.28	16	0.71x0.2
	mixing/combination set up of 2		0.45	1.14	16	0.356x0.2
	mixing/combination set up of 3		0.3	0.76	16	0.237x0.2
Carpet	single set up	4.76	0.9	0.68	6	0.57x0.2
	mixing/combination set up of 2		0.45	0.34	6	0.285x0.2
	mixing/combination set up of 3		0.3	0.23	6	0.19x0.2

The average observed temperature inside all chambers was 23.9°C with standard deviation of 0.2, and the average relative humidity was 55.0 % with standard deviation of 5. The temperature differences in the air exhausted from cones (diffusers) in different set ups were almost negligible with a standard deviation of 0.16. This shows that all samples were being conditioned in almost similar physical conditions.

3.4 SENSORY PANEL

An untrained sensory panel consisting of 25 participants performed the sensory assessment for all the experimental rounds. They aged between 18 and 79 years old with the average of 45.68 years old. 56% of the participants were males and 20% were smokers. The panel members were instructed on the measurement procedure. They were also instructed on the acceptability and intensity scales (Figures 3.3 and 3.4), which they were asked to mark on. The acceptability scale consisted of two separate parts, one from "clearly unacceptable" to "just unacceptable", and one from "just acceptable" to "clearly acceptable". Each part of this scale should have been considered as continuous. The disconnection in the middle of acceptability scale was allocated to help panel members decide if the odor is within the acceptable range or not.

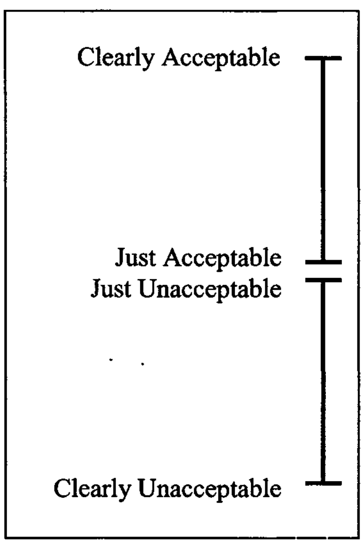


Figure 3.3. Acceptability scale

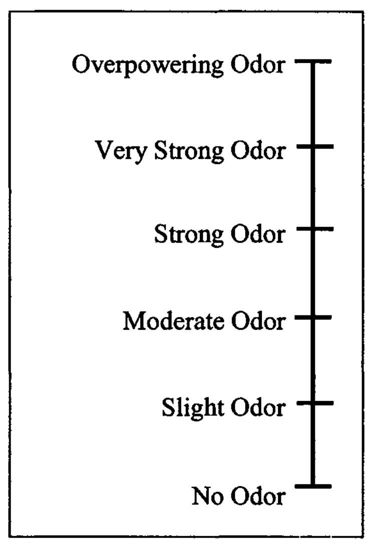


Figure 3.4. Intensity Scale

They were asked how they would accept the quality of air they were exposed to, if they were supposed to work/live in that situation. The "clearly unacceptable" vote was considered as -1, while the "clearly acceptable" one was considered as 1. The "just acceptable" and the "just unacceptable" votes were both considered as 0. Any votes in between was scaled to [-1, 1] interval using a linear scaling. The intensity scale was a continuous line divided into 5 different categories ranging from "no odour", considered as 0, to "overpowering odour" considered as 5.

The panel members assessed the immediate acceptability and intensity of the air in the test room and from the diffusers. The sensory panel exposure to chamber air was limited to 1 or 2 inhalation(s). They were instructed to mark on assessment sheets based on the initial perception. Subjects spent 3 minutes in the pre-test room, before beginning the assessment of the air acceptability and intensity in the main test room. They were instructed to return to the pre-test room and wait there for 2.5 minutes before starting the main round, including assessments of the air quality from cones. They spent 3 minutes interval, 1.5 minute in the main test room and 1.5 minute in the small room, between each assessment. The sensory team was divided into two groups; one group was performing the assessments while the other was spending 1.5 minute in the pre-test room ventilated with fresh air. If subjects had any doubt in an assessment, they were allowed to do the assessment for the second time, after a 20-sec interval.

No communication regarding the air quality of chambers was allowed during the assessment procedure. The panel members did the assessments of the cones in the random orders. They were also asked to put on a special cover for their shoes before entering the test room. During the experiments the test chambers were covered from outside with aluminium plates to hide the building products from the view of sensory panel.

3.5 EXPERIMENTAL PROCEDURE

Experiments were carried out for two consecutive days, and consisted of two rounds of twelve assessments each day. In each round, the air acceptability and air intensity of a specific chamber for one dilution rate of outlet were assessed. For this purpose one specific set of orifices was used. The dilution rates randomly varied from one CLIMPAQ to another in a certain round, using different sets of orifice plates.

Table 3.3. Physical conditions in the test room each day of the experiment

Day of Experiment	Temperature (°C)		Relative Humidity (%)	
	Average Value	Standard Deviation	Average Value	Standard Deviation
First Day	23.34	1.88	55.58	7.05
Second Day	24.94	0.67	45.96	1.99

The air exchange rate[9] (ACH) in the main test room at the time of experiments was 6 hr^{-1}. Similarly, the air exchange rate in the room next to main room where panel members were exposed to fresh air (pre-test room) was 7 hr^{-1}. Physical conditions of the test room, i.e. air temperature and relative humidity, during the days of experiments are presented in Table 3.3. A problem in air conditioning system caused the differences in physical conditions between the first and the second days of the experiments. A higher air temperature with a mean difference of 2°C was measured through diffusers compared to the air in the test room.

[9] The ratio of the inlet air flow rate to volume of test chamber.

3.6 DATA HANDLING AND STATISTICS

The experiment has two independent variables, i.e. dilution rate and set up. The dependent variables were the scaled values of air acceptability and air intensity. For every possible combination of dilution rate and set up a separate experiment was conducted (factorial design).

The Box Plot method was used to identify outliers in data set. Conducting this method for all set ups revealed very few outliers in all the observations. Considering that omitting the outliers make the data unbalanced, and there were not noticeable numbers of them, it was strongly believed that removing them from data sets would not make a difference in the results of statistical analysis. Therefore, outliers were not deleted in the statistical analysis procedure in this study.

The experiment was repeated 25 times (25 sensory subjects). A two-factor ANOVA analysis with replication was used for comparison between treatments (set ups). Another piece of information revealed by performing a two-factor ANOVA analysis is the interaction effect between the factors. There is no interaction effect between the dilution rates and the set ups if a change in dilution rate does not make a difference in the response to the change of set up, and vice versa. In the case where there is a significant interaction effect, the analysis should be repeated using separate parts of data in order to analyze the separate effect of set up and dilution rate. For all data analyses the level of significance was considered to be 0.05. All the statistical analyses were performed using Microsoft Excel and MATLAB Statistical Toolbox 6.5.1.

In addition to the statistical analyses, a visual inspection was also performed to confirm the results of data analyses for the differences between set ups or dilution rates. For this purpose, if the confidence intervals in two different set ups or dilution rates do not overlap, the effect is said to be statistically significant.

CHAPTER 4

EXPERIMENTAL RESULTS AND DISCUSSION

4.1 GENERAL

In this chapter, the experimental results of the test-chamber study are presented. Acceptability votes versus dilution rates were studied for all different set ups, and a comparison between the levels of acceptability for different single materials is carried out. Statistical analyses were performed to evaluate the possible differences between mixing and combination set ups. The result from this investigation examined the existence of any interaction amongst different building materials. Finally, the source strengths from single materials were added and the results were compared to Olf values of combination and mixing set ups, in order to evaluate the addition theory of Olf. Error bars plotted on figures are representative of standard deviation of data, unless otherwise specified. All data analyses are available in Appendix B. The cut-off *P* value used for the data analysis purposes is 0.05.

4.2 THE MEAN OF ACCEPTABILITY VOTES FOR BACKGROUND

Assessments of the main test room and the empty chamber considered as background checks were conducted in each round for both days of the experiments. The data from these tests reveal a comparison base regarding the level of acceptability of the air in the test chambers. The mean of acceptability votes based on the quality of perceived air from diffusers are plotted in Figures 4.1 and 4.2.

As it can be noticed, the means of the acceptability votes of air in both test room and empty chamber were almost constant during the whole experimental procedure for both days. Acceptability votes (mean± standard deviation) were 0.72 ±0.28 and 0.69 ±0.34 for the main test room and the empty test chamber, respectively. These values indicate good air quality in the background.

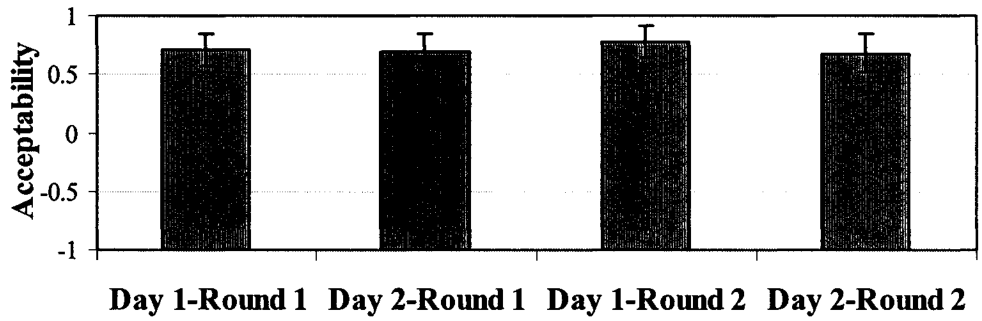


Figure 4.1. Mean acceptability of the main test room

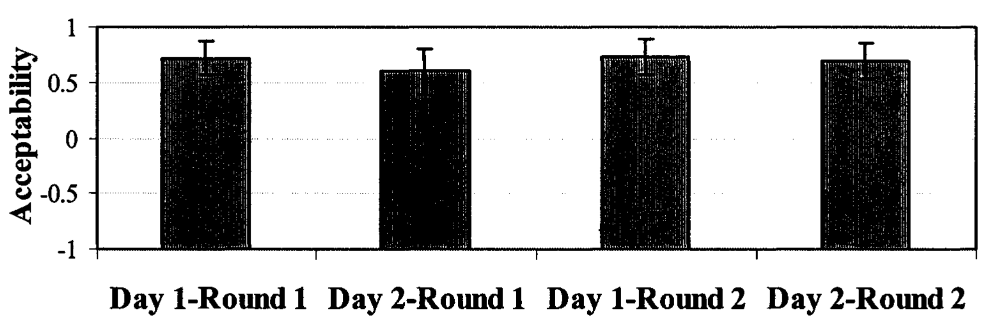


Figure 4.2. Mean acceptability of the empty test chamber

4.3 <u>EFFECT OF DIFFERENT DILUTION RATES</u>

The mean values of the votes at different dilution rates in each set up are plotted in Figures 4.3 to 4.8. Improvement in acceptability by increasing the dilution rates can be noted for all set ups except for dilution rates of 2.5 and 20 for the combination set up of paint and carpet. A technical problem in that set up is the possible justification for this unusual behavior. Intensity of odors follows a decreasing trend by increasing the level of dilution. However the degree of improvement for dissimilar set ups are different. The effect of increasing the dilution rate in improving acceptability of air exposed to building materials has been previously confirmed (Knudsen *et al.*, 1997a; Knudsen *et al.*, 1997b; Knudsen *et al.*, 1998; Haghighat *et al.*, 2001). Performing the data analysis for all different set ups showed significant difference in perceptions for different dilution rates in different set ups (P value < 0.05). P values representing the difference of votes were also calculated for each case, which are available in Appendix B.

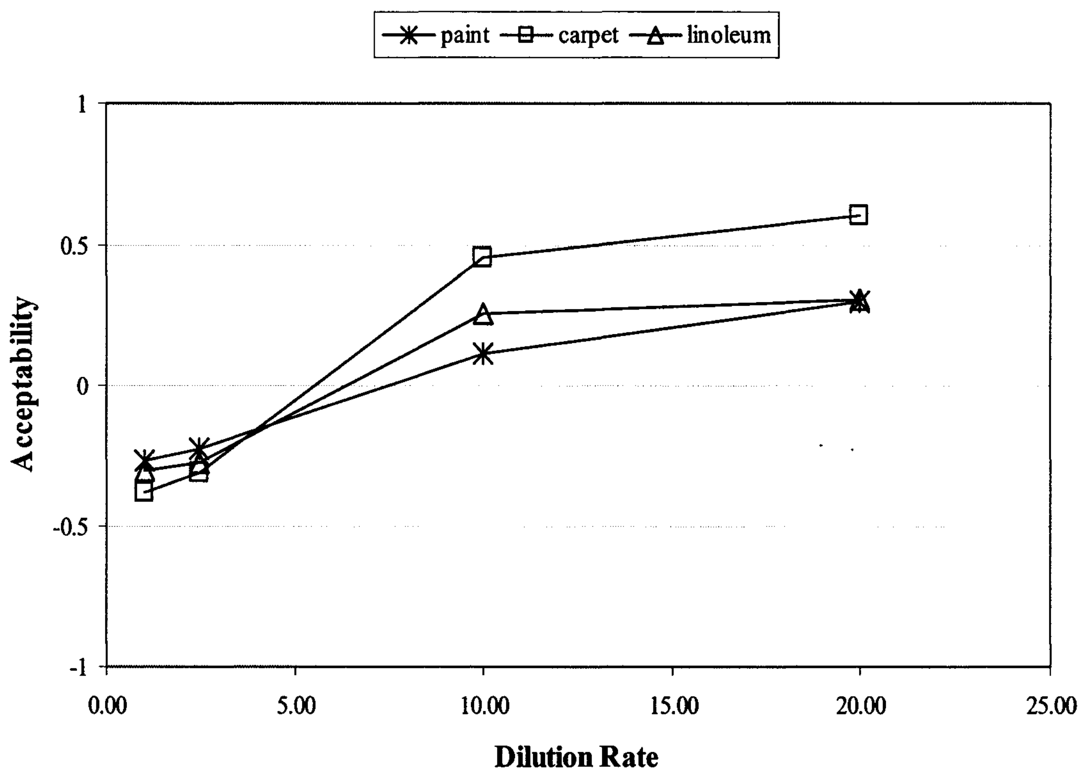


Figure 4.3. Mean of acceptability votes versus dilution rate- single set up

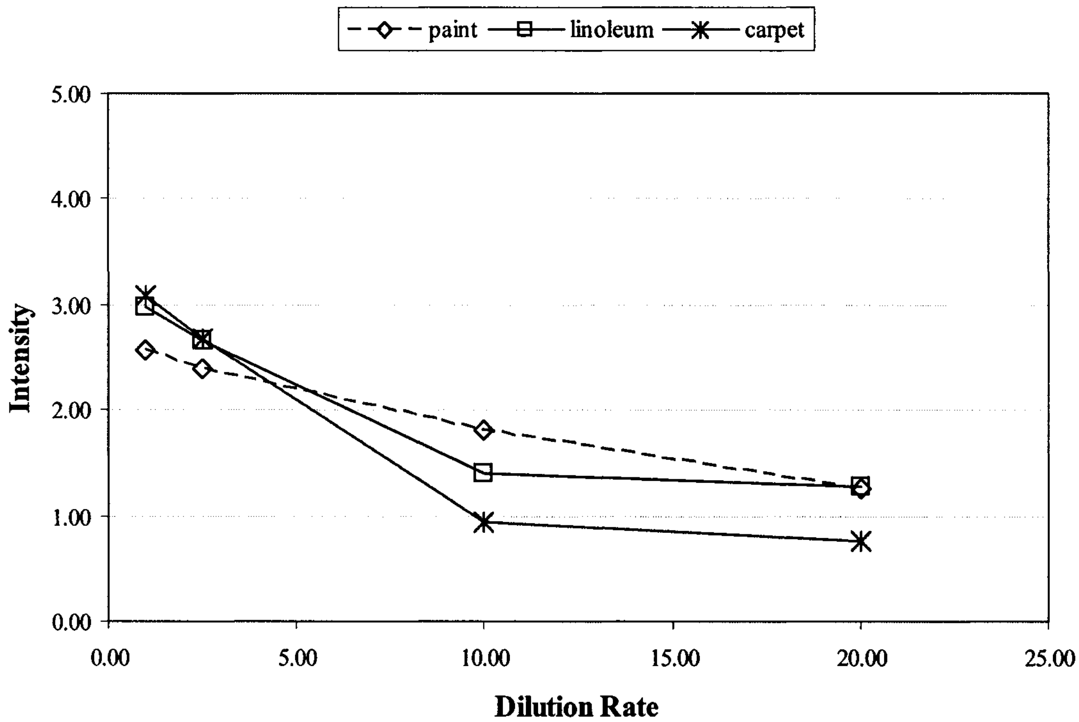


Figure 4.4. Mean of intensity votes versus dilution rate- single set up

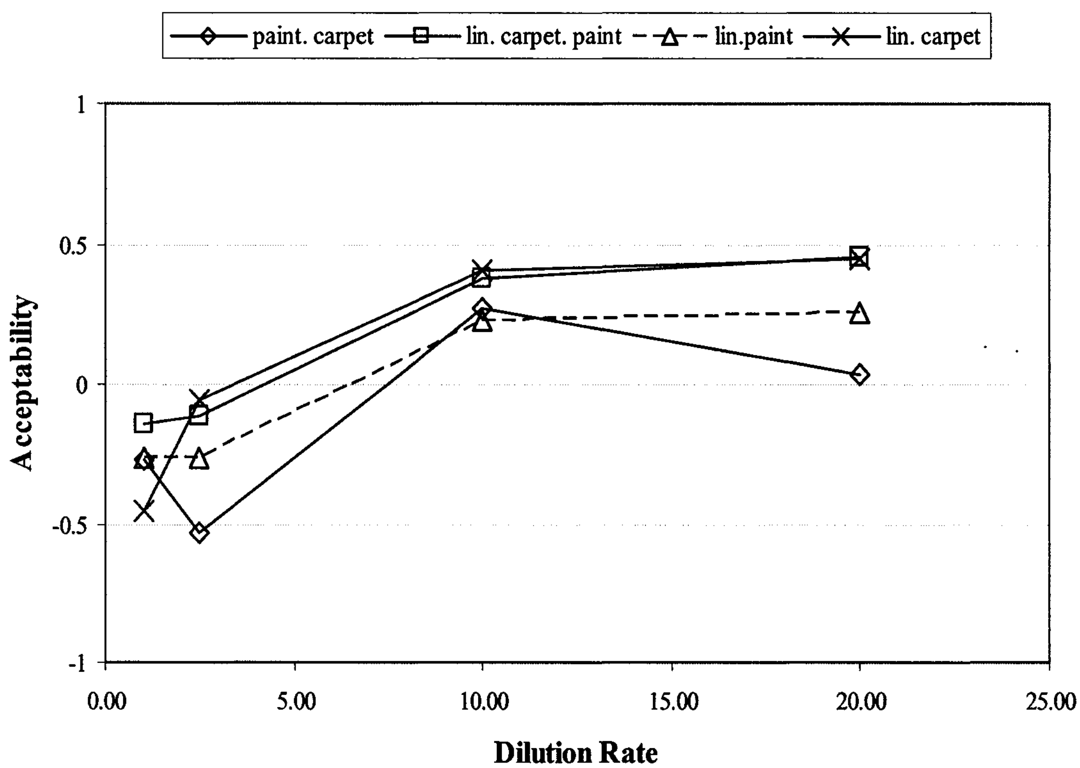


Figure 4.5. Mean of acceptability votes versus dilution rate- combination set up

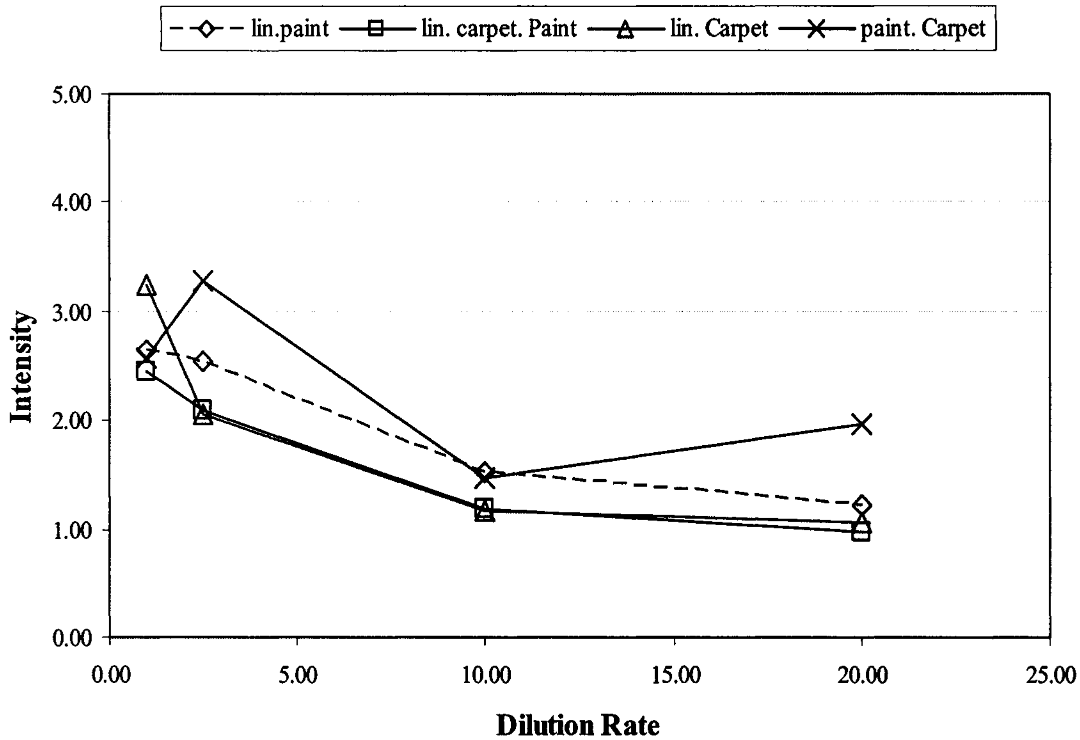


Figure 4.6. Mean of intensity votes versus dilution rate- combination set up

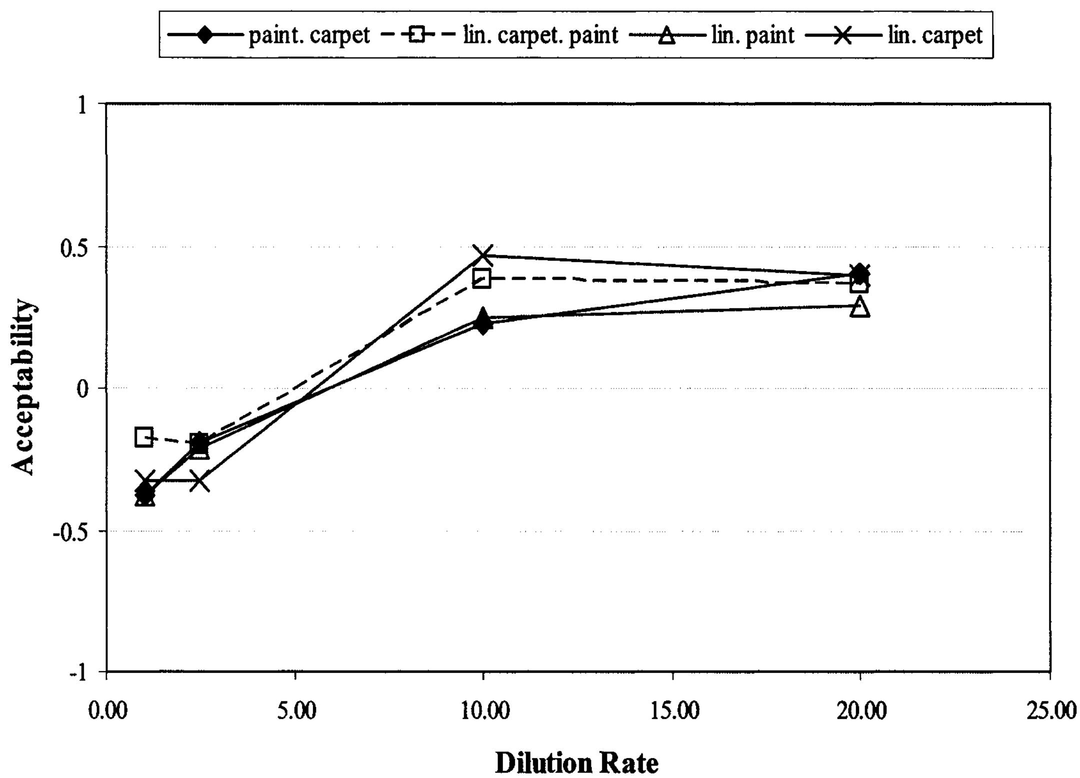


Figure 4.7. Mean of acceptability votes versus dilution rate- mixing set up

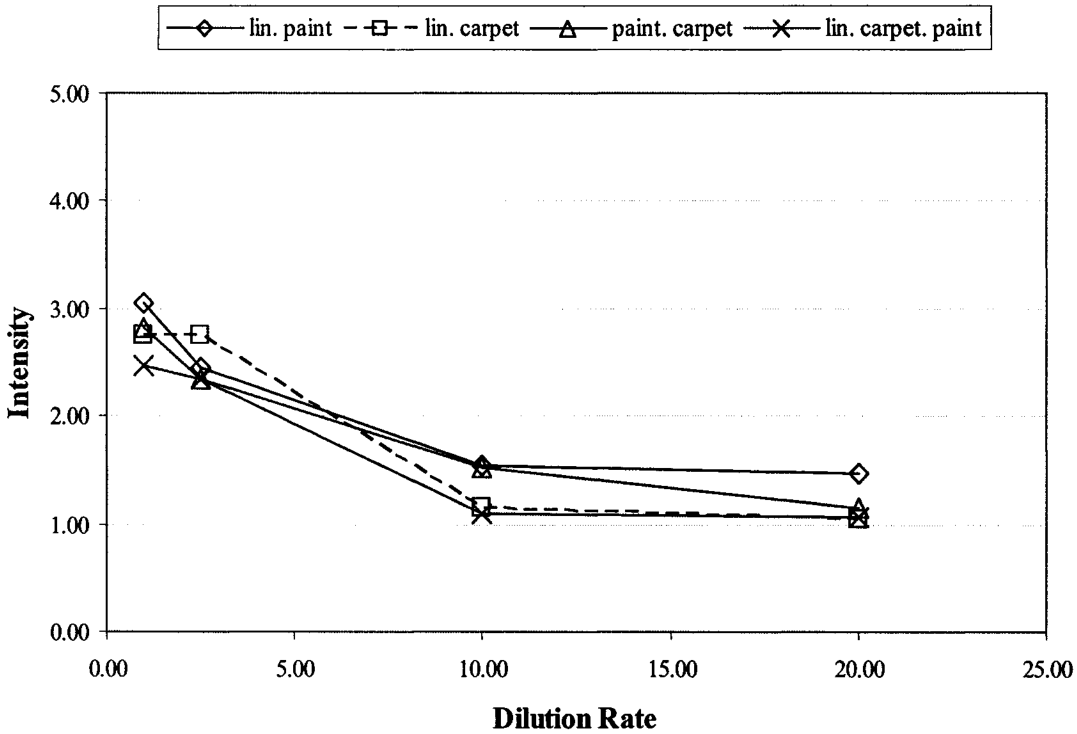
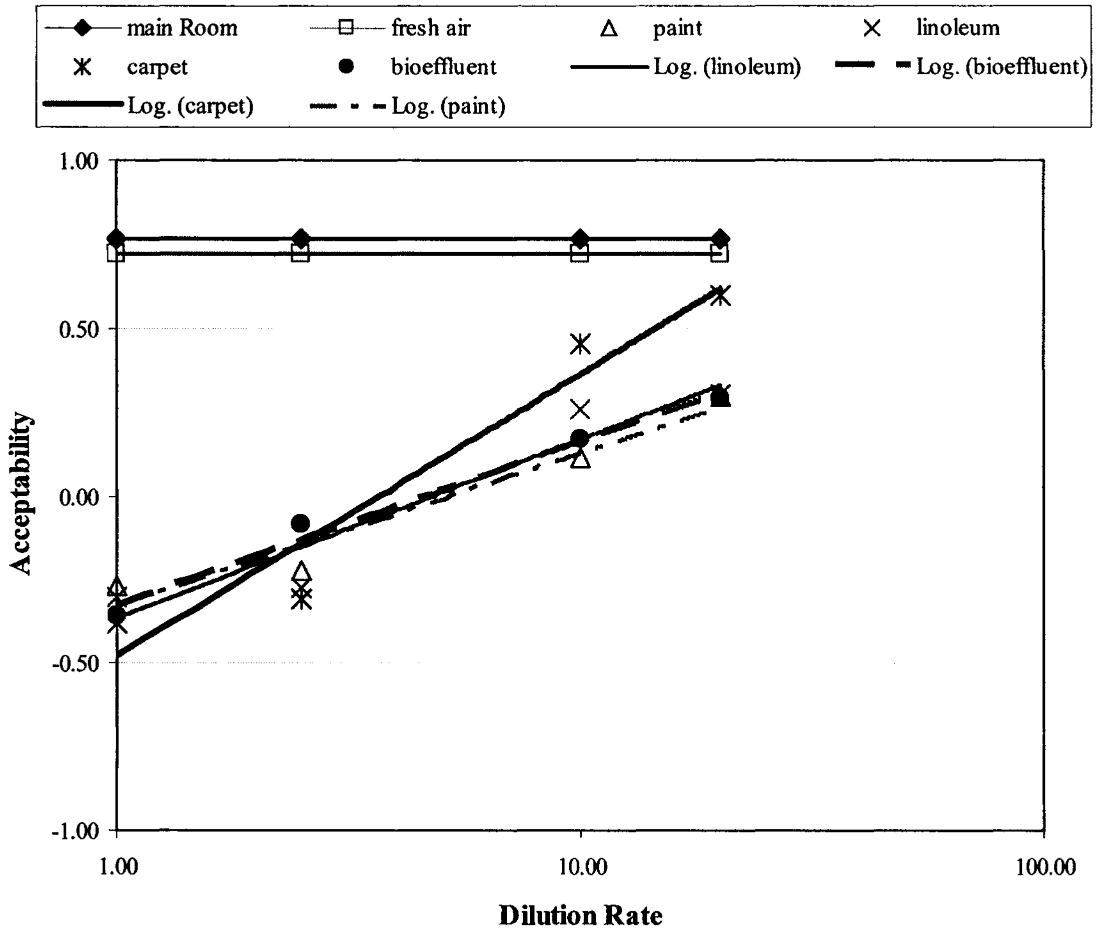


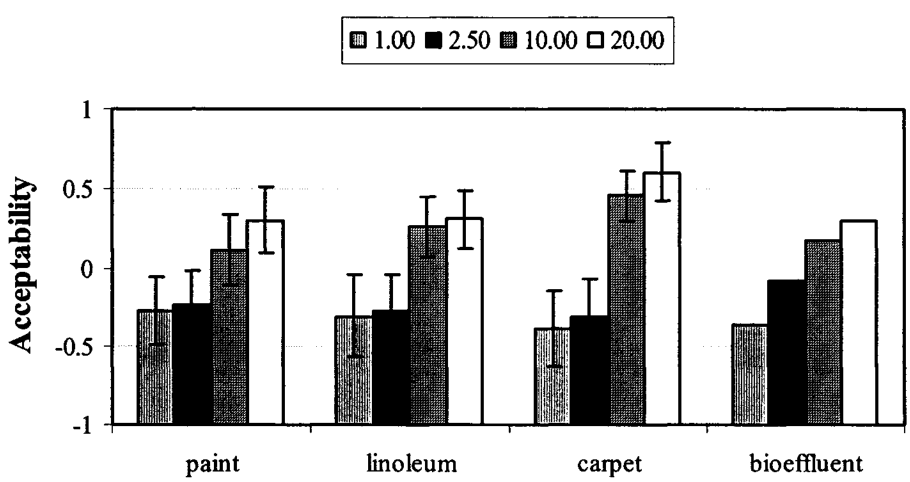
Figure 4.8. Mean of intensity votes versus dilution rate- mixing set up

4.4 EXPOSURE RESPONSE CURVE FOR SINGLE MATERIALS AND HUMAN BIOEFFLUENT

The equations of exposure response curves were obtained for the three single materials, performing a logarithmic regression between acceptability and dilution rate. Figure 4.9 demonstrates the exposure response curves for the three single materials, i.e. carpet, paint and linoleum, along with the level of air acceptability in the presence of one standard person, defined as human bioeffluent (Fanger, 1988; Gunnarsen and Fanger, 1992). This figure shows the mean acceptability of votes versus different dilution rates. The figure confirms that the only criterion in selecting the specimens, as mentioned in Chapter 3, for a start point of acceptability votes in the lower part of the scale, and far from both ends of the scale, has been fulfilled for all three types of materials.



(a)



(b)

Figure 4.9. Mean acceptability of single materials and human bioeffluent for different dilution rates, a) Trend lines of perceptions, b) Standard deviation of votes around the means

Table 4.1. Exposure response curves equations of single materials and bioeffluent

Materials	Trend Line Equation	R-squared Value
Carpet	Y=0.3356 Ln (X)- 0.4771	0.9416
Linoleum	Y=0.2327 Ln (X)- 0.3659	0.9162
Paint on Gypsum Board	Y=0.1979 Ln (X)- 0.3286	0.9501
Human Bioeffluent	Y=0.2129 Ln (X)- 0.3288	1

A statistical analysis to observe the difference among the bioeffluent and investigated individual building materials shows that:

- The difference of acceptability votes for single set ups of carpet and paint were marginally significant with P=0.06. There was a significant interaction between the effects of dilution rates and different set ups, with P value equals 0.0065. Since this value was less than 0.05, the analysis was repeated using separate parts of data in order to analyze the separate effects of set up and dilution rate. Further analysis showed that the significant differences between results for carpet and paint existed at dilution rate of 10 and 20. The P values in those two cases were 0.0029 and 0.009, respectively.
- The difference of acceptability votes for paint and linoleum was not significant (P value= 0.8). This meant that panel members could not distinguish between the acceptability level of paint and linoleum. There was merely a difference between acceptability of votes when different dilution rates were taken into account.

- The difference of acceptability votes for carpet and linoleum were not significant with *P*=0.12. However, the repetition of analysis for separate parts of data showed that the significant differences between results for carpet and linoleum can be observed at dilution rates of 10 and 20. The *P* values in those two cases were 0.05 and 0.007, respectively.
- The difference of acceptability votes for paint and human bioeffluent was not significant with *P* value equals to 0.6.
- *P* value representing the statistical difference between human bioeffluent and linoleum was 0.88, which is an indication of an insignificant difference.
- The statistical analysis performed for carpet and human bioeffluent showed a significant difference with the *P* value of 0.03.

The results from these analyses showed that carpet might be perceived differently compared to linoleum and paint, while the two later ones were almost assessed the same. However, the difference in perception when the air was polluted by carpet rather than two other materials only existed when outlet air from chambers was diluted to 10 and 20 times with unpolluted fresh air. Moreover, the sensory panel did not differentiate between the carpet with the other two building materials for the dilution rates of 1 and 2.5. Subjects could not also discriminate between the pollution level generated by the linoleum and paint. Figure 4.9 indicates that when these three specific types of materials were separately used with equal air specific flow rates in an office building, the air quality in each case can be perceived as the same as each other.

Data analyses also showed a significant difference between the acceptability votes caused by carpet compared to the acceptability votes caused by human bioeffluent (P=0.03). Based on the results from data analyses, there was no statistical difference between the acceptability level generated by the bioeffluent and the linoleum or paint.

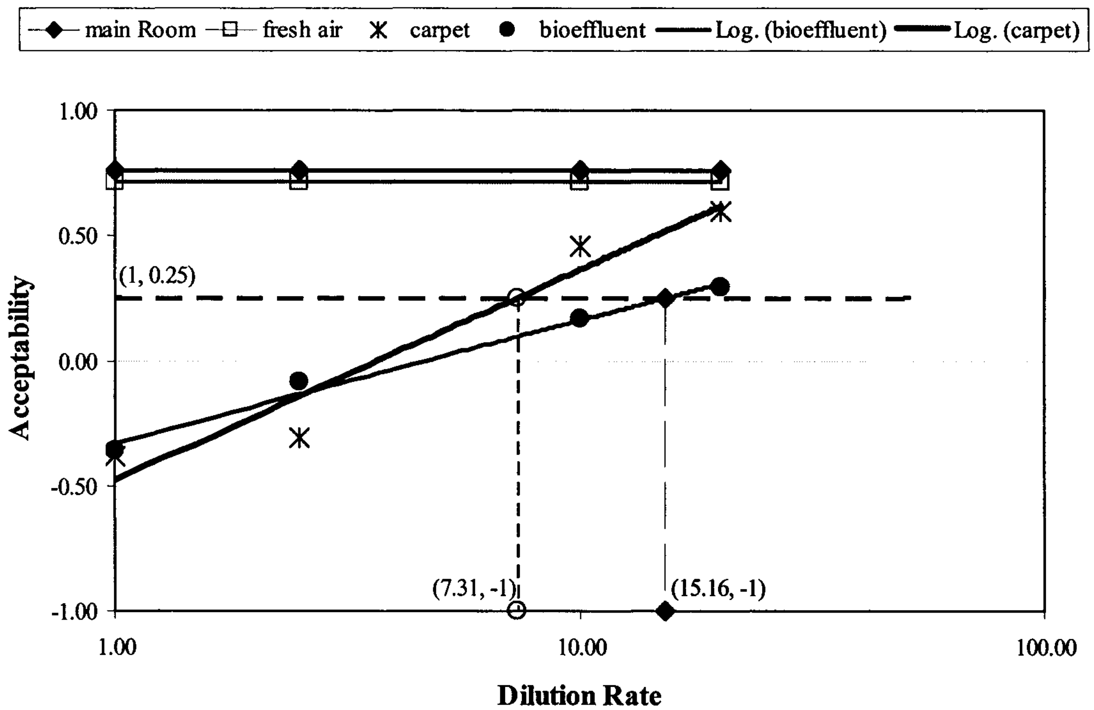


Figure 4.10. Difference between the required dilution rate when the air is polluted by carpet and bioeffluent to achieve the same level of acceptability

Furthermore, the slope of curve representing the acceptability votes of carpet was different from the two other building materials and human bioeffluent (Table 4.1). Based on this investigation, the dilution rate required to achieve a certain acceptability level was different between the carpet and the other investigated materials. Slopes of the curves for linoleum and paint were almost the same as bioeffluent, while the one for carpet was steeper. Figure 4.10 shows that lower ventilation rate is required when air is polluted by carpet to achieve an acceptability level of 0.25 compared to the time air is polluted by bioeffluent. The same conclusion can also be drawn for the difference of required ventilation rates for time air is being polluted by carpet and linoleum or paint. This conclusion is valid under the assumption that doubling the ventilation rate leads to twice dilution rate. This fact shows that generalizing the dissatisfaction level generated by different indoor materials by defining one general bundle of curves with different intercept but parallel to the curve of human bioeffluent is not the correct approach to solve indoor air quality problems. This has been also shown previously that different materials might have different exposure response curves with different slopes compared to each other and to human bioeffluent (Knudsen *et al.*, 1997a; Knudsen *et al.*, 1997b; Bluyssen and Cornelissen, 1997; Knudsen *et al.*, 1998).

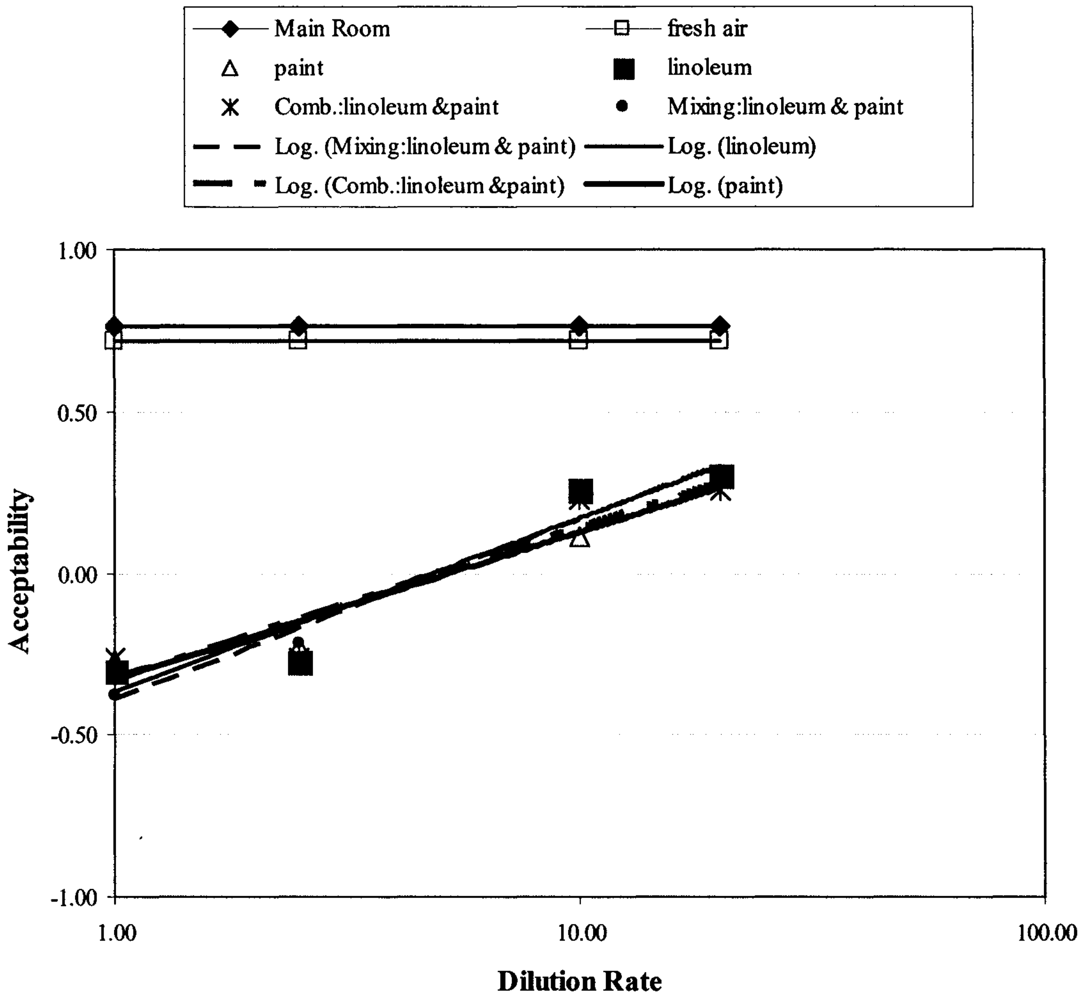
4.5 EXPOSURE RESPONSE CURVE FOR COMBINATION AND MIXING

The followings explains the differences of the results between different set ups of materials.

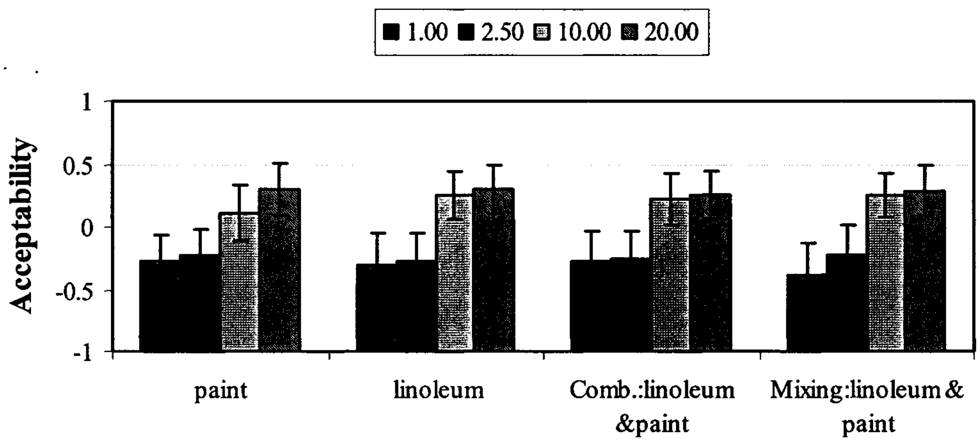
4.5.1 Linoleum & Paint

The mean values of acceptability votes versus different dilution rates for linoleum and paint when they were placed individually in separate single chambers, in combination, and the mixing set ups are shown in Figure 4.11.

Data analysis conducted to clarify the difference of perception between the mixing and the combination set ups of linoleum and paint showed that they were not statistically different. *P* value representing the difference between these two types of set ups was 0.97



(a)



(b)

Figure 4.11. Mean acceptability of air for single, combination and mixing set ups of linoleum and paint, a) Trend lines of perceptions, b) Standard deviation of votes around the means

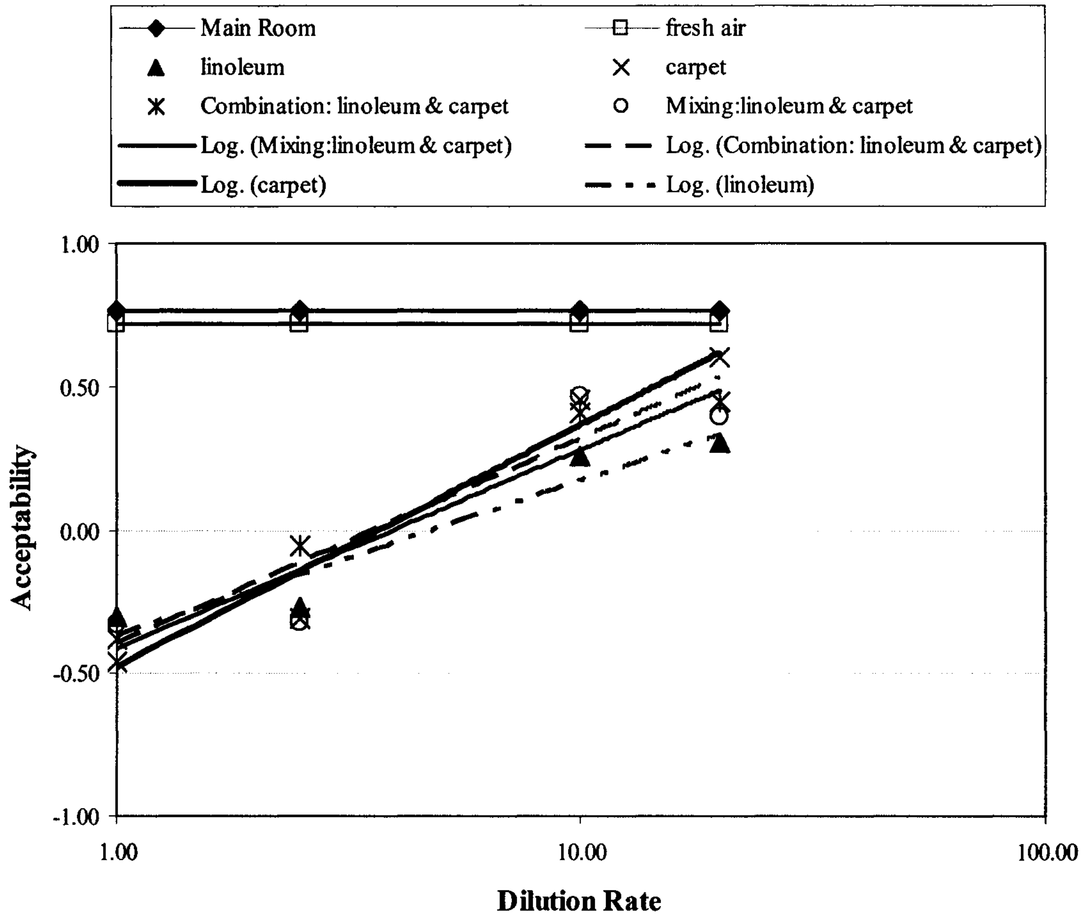
which was much higher than 0.05. A further investigation showed that there was no significant difference between single cases of linoleum and paint, compared to combination and mixing set ups.

4.5.2 Linoleum & Carpet

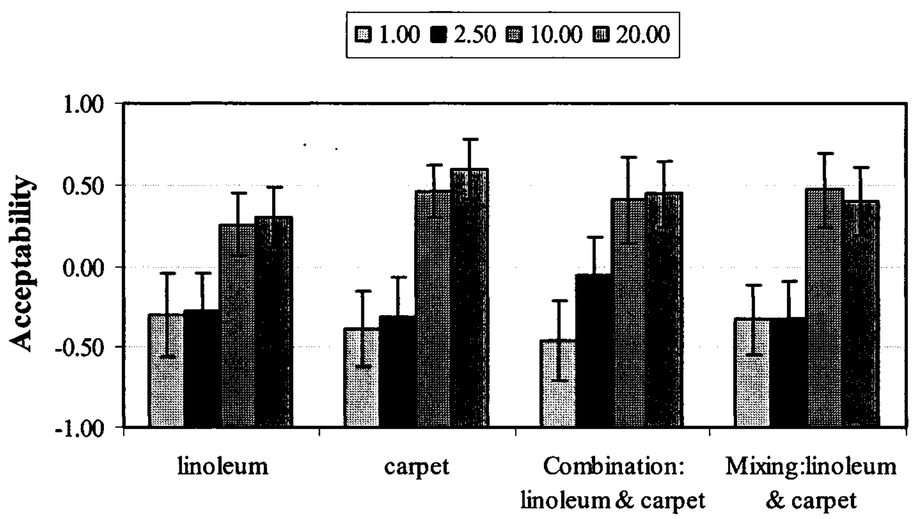
The means of acceptability votes versus different dilution rates for linoleum and carpet in single set ups, after being mixed in the mixing chamber, and in a combination set up are shown in Figure 4.12. The *P* value for combination and mixing set ups of samples prepared from carpet and linoleum was equal to 0.66. Based on this result the difference between these two configurations was not statistically significant. Furthermore, to investigate the difference between single set ups of carpet and linoleum, with the combination and mixing ones, it can be also concluded that there existed no significant difference between these arrangements. *P* values representing the statistical differences are available in Appendix B.

4.5.3 Carpet & Paint

Figure 4.13 shows the mean of acceptability votes as a function of dilution rate for single, combination, and mixing set ups of carpet and linoleum. The *P* value for the case of comparing the mixing and combination set ups of carpet and paint was 0.02. Data analysis also showed that there was an interaction effect between dilution rates and set ups. The interaction effect can be examined by conducting the analysis separately

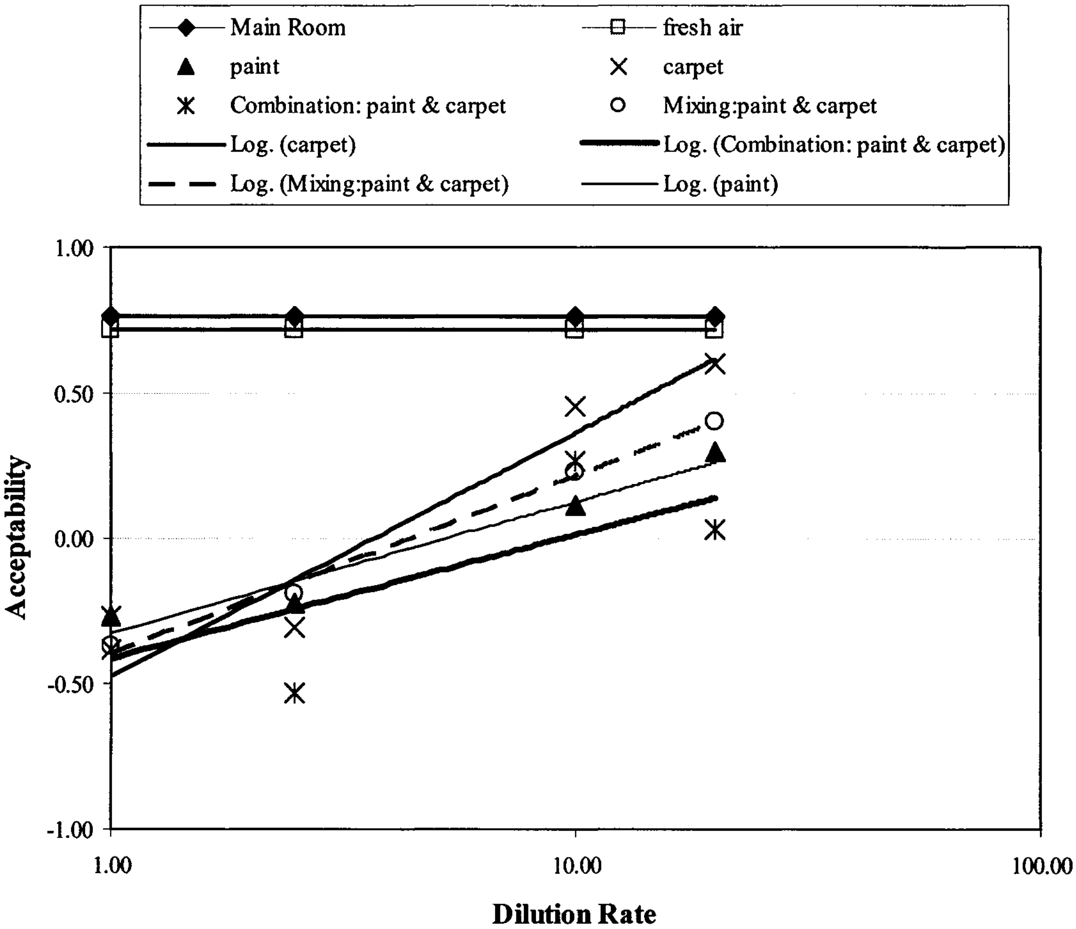


(a)

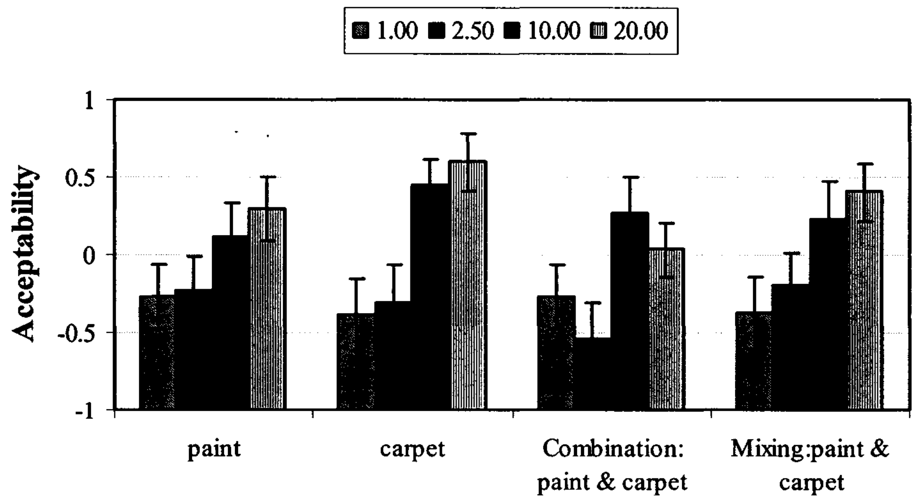


(b)

Figure 4.12. Mean acceptability of air for single, combination and mixing set ups of linoleum and carpet, a) Trend lines of perceptions, b) Standard deviation of votes around the means



(a)



(b)

Figure4.13. Mean acceptability of air for single, combination and mixing set ups of carpet and paint, a) Trend lines of perceptions, b) Standard deviation of votes around the means

for every dilution rates. This investigation shows that the differences are significant for dilution rates of 2.5 and 20. Since the value for the whole set up is less than 0.05, a significant difference could be concluded. However, by monitoring all the data in the combination set up of carpet and paint, it can be observed that the means of acceptability votes in second and fourth rounds do not follow the increasing trend of the curve. These two rounds included dilution rates of 2.5 and 20. This could be due to a technical problem in that specific chamber on the second day of experiments, as both rounds of experiments with dilution rates of 2.5 and 20 were conducted simultaneously in the second day of experiments.

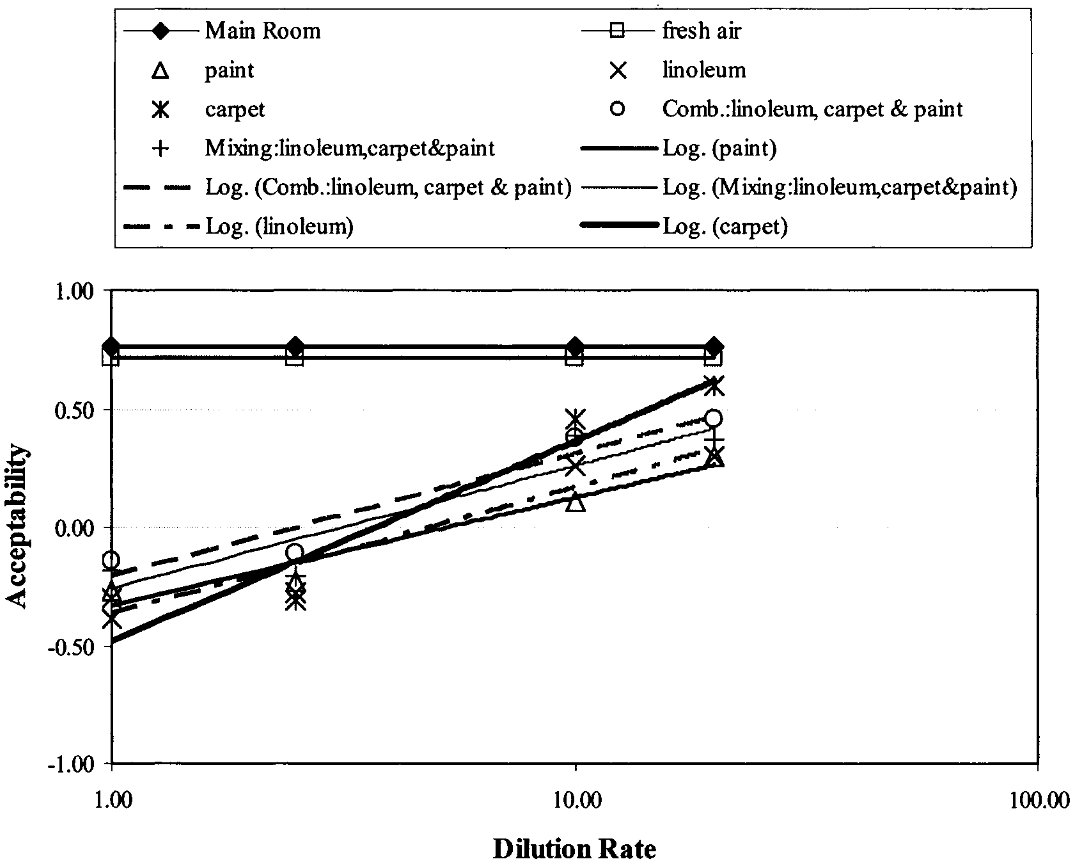
Data analysis to observe the possible differences between single set ups of paint and carpet and combination and mixing set ups, revealed a statistical difference between the single set ups and combination set up. There existed no differences between the single set ups and mixing set up. Due to the probable technical problems in the combination set up on the second day of the experiment, the corresponding *P* values were not reliable.

4.5.4 Carpet, Linoleum & Paint

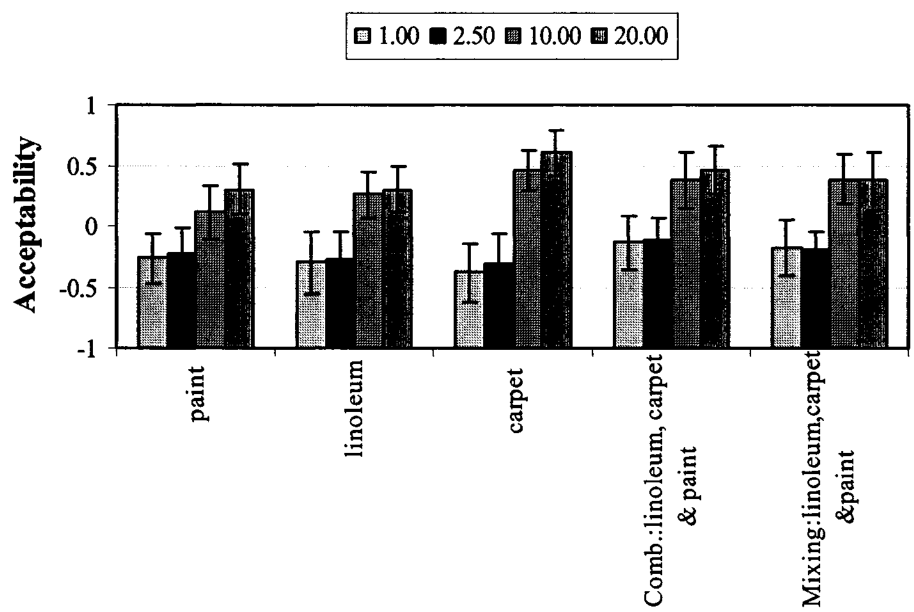
The means of acceptability votes for different dilution rates for carpet, linoleum and paint individually placed in separate single chambers, in combination set up, and in the mixing set up are shown in Figure 4.14. Data analysis showed that the difference of votes for acceptability of air in combination and mixing set ups for all three samples, i.e. carpet, linoleum and paint, was not statistically significant. The *P* value in this case was equal to 0.38 which was higher than 0.05, the cut-off *P* value.

The P values showing the statistical differences between the combination set up of linoleum and paint and their single set ups were 0.014 and 0.006, respectively. This investigation showed a significant difference between the combination and these two single set ups. Further analyses showed no difference amongst the other set ups.

Figure 4.15 shows the acceptability votes for all experimental set ups and dilution rates. Error bars in this figure represent the confidence intervals of the observations. Significant differences among different set ups were observed visually in this figure. Two sets of data, as it has been previously described in Chapter 3, were statistically different when their confidence interval bars are not overlapping.



(a)



(b)

Figure 4.14. Mean acceptability of air for single, combination and mixing set ups of linoleum, paint and carpet, a) Trend lines of perceptions, b) Standard deviation of votes around the means

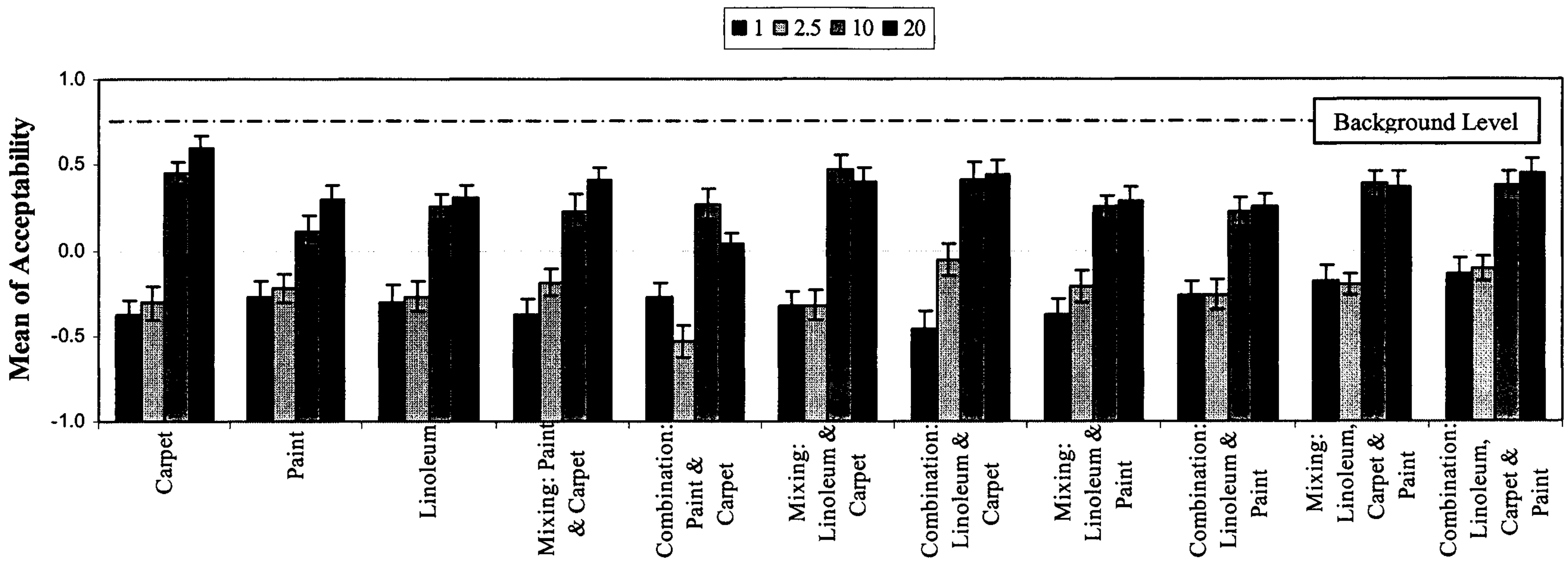


Figure 4.15. Mean acceptability of air for all different set ups and dilution rates

4.6 CALCULATION OF SENSORY POLLUTION LOAD

Using the equation proposed by Gunnarsen and Fanger (1992), the percentage of dissatisfied people was calculated as a function of the mean of acceptability votes in each set up and dilution rate:

$$PD = \left(\frac{\exp(-0.18 - 5.28 * Acc.)}{1 + \exp(-0.18 - 5.28 * Acc.)} \right) * 100 \qquad (4.1)$$

Where:

PD is the percentage of dissatisfied people (%)

$Acc.$ is the mean of acceptability votes

Furthermore, the perceived air quality in decipol was determined by utilizing the calculated values of percentage of dissatisfied people from the previous equation using Equation. 4.2 (Fanger, 1988):

$$C = 112(\ln(PD) - 5.98)^{-4} \qquad (4.2)$$

Where:

C is the perceived air quality (decipol)

PD is the percentage of dissatisfied people (%)

The sensory pollution load in olf can be calculated using the value of perceived air quality from Equation 4.2 and the measured flow rate in the comfort equation defined by Fanger (1989):

$$G = 0.1Q(C - C_0) \qquad (4.3)$$

Where:

G is the sensory pollution loads (olf)

Q is the outdoor air flow rate to the chamber (L/s)

C is the perceived air quality in the test chamber (decipol)

C_0 is the perceived air quality of the empty chamber (decipol)

4.7 ADDITION OF OLF VALUES

Calculated Olf values for mixing, combination and single set ups of three types of materials in different dilution rates are used to evaluate the theory of addition of sensory pollution loads. The area of materials was reduced to half and one third in different cases of combination and mixing set ups. The inlet air flow was also reduced to half and one third in each case correspondingly. This configuration proposes that the source strength in mixing and combination set ups of two materials was comparable to half of addition of loads from two single set ups with the same type of materials. For the case of three materials, source strength in mixing or combination set ups were compared to one third of addition of olf values from single set ups. The comparison of results was performed by conducting a series of data analysis for every group of materials to clarify if the prediction of sensory pollution loads for combination and mixing set ups is possible by the simple summation of Olf values from single materials. In order to confirm the results of data analyses, visual inspection was also performed for every group of materials. For this purpose, the actual source strengths were plotted versus the predicted source strengths in Figures 4.16 to 4.23. In these figures, small points represent individual votes, while large points represent means of individual votes for four different dilution rates.

4.7.1 Linoleum & Paint

Equations 4.1 to 4.3 were used to calculate the sensory pollution load expressed in olf for every single assessment votes of linoleum and paint individually, in the combination and the mixing set ups. The results from single set ups were added to each other and the comparisons were conducted between this addition, and data from mixing and combination set ups.

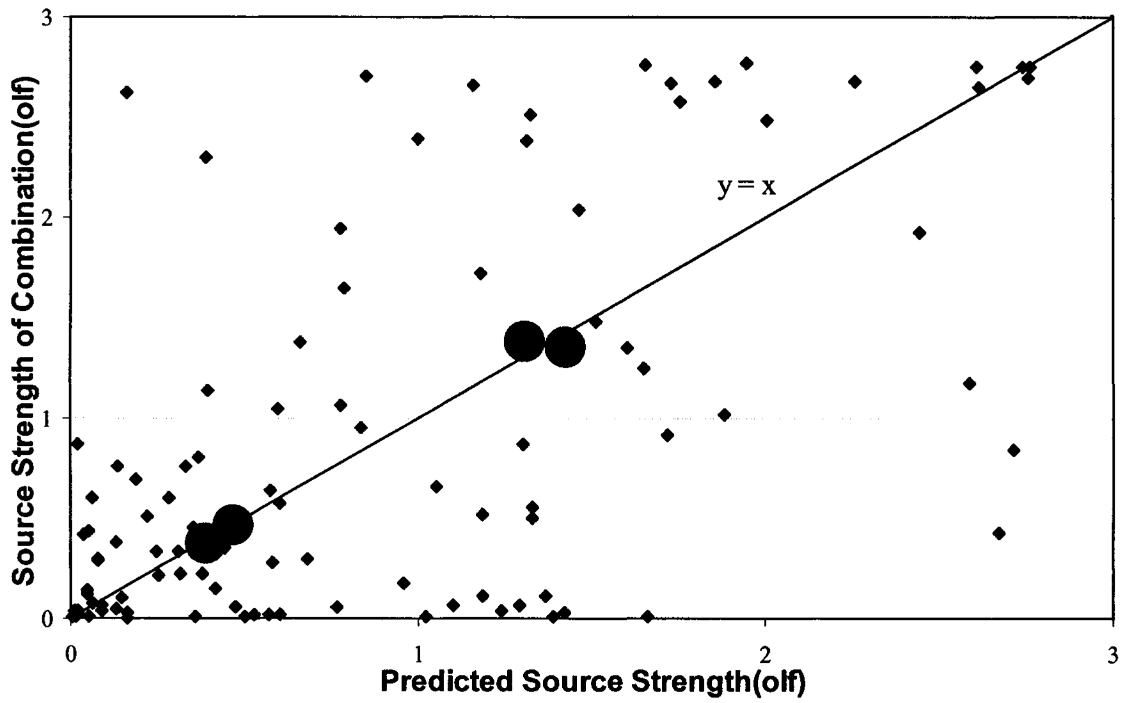


Figure 4.16. Source strength of combination versus addition of source strengths in single set ups-linoleum & paint

The *P* value representing the difference was 0.93 in the case of the combination and added value of single materials, and 0.92 in the case of mixing and single set ups. Since these values were much higher than the cut-off *P* value of 0.05, no significant difference between calculated sensory pollution loads and experimental sensory pollution loads can be concluded. Figures 4.16 and 4.17 show the source strength of combination and mixing set ups, respectively, versus the addition of loads of single set ups. As it can be observed, the data points representing the relation between the mean of actual source strength and the mean of predicted source strength is very close to the line of equity, $y=x$. This investigation shows that using the addition of Olfs to predict the quality of perceived air in presence of these two specific types of building materials can generally estimate the generated source strength.

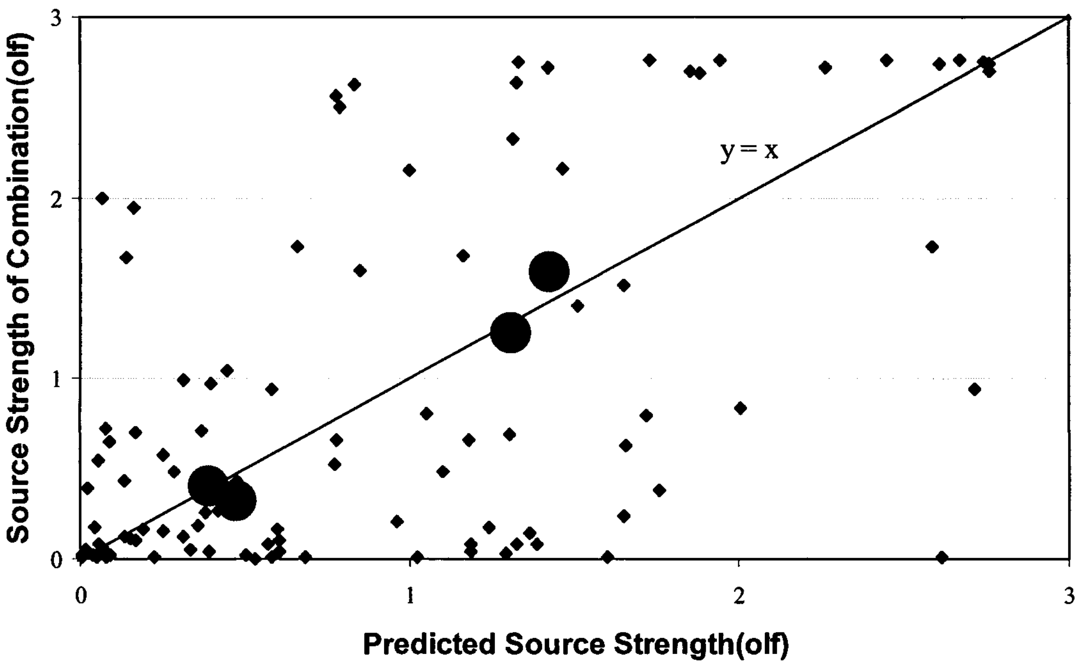


Figure 4.17. Source strength of mixture versus addition of source strengths in single set ups- linoleum & paint

4.7.2 Linoleum & Carpet

Performing an ANOVA data analysis to investigate the difference between the addition of source strengths from single materials and the source strength of combination set up revealed an insignificant difference with the P value of 0.86. The P value equaled 0.57 in the case of the difference between the addition of source strength of single set ups and source strength of mixing set up. The calculation procedure described in section 4.6 was conducted to determine the source strengths in different cases.

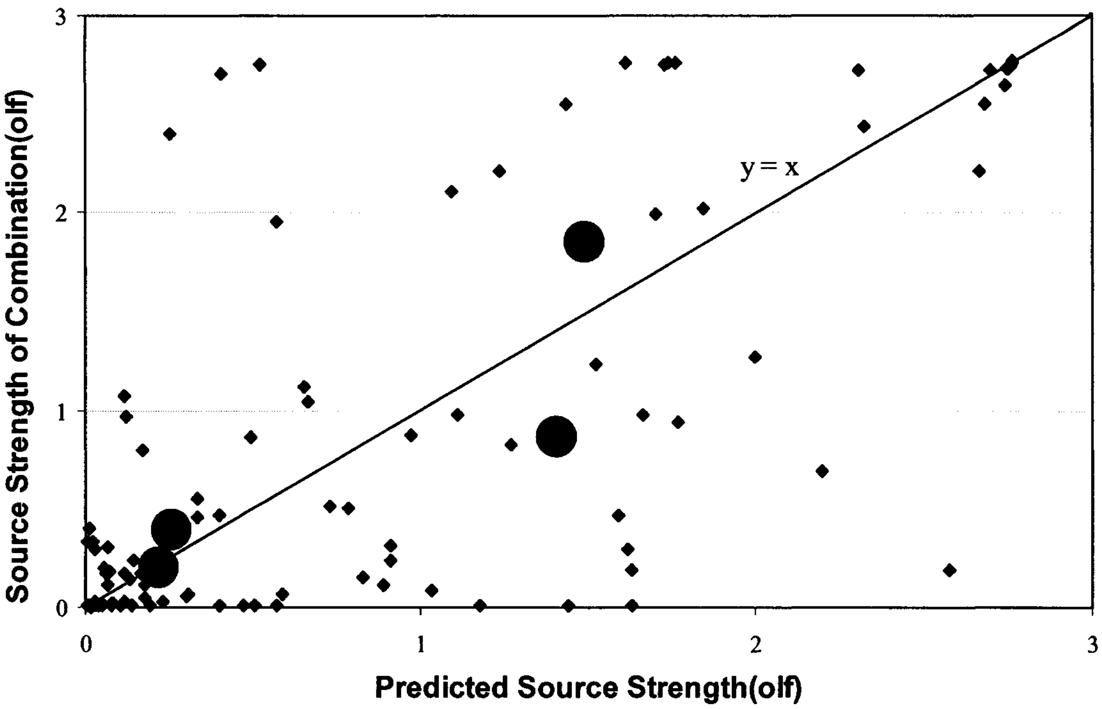


Figure 4.18. Source strength of combination versus addition of source strengths in single set ups- linoleum & carpet

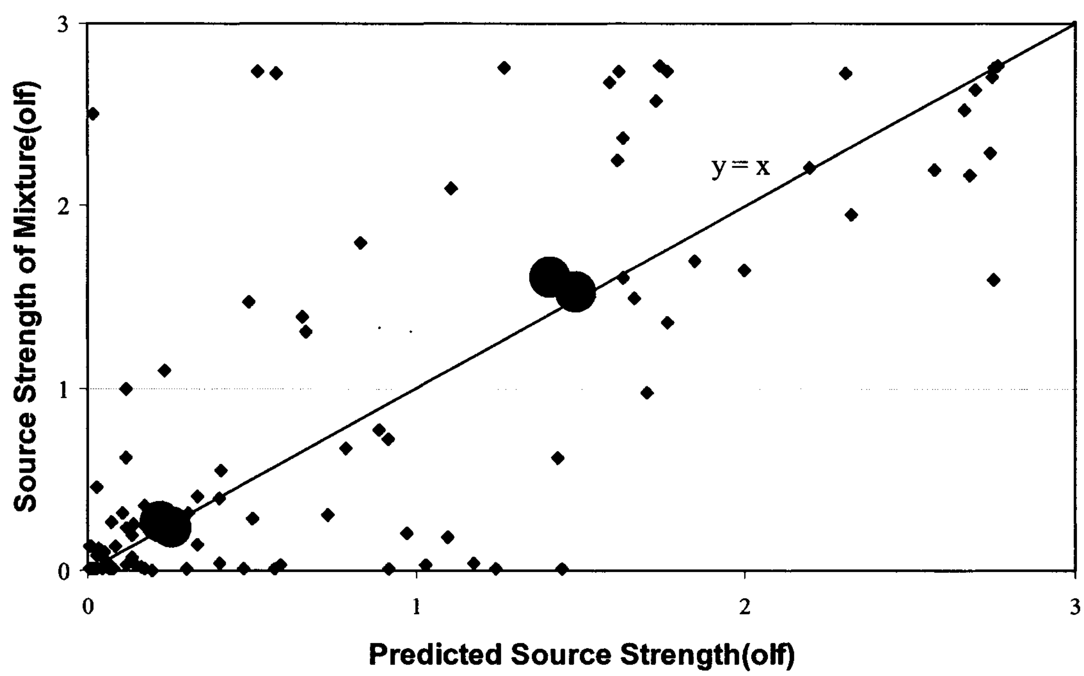


Figure 4.19. Source strength of mixture versus addition of source strengths in single set ups- linoleum & carpet

As it can be noticed in Figures 4.18 and 4.19, the means of addition of the source strengths of single materials versus the means of actual source strength lead to data points close to the equity line for the case of linoleum and carpet.

4.7.3 Carpet & Paint

The *P* value representing the difference between the addition of Olfs from single set ups of carpet and paint, and the combination of these two building materials was 0.015. The low *P* value in this case can be due to the technical problem already mentioned in previous sections. Figure 4.20 shows the actual source strength of combination versus addition of loads from single materials. The *P*-value equaled 0.91 in case of analysis performed between addition of Olfs from single set ups and mixing set up. Moreover, the insignificant difference in the case of mixing set up can be showed by observing the plot

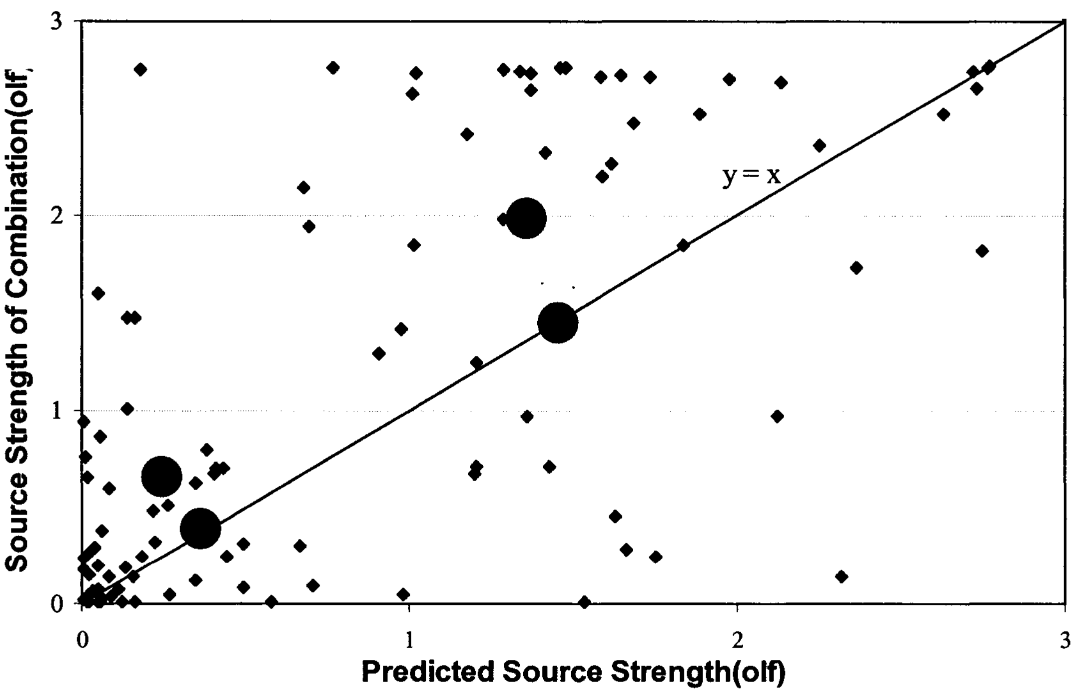


Figure 4.20. Source strength of combination versus addition of source strengths in single set ups-Paint & Carpet

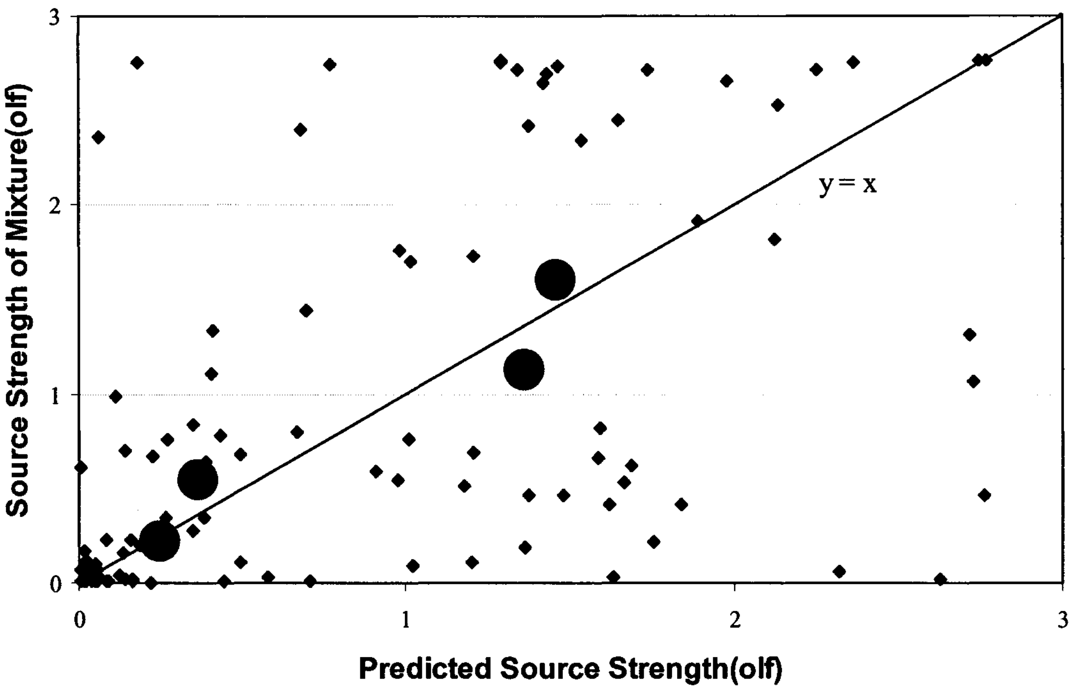


Figure 4.21. Source strength of mixture versus addition of source strengths in single set ups- Paint & Carpet

representing the source strength of mixing set up versus the predicted values, Figure 4.21.

4.7.4 Carpet, Linoleum & Paint

The last series of data analysis was performed for the case of carpet, linoleum and paint in single, combination and mixing set ups. The *P* values in these cases were 0.07 for difference between the added values of Olf from single materials and Olfs of combination set up, and 0.20 for the difference between the added values of Olf from single materials and Olfs of mixing set up. As it can be noted, insignificant differences existed in both cases. Figures 4.22 and 4.23 confirm the data analyses results, as the mean values in both cases are very close to the line of $y = x$. This investigation showed that predicting the level of acceptability when the air is polluted by carpet, linoleum and paint by adding the source strength caused by the same individual materials might be possible.

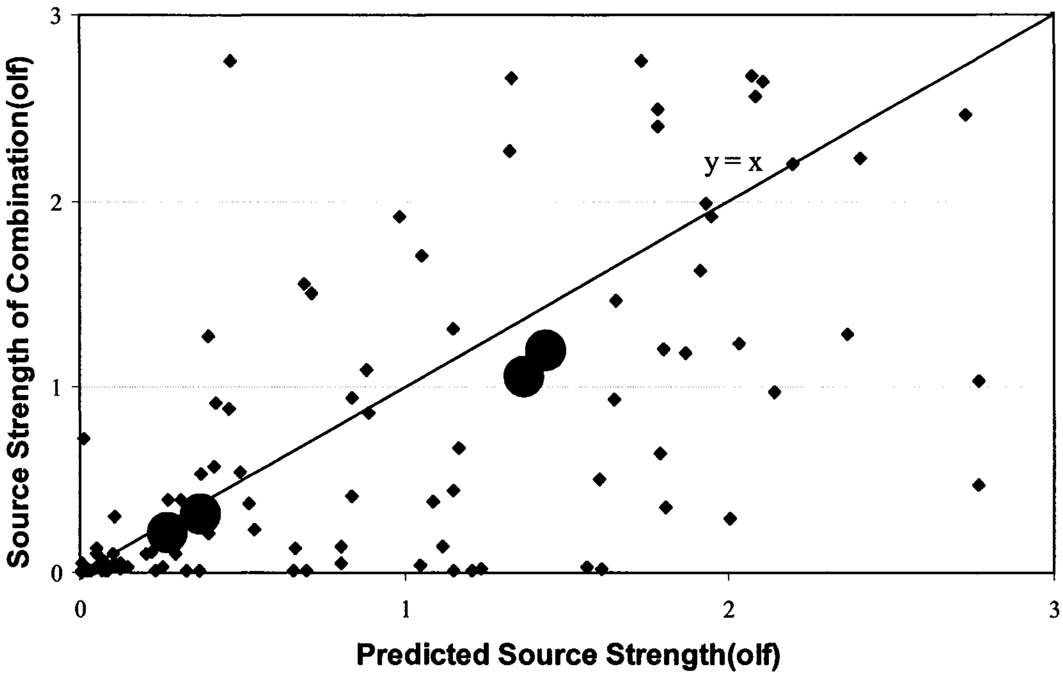


Figure 4.22. Source strength of combination versus addition of source strengths in single set ups- Paint, Linoleum & Carpet

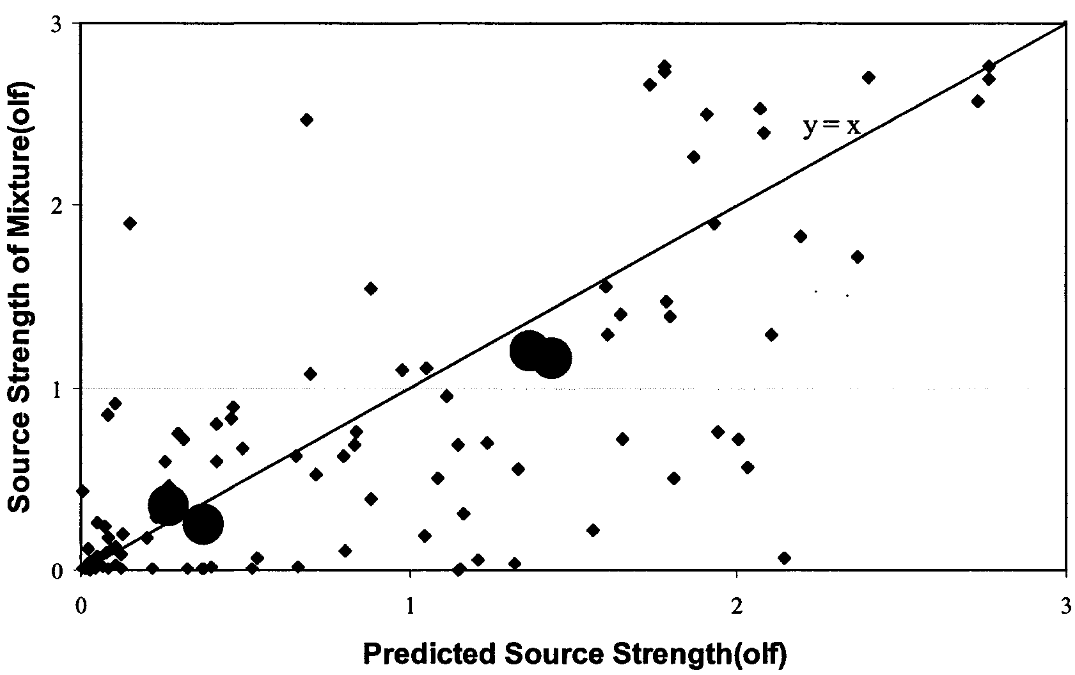


Figure 4.23. Source strength of mixture versus addition of source strengths in single set ups- Paint, Linoleum & Carpet

4.8 FURTHER DISCUSSION OF DATA

4.8.1 Variable Physical Conditions in Two Consecutive Days of Experiments

As it has been mentioned in section 3.5, temperature and relative humidity were not constant during the whole experimental procedure in both days. This change of physical conditions could affect the level of the acceptability of air. Fang *et. al* (1998) correlated the enthalpy of air based on temperature and relative humidity to the unacceptability vote for different materials. The enthalpy of air using physical conditions were equal on both days of experiments, as it was the objective of air conditioning system to maintain a constant enthalpy of inlet air to room. Moreover, the increase of temperature on the second day compared to the first day was followed by a decrease in the relative humidity of the air. This fact kept the enthalpy of air constant with a negligible difference. Based on this argument, the differences of votes on the two consecutive days of experiments cannot be justified by the differences in temperature and relative humidity.

4.8.2 Mean of Acceptability versus Mean of Intensity

Figure 4.24 shows that the mean of acceptability votes and the mean of intensity votes are finely correlated. In this figure the line $y = -0.4x + 1$ connects the upper extremes of both axes, and reflects the expected trend of an ideal experimental situation. In this condition, the no odor intensity defined as 0 should be perceived as the most acceptable air quality (air acceptability =1), and vice versa. As it can be noted from this figure, the data followed the expected trend line. Based on the experimental procedure performed in the current study, more intense odors were assessed as less acceptable by panel members.

The reverse phenomenon was observed for less intense odors as they have been perceived more acceptable.

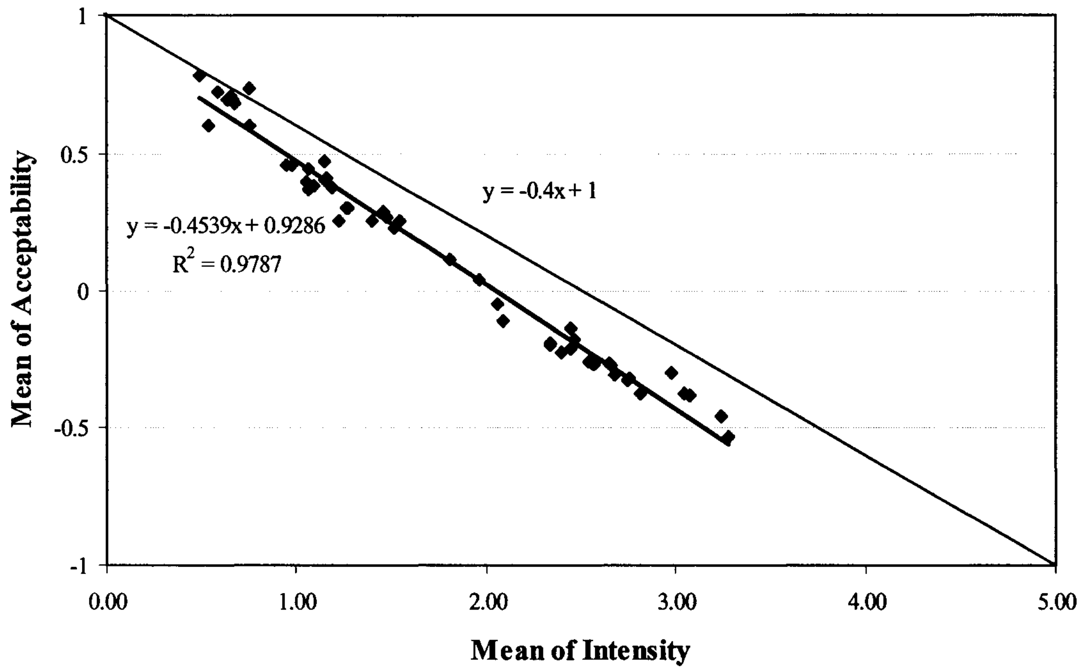


Figure 4.24. The mean of acceptability votes as a function of the mean of intensity votes

4.8.3 Standard Deviation of Votes

Figures 4.25 and 4.26 show the variation of the observations around the means. The standard deviations of votes were plotted versus the corresponded mean values of votes in these figures. Figure 4.25 suggests that the standard deviation decreased with the magnitude of the measurement (the means of observations in each set up). Based on this, the variability of votes decreased as the dilution rate increased. People were more in agreement about their votes at the upper end of the scale which is the most diluted situation. On the other hand, in Figure 4.26 there is a clear increasing relationship between standard deviation of intensity and mean value of intensity, indicating that the

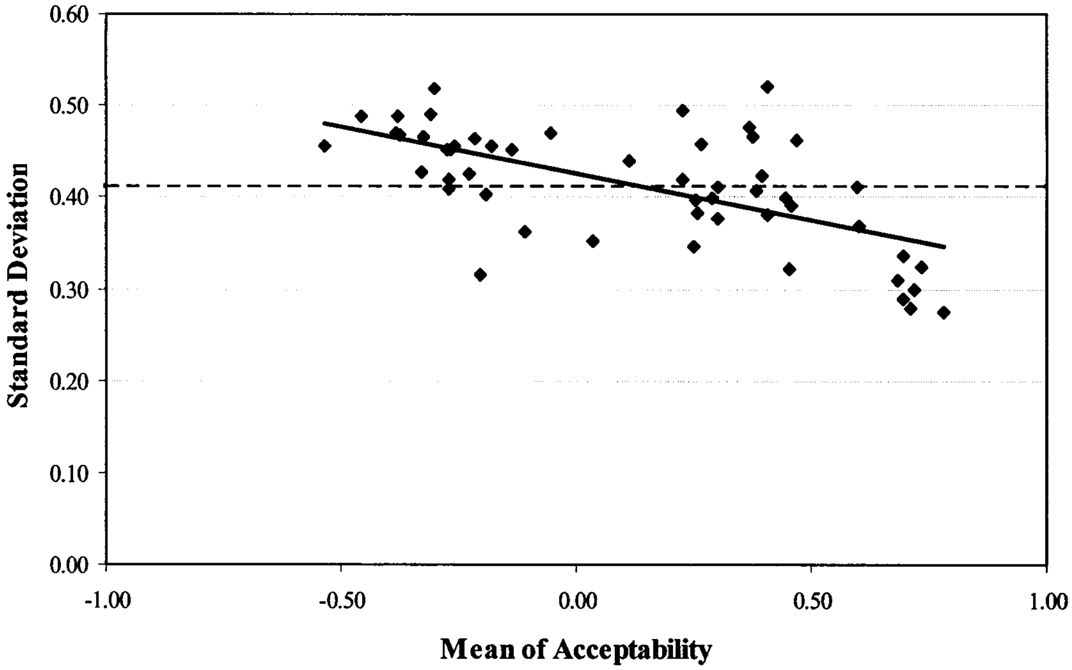


Figure 4.25. The standard deviation of acceptability votes versus the mean of acceptability votes

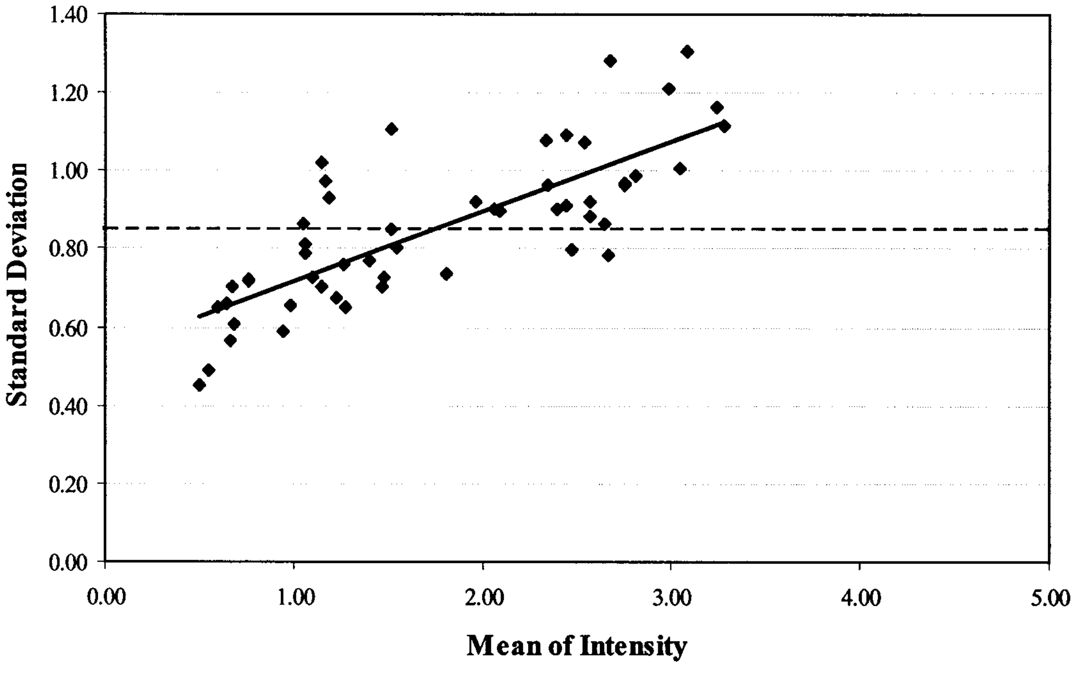


Figure 4.26. The experimental standard deviation of intensity votes versus the mean of intensity votes

standard deviation increased with the magnitude of air intensity. This figure suggests that subjects were more in agreement concerning their votes in less intense odors. Since less intense odors would result in more acceptability, Figure 4.24, same principal of more variation in votes in less acceptable or more intense odors can be concluded from both Figures 4.25 and 4.26.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

In the research presented in this literature a series of experimental procedure was carried out in order to determine the impact of emissions from building products on the perceived air quality at different concentrations of air pollutants. Three different set ups were used in this experimental work and the results have been statistically analyzed and compared to highlight the differences. In each case a sensory panel assessed the quality of perceived air, by marking on a scale they had been provided with, for four different dilution rates. Building materials considered for this study included linoleum, paint applied on gypsum board, and carpet.

In the first set up (single set up) the building materials used for this study were individually placed in single test chambers. This set up was considered to study the similarity of sensory pollution loads generated by different building materials and one standard person. Sensory subjects assessed the quality of perceived air in each case. Experimental results for different materials were compared to each other and the calculated perceived air quality when pollution is generated by one standard person. This comparison is used to evaluate the accuracy of considering similar characteristic for all building materials and bioeffluent.

The second type (combination set up) of set up was considered to investigate the accuracy of predicting the acceptability of air in presence of combined materials by adding the Olf values generated by single materials. In this set up, building materials in combination of two or three were placed inside one single chamber. The acceptability votes from this experimental procedure were used to calculate the source strengths of combined materials. Source strength values from first set up were also calculated. A comparison has been performed between the Olf of combination set up and corresponding addition of Olfs from single set up.

The third type of set up (mixing set up) in this experimental procedure was considered in order to determine the existence of any interaction effect amongst building materials. In this set up, the materials were placed individually inside the test chambers. Exhausts from two or three different CLIMPAQs were mixed in a mixing chamber before the exhaust air from the mixing chamber was being assessed by subjects. The existence of any interaction effect amongst building materials was obtained by comparing the votes from combination and mixing set ups.

The curves representing the level of acceptability versus dilution rates in all different set ups were demonstrating an increasing trend. This showed that subjects perceived air more acceptable at higher dilution rates. In the other words, the air can be perceived more acceptable when it is diluted by some factors of unpolluted fresh air.

5.2 CONCLUSIONS

The conclusions of the research presented in this thesis are categorized as following:

5.2.1 Theory of Olf

- The slope of exposure response curve for the single set up of carpet was different from the slopes of other materials and the bioeffluent. The curve corresponding to carpet was steeper compared to the rest of materials and human bioeffluent. As the result, less ventilation rate is required when air is polluted by carpet compared to the other investigated materials to reach a certain level of acceptability.
- The results of these experiments reject the theory of characterizing the sensory pollution load generated by different materials by introducing one single number expressed as Olf, which confirms the conclusion drawn by Knudsen *et al.* (1997a), Knudsen *et al.* (1997b), Bluyssen and Cornelissen (1997), and Knudsen *et al.* (1998).

5.2.2 Theory of Addition

- Adding the source strength of pollutants from single set ups generally revealed values close to the calculated Olfs based on the votes from combination and mixing set ups. This finding proposes that predicting the level of dissatisfaction when the indoor air is polluted by several building materials by simply adding the Olf values of individual materials can be used as the first approximation. This finding confirms the conclusions previously drawn by Fanger (1988), Bluyssen and Fanger (1991), and Jolk (1995). The results from this study are only valid for the selected type of materials and cannot be generalized without further investigations.

5.2.3 Interaction Effect

- Comparing the results from mixing and combination set ups from the same type of materials revealed very similar acceptability votes in all cases. This result suggests that the interaction effect amongst these three building materials, causing the compounds emitted by one be adsorbed by other(s), is almost negligible from perception point of view.
- The acceptability votes for mixing and combination set ups were almost the same as the acceptability votes of the corresponding single materials. This finding suggests that furnishing an office building with one single building materials or a combination of two or three of the specimens selected for this literature does not make a difference in the acceptability level of air. To be more specific, equal air specific flow rate in all different set ups is the potential reason of insignificant differences among the means of acceptability votes for different set ups.

5.3 LIMITATIONS OF PRESENT STUDY

- The results of this research are valid when the loading factor of materials is similar to the standard model room.
- The results of this study are specific for the selected materials and cannot be generalized without further investigations.
- The air exchange rate inside the test chambers was much higher than the normal conditioning situation in buildings. This value was 60 hr^{-1} in single and combination set ups, while ASHRAE standard 62-2001 suggests 1.5 to 3 hr^{-1} for office buildings and indoor places. Compounds emitted from building materials would be swept away

much faster from test chambers compared to standard office buildings, and the concentration of pollutants would decrease in smaller time interval due to higher air exchange rate inside CLIMPAQs. Due to this reason, acceptability votes obtained from this research can be compared to acceptability level caused by the same materials in a standard office building after passing a longer period from the time the place is furnished or renovated.

5.4 RECOMMENDATIONS FOR FURTHER STUDIES

Some further investigations are required to fully understand the effect of building materials on perceived air quality. The following areas of research can enhance the current work if being considered in the later studies in this field:

- Different types of materials other than the ones already used in this study should be investigated.
- An attempt to correlate the chemical concentration results with the results of sensory assessment should be made.
- The air specific flow rate should be changed to get the same acceptability vote for all single materials at the highest concentration of compounds (absence of dilution). In this case, the start point for all different single materials in acceptability scale chart will be the same and a shift in exposure response curves can be observed. This may result in significant differences between investigated materials. The change of air specific flow rate can be obtained by increasing the area of materials proposed for this study.

- To validate the results obtained from test chambers, some field measurements with the same type of materials should be performed
- The air exchange rate inside test chambers should be reduced to comply with the standard air exchange rate inside one standard office building, 2 hr^{-1} (ASHRAE standard 62-2001).

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APPENDIX A

CALIBRATION PROCEDURE

The calibration procedure consisted of two main parts: one to set inlet and outlet airflow rates to the chamber and exhaust from diffusers, and the air exchange rate, and the other one for dilution experiments in order to achieve different concentrations of polluted air for sensory assessments through diffusers.

Before starting the main calibration procedure, in order to detect any leakages from chambers or through connecting pipes, a certain amount of tracer gas was dosed via holes mounted in the inlet air pipes to the chambers. The concentration of tracer gas was checked using a Bruel and Kjaer multi gas monitor at several points inside chambers and in the pipes to diffusers, and also in mixing chamber in case of mixing set-up. In this experimental procedure no significant leakage or decrease in amount of tracer gas was noticed. N_2O gas was used as the tracer gas for calibration. In all set ups, the inlet and outlet flows were assumed to be the same.

A.1 CALIBRATION OF AIRFLOW RATES

A.1.1 Single/combination set ups

In the first set of calibration, the airflow entering and exiting chambers in case of single/combination set-ups was adjusted using a hot wire anemometer. The device was calibrated to relate velocity to airflow (Figure A.1). The velocity meter was mounted at the pipe connecting the outlet from chamber to the cone. In this case, the velocity was adjusted to 1.50 m/s, which corresponds to 0.9 L/s flow of air. The outlet valve from chamber was completely open, and the adjustment was carried out by setting the inlet valve.

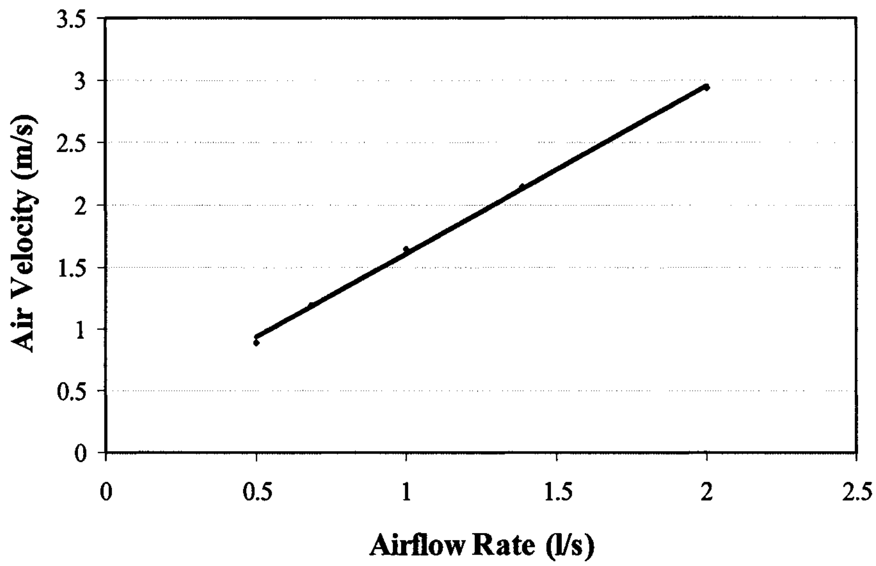

Figure A. 1. Calibration curve of hotwire anemometer

In order to obtain an approximate level of the concentration of pollutants inside chambers, a constant amount of tracer gas was dosed in the hole at the inlet air pipe in all chambers, and concentration of tracer gas inside diffusers was monitored. Before the injection of a specific quantity of N_2O in each chamber, the background concentration of this gas in the chamber was measured. Measuring the concentration of N_2O inside the chamber was conducted using N_2O filter in the measurement device at approximate intervals of 60s.

After adjusting the flow, the dosing system was disconnected, and the decrease in concentration of N_2O versus time in some of chambers was monitored until it reached 5-6 times higher than the background concentration. The ACH can be found by plotting the decay curve, represented by following equation:

$$C = C_0 e^{-NT} \tag{A-1}$$

Where:

C is the NO_2 concentration in the chamber (ppm)

C_0 is the initial concentration of N_2O (ppm)

N is the air exchange rate (hr^{-1})

T is time (hr)

Observing air exchange rate is also a double check, since there is one degree of freedom between ACH and inlet airflow, and once one is adjusted, the other one will be adjusted by itself.

A.1.2 Mixing Set Ups

In the mixing set ups, the tracer gas was introduced to the chambers containing materials once at a time, and measurement of the concentration of N_2O at outlet of mixing chamber, inside diffuser, was performed using a multi gas monitor. The inlet air flow rate to the chambers was adjusted in a way that the concentration of N_2O from diffuser in mixing chambers maintained constant all the time, when pollutants were being dosed in only one of the CLIMPAQs containing samples.

The level of concentration should have also been the same as the concentration of tracer gas in single/combination set ups. The monitored numbers were compared to the concentration of tracer gas at the time of dosing the same amount of N_2O in calibrated single/combination set ups.

This calibration procedure was performed to assure that same amount of airflow from each of the CLIMPAQs were being mixed in the mixing chamber. Furthermore, the airflow for sensory assessment was the same as in all different set ups.

A.2 CALIBRATION OF DILUTION RATES

In the second set of calibration the dilution rates, using available orifice plates in the indoor climate laboratory at Danish Building and Urban Research, Denmark, were measured. N_2O gas was dosed at a constant rate into the test chambers in order to adjust the performance of the dilution system. The dilution rate of pollutants for sensory assessment was determined by measuring the concentration of N_2O once inside cones and once through a hole in the exhaust pipes. Different concentrations of pollutants in the diffusers were achieved by placing different sets of orifice plates in pipes connecting supply fresh air and outlet of test chambers to diffusers.

The first set of orifices that led undiluted outlet for sensory assessments was considered as 1, while by dividing the outlet concentration of N_2O using other sets to undiluted one, dilution rates of 2.5, 10, and 20 were achieved (Table 3.1)

APPENDIX B

EXPERIMENTAL DATA AND DATA ANALYSES

B.1 RAW EXPERIMENTAL DATA

Table B. 1 Raw experimental data - Main room

Panel Subjects	Acceptability: Main room				Intensity: Main room			
	1	2	3	4	1	2	3	4
1	0.10	0.17	0.83	-0.15	2.05	2.01	1.02	2.48
2	0.74	0.57	0.08	0.06	0.52	0.19	1.27	1.70
3	0.84	0.79	0.88	0.90	0.37	0.29	0.35	0.25
4	0.95	0.94	0.78	0.94	0.23	0.77	1.33	0.20
5	0.94	0.92	0.88	0.90	0.11	0.16	0.23	0.13
6	0.32	0.38	0.3	0.27	1.40	1.40	1.51	1.64
7	0.87	0.79	0.88	0.75	0.94	0.36	0.27	0.45
8	0.49	0.49	0.56	0.25	0.51	0.87	0.28	1.23
9	0.95	0.58	0.86	0.91	0.51	1.53	0.54	0.39
10	0.68	-0.10	0.92	0.91	0.52	1.76	0.18	0.18
11	0.92	0.91	0.93	0.91	0.18	0.19	0.22	0.42
12	0.72	0.73	0.92	0.50	0.54	0.49	0.14	0.73
13	0.52	0.92	0.89	0.83	0.72	0.17	0.28	0.43
14	0.31	0.14	0.79	0.62	2.13	2.24	0.98	1.09
15	0.90	0.74	0.92	0.93	0.28	0.71	0.20	0.15
16	0.98	0.95	0.99	0.97	0.06	0.03	0.03	0.09
17	-0.01	0.58	1	0.54	1.15	0.17	0.34	0.34
18	0.89	0.92	0.26	0.71	0.34	0.26	1.19	1.37
19	0.56	0.97	1	0.98	1.10	0.03	0.03	1.05
20	0.88	0.89	0.95	0.85	0.31	0.27	0.17	0.34
21	0.87	0.87	0.9	0.85	0.83		0.26	0.27
22	0.84	0.57	0.94	0.70	0.26	0.83	0.28	0.69
23	0.64	0.89	0.92	0.70	1.17	0.30	0.20	0.60
24	0.97	0.86	0.17	0.35	0.11	0.25	0.84	0.48
25	0.86	0.91	0.95	0.91	0.22	0.10	0.22	0.22
Mean	**0.71**	**0.70**	**0.78**	**0.68**	**0.66**	**0.64**	**0.49**	**0.68**
Standard Deviation	**0.28**	**0.29**	**0.27**	**0.31**	**0.57**	**0.66**	**0.45**	**0.61**

Table B. 2 Raw experimental data - Linoleum, Carpet & Paint (mixing)

Panel Subjects	Acceptability: linoleum, Carpet & Paint (mixing)				Intensity: linoleum, Carpet & Paint (mixing)			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.97	-0.63	0.55	0.01	3.98	2.48	1.03	1.92
2	-0.02	-0.09	0.96	0.91	1.56	2.71	0.10	0.23
3	-0.24	-0.19	0.23	0.31	3.34	2.00	1.68	0.90
4	-0.65	-0.06	0.08	0.96	4.23	3.16	2.11	0.28
5	-0.08	-0.39	-0.09	-0.30	2.19	2.41	1.95	1.88
6	-0.15	-0.08	0.15	-0.08	2.17	2.65	2.60	2.30
7	-0.83	-0.34	-0.11	0.11	3.52	2.46	1.03	0.94
8	-0.03	-0.1	0.16	0.08	1.88	1.23	2.19	1.21
9	0.13	0.03	0.84	0.88	2.07	2.07	0.41	0.71
10	0.33	-0.37	-0.18	0.85	1.50	2.25	0.98	0.22
11	-0.04	-0.3	-0.07	-0.05	2.20	3.67	2.09	1.90
12	-0.51	-0.02	0.91	0.67	3.16	2.05	0.24	0.41
13	-0.24	-0.26	0.41	0.79	2.55	2.81	1.03	0.88
14	0.46	-0.28	0.17	0.24	1.80	2.12	1.10	1.66
15	0.60	-0.12	0.23	0.27	1.98	1.21	1.21	1.25
16	0.35	0.15	0.64	0.98	2.30	2.75	1.07	0.09
17	-0.57	-0.77	-0.14	-0.61	3.02	4.83	1.17	2.90
18	-0.89	-0.68	0.36	0.96	3.81	3.79	1.31	0.08
19	-0.98	-0.82	0.97	0.00	2.07	1.88	0.00	1.00
20	-0.04	-0.1	0.68	-0.05	2.14	1.57	0.70	1.27
21	-0.26	-0.09	-0.10	-0.14	1.73	3.10		2.56
22	-0.19	-0.39	0.25	0.88	2.59	2.61	1.32	0.36
23	-0.13	0.51	0.84	0.60	2.67	1.37	0.49	0.90
24	-0.06	0.07	0.96	0.10	1.53	1.25	0.18	0.53
25	0.52	0.29	0.90	0.88	1.76	0.22	0.28	0.22
Mean	**-0.18**	**-0.20**	**0.38**	**0.37**	**2.47**	**2.34**	**1.10**	**1.06**
Standard Deviation	**0.45**	**0.31**	**0.41**	**0.48**	**0.80**	**0.96**	**0.73**	**0.81**

Table B. 3 Raw experimental data – Paint (single)

Panel subjects	Acceptability: Paint				Intensity: Paint			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.46	-0.67	-0.20	0.99	2.49	2.94	2.45	0.04
2	-0.41	-0.03	-0.10	0.07	2.56	1.64	2.33	1.65
3	-0.34	-0.23	0.25	0.44	2.34	2.46	1.42	1.27
4	-0.90	-0.25	0.07	0.78	3.75	3.69	2.10	1.15
5	-0.29	-0.36	-0.11	-0.25	2.34	2.40	2.53	2.18
6	-0.20	0.16	-0.07	-0.35	2.44	2.66	2.50	2.56
7	-0.37	-0.84	-0.16	0.3	2.66	2.50	1.93	0.74
8	-0.04	-0.08	0.04	-0.02	1.97	1.56	1.43	1.78
9	-0.54	-0.05	0.50	0.29	2.96	2.18	1.66	1.88
10	-0.18	-0.23	0.10	-0.04	2.02	2.01	1.43	1.01
11	-0.83	-0.70	-0.07	-0.06	3.81	3.80	2.15	1.80
12	0.28	0.50	0.59	0.54	0.68	0.73	0.78	0.78
13	-0.20	-0.38	0.54	0.26	2.46	2.95	1.27	1.02
14	-0.14	0.14	0.25	0.38	2.55	1.36	1.76	1.18
15	-0.29	0.15	0.57	0.22	2.97	1.29	1.18	1.34

16	0.21	0.24	0.72	0.36	2.91	2.42	1.21	1.47
17	-0.86	-0.76	0.12	-0.43	3.77	4.38	1.95	2.89
18		-0.82	-0.62	0.27	4.42	3.85	3.13	0.84
19	-0.98	-0.98	-0.99	1	2.86	2.97	2.03	0.03
20	-0.20	-0.69	-0.02	-0.08	1.73	2.34	1.26	1.38
21	0.09	-0.32	-0.05	0.1		2.75	2.25	1.43
22	-0.75	0.26	-0.44	0.94	3.52	1.74	3.49	0.23
23	0.63	0.32	0.29	0.18	1.52	1.81	1.76	2.21
24	-0.06	-0.34	0.88	0.81	1.21	2.14	0.21	0.27
25	0.45	0.27	0.75	0.78	1.73	1.27	0.95	0.46
Mean	**-0.27**	**-0.23**	**0.11**	**0.30**	**2.57**	**2.39**	**1.81**	**1.26**
Standard Deviation	**0.42**	**0.42**	**0.44**	**0.41**	**0.88**	**0.90**	**0.73**	**0.76**

Table B. 4 Raw experimental data – Linoleum (single)

Panel subjects	Acceptability: Linoleum				Intensity: Linoleum			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.98	-0.98	0.50	0.78	4.94	3.42	1.01	1.00
2	-0.08	-0.87	0.20	0.06	2.28	3.58	1.65	1.27
3	-0.44	0.15	0.15	0.27	2.17	1.53	1.81	1.13
4	-0.09	-0.13	0.04	0.75	2.87	3.27	2.46	0.96
5	-0.01	-0.29	0.23	-0.23	2.13	2.43	0.77	2.16
6	0.18	-0.09	-0.54	0.16	1.58	2.71	2.62	2.68
7	-0.83	-0.32	0.10	0.25	3.92	2.39	1.53	0.59
8	0.06	-0.04	0.20	0.02	1.74	1.82	1.55	0.95
9	0.43	0.08	-0.15	0.20	1.15	2.25	3.03	2.07
10	-0.75	-0.74	-0.37	-0.68	3.98	2.48	2.13	2.42
11	-0.88	-0.32	-0.09	-0.03	4.21	3.13	2.40	2.20
12	-0.90	-0.02	0.64	0.06	4.75	2.69	1.12	1.87
13	-0.28	-0.47	0.43	0.59	3.03	3.40	0.50	0.95
14	0.09	-0.59	0.30	0.54	3.97	2.78	2.00	1.25
15	0.59	-0.12	0.56	0.34	1.19	2.15	1.02	0.96
16	-0.06	0.32	0.52	0.80	3.49	3.30	1.30	0.44
17	-0.97	-0.64	-0.17	0.51	4.87	3.77	1.15	0.97
18	-0.94	-0.93	-0.03	-0.16	4.81	3.85	1.88	1.84
19	-0.97	-0.97	0.16	0.04	3.01	2.91	0.95	1.02
20	-0.75	-0.04	-0.05	0.35	2.57	1.52	0.91	0.82
21	-0.65	-0.66	0.56	0.44	3.50	3.48		1.51
22	0.07	0.13	0.76	0.82	2.81	2.75	0.39	0.65
23	0.14	0.14	0.68	0.50	2.18	1.81	0.84	1.33
24	-0.06	-0.28	0.96	0.31	1.86	2.40	0.15	0.52
25	0.51	0.84	0.84	0.87	1.51	0.75	0.43	0.30
Mean	**-0.30**	**-0.27**	**0.26**	**0.30**	**2.98**	**2.66**	**1.40**	**1.27**
Standard Deviation	**0.52**	**0.45**	**0.38**	**0.38**	**1.21**	**0.78**	**0.77**	**0.65**

Table B. 5 Raw experimental data - Linoleum & Paint (comb.)

Panel subjects	Acceptability: Linoleum & Paint (comb.)				Intensity: Linoleum & Paint (comb.)			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.40	-0.96	-0.52	1	2.98	3.93	2.96	0.65
2	-0.04	-0.62	0.04	-0.08	2.88	3.08	1.88	1.21

3	-0.17	-0.18	0.14	0.01	2.60	2.74	1.68	2.01
4	-0.78	-0.01	0.09	0.08	3.86	2.89	1.89	0.94
5	-0.57	-0.84	-0.20	-0.28	2.98	3.19	2.85	1.86
6	-0.26	-0.14	-0.22	-0.1	2.47	2.51	2.50	2.58
7	-0.79	-0.76	0.13	0.06	2.83	3.43	1.78	1.15
8	0.05	-0.06	0.36	0.06	1.84	1.44	1.54	1.19
9	0.26	-0.40	0.62	0.88	1.86	3.16	0.95	0.26
10	-0.78	-0.75	0.44	-0.25	3.75	3.00	0.57	1.58
11	-0.12	-0.15	-0.11	-0.05	2.33	2.06	2.79	2.12
12	0.56	-0.02	0.59	-0.02	1.15	2.02	0.73	2.13
13	-0.13	-0.34	0.08	0.02	2.53	2.94	1.57	1.14
14	-0.18	-0.56	0.83	0.08	3.12	3.66	0.17	1.21
15	0.37	0.38	0.70	0.33	1.27	1.13	0.21	0.92
16	0.13	0.26	0.41	0.7	3.41	3.12	1.51	0.69
17	-0.93	-0.93	-0.68	-0.05	4.84	4.86	3.05	1.95
18	-0.92	-0.82	0.87	0.97	3.40	2.85	0.34	0.11
19	-1.00	0.01	0.00	0.59	1.98	1.05	1.02	0.98
20	-0.43	0.35	-0.04	0.52	2.19	0.63	1.61	0.60
21	-0.21	-0.64	-0.07	-0.13		3.72	1.46	2.32
22	-0.73	0.27	0.24	0.46	3.27	1.81	1.58	0.58
23	0.20	0.17	0.60	0.46	2.10	1.91	1.59	1.27
24	-0.10	-0.32	0.46	0.21	2.10	1.76	1.28	0.54
25	0.34	0.60	0.87	0.88	1.81	0.65	0.46	0.65
Mean	**-0.26**	**-0.26**	**0.23**	**0.25**	**2.65**	**2.54**	**1.52**	**1.23**
Standard Deviation	**0.45**	**0.46**	**0.42**	**0.40**	**0.86**	**1.07**	**0.85**	**0.68**

Table B. 6 Raw experimental data - Empty Chamber

Panel subjects	Acceptability: Empty Chamber				Intensity: Empty Chamber			
	1	2	3	4	1	2	3	4
1	1.00	0.81	0.98	0.99	0.56	0.08	1.02	0.46
2	0.98	0.05	0.95	0.78	0.10	0.14	0.90	0.31
3	0.90	0.8	0.85	0.48	0.84	0.39	0.56	1.04
4	0.92	0.81	0.94	0.93	0.30	0.72	1.16	0.62
5	0.43	0.56	0.71	0.59	0.37	0.47	0.71	0.25
6	0.59	-0.31	0.14	-0.17	2.50	1.43	3.14	2.66
7	0.95	0.95	0.91	0.55	0.24	0.25	0.11	0.55
8	0.25	0.07	0.05	0.21	1.78	0.38	1.33	0.91
9	0.79	0.94	0.85	0.09	0.31	0.88	0.15	2.32
10	0.89	1	0.51	0.98	0.47	0.27	0.00	0.06
11	0.77	0.31	0.11	-0.04	1.25	0.40	0.85	1.89
12	0.68	0.92	0.84	0.80	0.30	0.73	0.14	0.36
13	0.98	0.79	0.89	0.88	0.17	0.12	0.74	0.76
14	0.38	0.16	0.97	0.74	1.04	1.59	1.75	1.25
15	0.79	0.83	0.90	0.86	0.30	0.95	0.38	0.29
16	0.90	0.92	0.97	0.90	0.02	0.17	0.21	0.14
17	1.00	0.74	0.95	0.99	0.05	0.00	0.49	0.03
18	0.97	0.97	0.95	0.97	0.09	0.16	0.09	0.09
19	0.01	0.98	0.98	0.97	0.96	1.04	0.08	0.04
20	0.90	0.35	0.86	0.74	0.24	0.34	0.65	0.53
21	0.63	0.22	0.29	0.61		0.40	1.61	0.84
22	0.88	0.91	0.09	0.85	1.73	0.42	0.22	0.73
23	0.23	0.53	0.91	0.86	0.17	1.81	1.29	0.30

24	0.21	-0.29	0.87	0.91	0.10	0.37	1.15	0.15
25	0.99	0.95	0.90	0.88	0.21	0.13	0.18	0.18
Mean	**0.72**	**0.60**	**0.73**	**0.69**	**0.59**	**0.55**	**0.76**	**0.67**
Standard Deviation	**0.30**	**0.41**	**0.32**	**0.34**	**0.65**	**0.49**	**0.72**	**0.70**

Table B. 7 Raw experimental data – Carpet (single)

Panel subjects	**Acceptability: Carpet**				**Intensity: Carpet**			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	0.00	0.02	0.59	0.8	2.46	1.52	1.08	1.39
2	-0.97	-0.94	-0.07	0.82	4.81	4.76	2.50	0.35
3	-0.67	-0.28	0.83	0.82	2.74	3.23	0.84	0.97
4	-0.96	0.17	0.66	0.95	4.84	2.08	1.27	0.12
5	-0.02	-0.62	0.62	0.43	1.16	3.11	0.65	0.46
6	-0.43	-0.65	0.21	-0.35	3.31	3.41	1.25	3.12
7	-0.81	-0.92	0.60	0.6	4.15	4.77	0.53	0.41
8	-0.23	-0.23	0.30	0.1	2.87	1.51	0.58	1.23
9	-0.53	-0.35	0.99	0.96	3.29	1.95	0.13	0.10
10	-0.86	-0.81	0.72	0.07	4.20	3.44	0.29	0.99
11	-0.07	-0.04	0.29	0.34	2.08	2.22	0.74	0.68
12	-0.98	-0.86	0.63	0.73	4.85	4.64	0.73	0.34
13	-0.49	-0.26	0.84	0.9	2.97	2.97	0.98	0.21
14	-0.99	-0.86	0.40	0.14	4.97	4.10	0.58	2.11
15	0.01	0.05	0.62	0.51	2.00	0.95	0.80	0.48
16	-0.12	0.16	0.52	0.96	4.09	2.94	0.77	0.19
17	-0.10	0.51	0.24	0.94	1.74	0.81	0.93	0.05
18	-0.94	-0.91	-0.05	0.86	4.83	4.67	0.71	0.48
19	-0.98	-0.97	-0.01	0.01	3.97	4.01	1.13	0.98
20	0.13	-0.80	0.88	0.92	0.76	2.14	0.34	0.24
21	-0.46	-0.10	0.11	0.74		1.89	0.87	0.52
22	0.16	0.24	0.07	0.63	1.80	1.47	1.90	0.56
23	0.54	0.57	0.19	0.9	1.55	1.38	2.19	0.73
24	-0.08	0.07	0.90	0.34	2.29	1.13	0.24	0.40
25	0.30	0.10	0.30	0.88	2.22	1.85	1.61	1.85
Mean	**-0.38**	**-0.31**	**0.45**	**0.60**	**3.08**	**2.68**	**0.95**	**0.76**
Standard Deviation	**0.47**	**0.49**	**0.32**	**0.37**	**1.30**	**1.28**	**0.59**	**0.72**

Table B. 8 Raw experimental data - Linoleum, Carpet & Paint (comb.)

Panel subjects	**Acceptability: Linoleum, Carpet & Paint (comb.)**				**Intensity: Linoleum, Carpet & Paint (comb.)**			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.62	-0.32	-0.23	0.99	3.00	2.99	3.24	0.33
2	0.05	0.09	0.04	0.25	2.15	0.73	1.63	0.66
3	-0.75	-0.39	0.38	0.22	2.96	2.40	1.61	1.00
4	-0.78	0.42	0.96	0.97	3.85	1.56	0.28	0.25
5	-0.15	-0.41	0.03	-0.13	2.80	2.25	1.57	1.55
6	0.21	-0.24	0.43	0.55	2.45	2.72	1.62	1.71
7	-0.50	-0.23	-0.14	0.38	2.50	2.21	2.32	0.55

8	-0.29	0.02	0.26	0.14	2.12	1.26	1.13	1.17
9	0.51	-0.19	0.83	0.75	1.09	2.65	0.50	0.95
10	-0.16	-0.48	0.80	0.79	1.41	2.01	0.54	0.40
11	-0.22	-0.01	-0.03	-0.04	2.20	2.12	1.86	2.26
12	-0.21	0.04	0.88	0.4	3.18	2.21	0.39	0.84
13	0.57	-0.21	0.76	0.65	0.89	2.58	0.41	0.96
14	-0.51	-0.06	0.51	0.51	4.23	2.07	0.86	1.35
15	0.23	-0.13	0.73	0.6	1.88	1.12	0.33	0.56
16	0.13	0.42	0.61	0.94	3.45	2.23	1.19	0.13
17	-0.67	-0.94	-0.93	-0.3	3.86	4.85	3.95	2.59
18	-0.57	-0.60	0.97	0.97	2.50	2.77	0.14	0.09
19	-0.01	-0.17	0.01	0.03	1.97	2.00	1.02	0.91
20	-0.77	-0.39	-0.03	0.52	2.36	1.71	1.17	0.76
21	-0.15	-0.28	0.26	0.08		3.19	0.79	1.79
22	-0.34	0.51	0.21	-0.09	3.30	1.26	1.27	1.78
23	0.56	0.27	0.73	0.81	1.55	1.76	1.17	0.52
24	0.71	-0.07	0.39	0.48	1.16	0.80	0.52	0.55
25	0.26	0.60	0.92	0.92	1.81	0.80	0.20	0.80
Mean	**-0.14**	**-0.11**	**0.37**	**0.46**	**2.44**	**2.09**	**1.19**	**0.98**
Standard Deviation	**0.45**	**0.36**	**0.47**	**0.39**	**0.91**	**0.90**	**0.93**	**0.66**

Table B. 9 Raw experimental data - Linoleum & Paint (mixing)

Panel subjects	**Acceptability: Linoleum & Paint (mixing)**				**Intensity: Linoleum & Paint (mixing)**			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.97	-0.29	0.46	-0.40	3.98	2.48	0.98	2.53
2	-0.74	-0.12	0.01	0.19	3.38	1.43	1.59	1.71
3	-0.81	-0.68	-0.04	-0.03	3.24	3.21	2.27	2.01
4	-0.97	-0.94	0.89	0.78	4.96	4.93	1.28	1.45
5	-0.47	-0.31	-0.16	-0.26	3.17	2.69	1.49	2.38
6	-0.34	-0.11	0.12	-0.33	3.46	2.46	2.33	2.81
7	-0.86	-0.33	-0.16	0.24	3.67	2.67	1.59	1.21
8	-0.18	-0.15	-0.07	0.20	1.84	2.13	1.40	0.83
9	0.30	-0.07	0.26	0.16	1.73	2.76	1.86	2.08
10	-0.83	0.69	0.17	0.77	4.14	0.62	1.00	0.26
11	-0.15	-0.73	-0.09	-0.01	2.80	3.07	2.14	2.08
12	-0.87	0.42	0.03	0.80	4.69	0.52	1.91	0.62
13	-0.08	-0.07	0.87	0.60	2.58	2.72	0.36	1.00
14	0.18	-0.54	0.31	-0.09	2.03	3.70	3.47	2.52
15	-0.02	0.01	0.39	0.36	2.82	1.52	1.06	1.03
16	0.11	0.2	0.23	0.70	3.41	3.50	3.19	0.72
17	-0.94	-0.91	0.04	-0.42	4.89	4.80	1.91	2.36
18	-0.92	-0.82	-0.06	0.59	3.87	2.55	1.67	0.86
19	-0.98	-0.97	0.01	0.98	2.02	2.02	2.01	1.00
20	-0.47	-0.01	0.43	0.27	2.57	1.05	0.56	1.45
21	-0.34	0.31	-0.11	0.44	2.76	2.77		1.27
22	-0.08	0.25	0.77	0.62	2.57	2.19	0.27	0.84
23	0.10	0.14	0.49	0.54	2.32	2.15	1.30	1.42
24	0.41	-0.63	0.92	0.18	1.34	1.80	0.71	0.97
25	0.49	0.3	0.56	0.30	1.82	1.40	0.80	1.19
Mean	**-0.38**	**-0.21**	**0.25**	**0.29**	**3.04**	**2.45**	**1.55**	**1.46**
Standard	**0.49**	**0.46**	**0.35**	**0.40**	**1.01**	**1.09**	**0.80**	**0.70**

Deviation								

Table B. 10 Raw experimental data - Linoleum & Carpet (comb.)

Panel subjects	Acceptability: Linoleum & Carpet (comb.)				Intensity: Linoleum & Carpet (comb.)			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.97	0	0.96	0.85	2.49	1.99	1.05	0.38
2	-0.94	-0.76	0.86	0.24	4.91	3.18	0.44	1.28
3	-0.87	0.2	0.92	0.15	3.23	1.32	0.66	1.12
4	-0.95	-0.95	0.96	0.06	4.96	4.23	0.28	1.80
5	-0.13	-0.23	0.17	-0.19	2.61	2.24	1.12	1.81
6	-0.45	0.16	-0.49	-0.13	2.57	1.70	2.65	2.76
7	-0.88	-0.08	0.12	0.08	4.70	2.06	1.33	1.12
8	-0.02	0.07	-0.16	-0.03	1.92	1.60	1.94	1.36
9	0.75	0.3	0.96	0.78	0.52	1.88	0.22	0.60
10	-0.67	-0.49	0.12	0.82	3.61	2.00	1.56	0.34
11	-0.42	-0.16	-0.83	0.35	2.32	3.05	4.51	0.70
12	-0.89	0.08	0.90	0.42	4.75	1.76	0.18	2.13
13	-0.43	-0.15	0.51	0.03	3.00	2.78	0.79	1.95
14	-0.22	0.16	0.24	0.18	3.77	1.57	1.56	2.16
15	0.54	0.35	0.06	0.66	1.73	0.84	0.99	0.43
16	-0.02	0.21	0.67	0.87	3.22	1.82	1.18	0.09
17	-0.95	-0.12	-0.40	1.00	4.90	2.12	1.88	0.65
18	-0.92	-0.9	0.80	0.97	4.15	3.80	0.60	0.08
19	-0.98	-0.97	0.00	0.00	3.98	1.96	1.01	2.01
20	-0.67	0.74	0.39	0.81	2.44	0.47	1.22	0.34
21	-0.59	-0.16	0.75	0.08	3.74	3.10		1.79
22	-0.57	-0.11	0.17	0.87	4.29	2.47	1.88	0.30
23	-0.18	0.51	0.67	0.88	2.56	1.39	0.73	0.27
24	-0.18	0.25	0.94	0.58	2.43	1.35	0.11	0.27
25	0.18	0.72	0.91	0.78	2.30	0.84	0.10	0.74
Mean	**-0.46**	**-0.05**	**0.41**	**0.44**	**3.24**	**2.06**	**1.16**	**1.06**
Standard Deviation	**0.49**	**0.47**	**0.52**	**0.40**	**1.16**	**0.90**	**0.97**	**0.79**

Table B. 11 Raw experimental data - Linoleum & Carpet (mixing)

Panel subjects	Acceptability: Linoleum & Carpet(mixing)				Intensity: Linoleum & Carpet(mixing)			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.50	-0.78	0.00	0.83	2.98	2.75	3.00	0.45
2	-0.68	-0.52	0.44	0.05	2.77	2.78	1.52	0.46
3	-0.88	-0.36	0.07	0.38	3.10	2.64	2.04	1.14
4	-0.98	-0.90	1.00	0.22	4.80	4.86	0.12	2.70
5	-0.28	-0.32	0.10	-0.26	3.16	2.36	1.78	2.39
6	0.16	-0.56	0.76	0.15	2.34	3.45	1.22	2.48
7	-0.73	-0.49	0.47	0.88	3.69	2.61	0.65	0.38
8	-0.07	-0.09	-0.06	0.21	1.26	1.36	1.65	0.84
9	0.44	0.53	0.91	0.78	1.33	1.70	0.20	0.46
10	-0.47	-0.64	0.73	0.87	1.81	2.99	0.44	0.14
11	-0.16	-0.45	-0.03	0.07	2.50	3.43	2.10	0.93
12	-0.31	-0.88	0.78	0.87	3.41	4.16	0.44	0.26
13	-0.34	-0.25	0.89	0.7	3.59	3.16	0.51	0.90
14	-0.29	-0.48	0.51	0.12	2.25	2.98	1.21	2.13

15	-0.19	0.49	0.70	0.26	2.81	1.17	1.19	1.18
16	0.08	0.16	0.86	0.92	3.28	3.40	0.69	0.17
17	-0.90	-0.94	-0.88	-0.63	3.07	4.47	4.54	2.89
18	-0.94	-0.83	0.95	0.09	4.81	3.67	0.14	1.82
19	-0.97	-0.98	0.02	0.03	2.95	2.99	1.02	1.00
20	-0.06	-0.31	0.73	0.23	1.87	2.16	0.42	0.68
21	-0.40	-0.29	0.11	0.32		2.80	0.89	1.51
22	0.11	0.12	0.55	0.22	1.45	2.15	1.15	0.57
23	-0.16	0.48	0.22	0.88	2.64	1.51	1.39	0.42
24	-0.24	-0.10	0.94	0.94	2.79	1.88	0.16	0.08
25	0.57	0.33	0.94	0.77	1.32	1.41	0.20	0.36
Mean	**-0.33**	**-0.32**	**0.47**	**0.40**	**2.75**	**2.75**	**1.15**	**1.05**
Standard Deviation	**0.43**	**0.47**	**0.46**	**0.42**	**0.96**	**0.97**	**1.02**	**0.87**

Table B. 12 Raw experimental data - Paint & Carpet (comb.)

Panel subjects	Acceptability: Paint & Carpet (comb.)				Intensity: Paint & Carpet (comb.)			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20
1	-0.41	-0.97	0.99	-0.15	2.03	3.94	1.01	1.98
2	-0.34	-0.86	0.28	-0.28	3.83	3.22	1.45	2.09
3	-0.16	-0.76	0.03	0.1	2.14	3.32	1.32	1.67
4	-0.37	-0.96	0.75	0.12	2.81	4.94	1.77	1.76
5	-0.37	-0.80	-0.08	-0.4	3.14	3.24	2.10	2.61
6	-0.48	-0.16	-0.08	0.11	3.41	2.81	2.20	2.69
7	-0.55	-0.77	0.07	-0.31	3.04	3.74	1.52	2.38
8	-0.24	-0.27	0.06	0.06	2.12	2.75	1.17	1.49
9	0.21	-0.58	0.69	0.33	1.57	3.19	1.31	1.87
10	-0.65	-0.83	-0.17	0.11	2.37	3.98	1.55	1.21
11	-0.62	-0.84	-0.11	-0.06	3.77	4.51	2.25	2.10
12	-0.09	-0.88	0.65	-0.07	3.12	4.71	0.68	3.03
13	0.09	-0.51	0.60	-0.13	1.75	3.57	0.85	2.57
14	-0.37	-0.95	0.21	0.16	3.91	4.89	1.82	1.43
15	0.42	0.41	0.43	-0.05	1.26	0.85	1.31	2.05
16	0.29	0.20	0.78	0.35	2.45	2.50	1.20	2.70
17	-0.85	-0.91	-0.93	-0.88	2.89	4.80	3.93	4.72
18	-0.95	-0.91	0.93	0.92	4.54	4.69	0.18	0.15
19	-1.00	-0.98	0.00	-0.01	2.00	2.99	2.01	1.95
20	-0.46	-0.64	-0.02	0.23	2.53	2.56	1.15	0.64
21	-0.09	-0.22	-0.08	-0.28		2.73	1.62	2.32
22	-0.54	0.31	-0.08	-0.1	2.80	1.67	1.62	2.50
23	0.19	0.15	0.70	0.46	1.69	2.10	1.22	1.70
24	0.08	-0.73	0.16	0.08	1.18	2.75	1.29	0.73
25	0.49	0.11	0.89	0.56	1.21	1.48	0.38	0.83
Mean	**-0.27**	**-0.53**	**0.27**	**0.03**	**2.56**	**3.28**	**1.48**	**1.97**
Standard Deviation	**0.41**	**0.46**	**0.46**	**0.35**	**0.92**	**1.11**	**0.73**	**0.92**

Table B. 13 Raw experimental data - Paint & Carpet (mixing)

Panel subjects	Acceptability: Paint & Carpet(mixing)				Intensity: Paint & Carpet(mixing)			
	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20	Dilution Rate 1	Dilution Rate 2.5	Dilution Rate 10	Dilution Rate 20

1	-0.97	0	0.51	0.33	3.97	1.51	1.01	1.00
2	-0.93	-0.6	0.70	0.91	4.54	3.72	0.83	0.56
3	-0.37	-0.58	-0.55	0.24	3.06	2.44	3.00	1.28
4	-0.97	-0.91	0.60	-0.06	4.20	4.67	1.76	2.75
5	-0.33	-0.65	-0.24	-0.27	3.13	3.07	2.73	2.44
6	-0.12	0.16	-0.19	0.14	2.38	2.48	2.26	2.50
7	-0.85	-0.18	-0.08	0.28	3.81	1.44	1.84	0.82
8	-0.05	-0.03	-0.07	-0.06	1.22	1.88	1.17	1.29
9	0.38	-0.02	0.59	0.65	2.10	2.22	1.03	1.27
10	-0.39	-0.76	0.60	0.90	2.02	2.49	0.84	0.54
11	-0.06	-0.07	0.05	0.09	2.33	2.80	1.83	1.50
12	-0.82	0	0.82	0.40	4.20	2.03	0.20	0.76
13	-0.03	0.02	0.18	0.35	2.44	1.93	1.12	0.95
14	0.02	-0.89	0.12	0.19	2.89	3.76	1.27	2.11
15	-0.35	-0.1	0.79	0.77	2.03	1.97	0.43	0.57
16	0.25	0.13	0.32	0.53	1.95	3.15	1.39	1.12
17	-0.84	-0.85	-0.94	0.30	3.30	4.81	4.92	0.55
18	-0.93	-0.24	-0.54	0.82	4.61	1.89	3.35	0.33
19	-0.97	0	0.53	0.98	2.02	1.03	1.01	1.02
20	-0.57	0.66	0.05	-0.12	2.75	0.36	1.10	1.35
21	-0.34	-0.08	-0.10	-0.08	2.77	2.75		1.82
22	-0.75	-0.16	0.25	0.33	3.52	1.36	1.77	0.77
23	0.26	0.35	0.45	0.72	1.78	1.76	1.21	0.86
24	-0.11	-0.1	0.92	0.93	1.51	1.66	0.15	0.20
25	0.50	0.15	0.94	0.85	1.71	1.27	0.30	0.38
Mean	**-0.37**	**-0.19**	**0.23**	**0.40**	**2.81**	**2.34**	**1.52**	**1.15**
Standard Deviation	**0.47**	**0.40**	**0.49**	**0.38**	**0.99**	**1.08**	**1.10**	**0.70**

B.2 DATA ANALYSIS

B.2.1 Data Analysis for Dilution Rates

Table B. 14 Data analysis for dilution rates - Single Setup: Carpet

Single Setup: Carpet

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Dilution 1	25	-9.55444	-0.38218	0.219869
Dilution 2.5	25	-7.71852	-0.30874	0.240388
Dilution 10	25	11.37181	0.454872	0.102686
Dilution 20	25	15	0.6	0.13605

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19.37935	3	6.459783	36.96625	5.72E-16	2.699393
Within Groups	16.77582	96	0.174748			
Total	36.15517	99				

Table B. 15 Data analysis for dilution rates - Single Setup: Paint

Single Setup: Paint						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Dilution 1	25	-6.65026	-0.26601	0.168701		
Dilution 2.5	25	-5.67838	-0.22714	0.179934		
Dilution 10	25	2.829588	0.113184	0.193147		
Dilution 20	25	7.48	0.2992	0.168749		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.576308	3	1.858769	10.46412	5.1E-06	2.699393
Within Groups	17.05274	96	0.177633			
Total	22.62905	99				

Table B. 16 Data analysis for dilution rates - Single Setup: Linoleum

Single Setup: Linoleum						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Dilution 1	25	-7.54811	-0.30192	0.268043		
Dilution 2.5	25	-6.84	-0.2736	0.204049		
Dilution 10	25	6.407811	0.256312	0.146815		
Dilution 20	25	7.547676	0.301907	0.141562		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.069611	3	2.68987	14.1485	1.04E-07	2.699393
Within Groups	18.25124	96	0.190117			
Total	26.32085	99				

Table B. 17 Data analysis for dilution rates - Mixing Setup: Carpet & Paint

Mixing Setup: Carpet & Paint						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Dilution 1	25	-9.33973	-0.37359	0.219365		
Dilution 2.5	25	10.11324	0.40453	0.144256		
Dilution 10	25	5.694305	0.227772	0.243446		
Dilution 20	25	-4.75	-0.19	0.16285		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.750329	3	3.25011	16.88551	6.92E-09	2.699394
Within Groups	18.478	96	0.192479			

Total	28.22833	99

Table B. 18 Data analysis for dilution rates - Combination Setup: Carpet & Paint

Combination Setup: Carpet & Paint

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Dilution 1	25	-6.77242	-0.2709	0.167416
Dilution 2.5	25	-13.3633	-0.53453	0.208236
Dilution 10	25	6.661401	0.266456	0.209161
Dilution 20	25	0.87	0.0348	0.123234

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.194295	3	3.064765	17.31391	4.59E-09	2.699393
Within Groups	16.99312	96	0.177012			
Total	26.18742	99				

Table B. 19 Data analysis for dilution rates - Mixing Setup: Linoleum & Carpet

Mixing Setup: Linoleum & Carpet

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Dilution 1	25	-8.1909	-0.32764	0.182837
Dilution 2.5	25	-8.0761	-0.32305	0.216697
Dilution 10	25	11.7106	0.468424	0.212905
Dilution 20	25	9.9	0.396	0.178267

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.41301	3	4.804338	24.30403	8.73E-12	2.699393
Within Groups	18.97695	96	0.197677			
Total	33.38997	99				

Table B. 20 Data analysis for dilution rates - Combination Setup: Linoleum & Carpet

Combination Setup: Linoleum & Carpet

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Dilution 1	25	-11.4309	-0.45724	0.238372
Dilution 2.5	25	-1.33	-0.0532	0.221148
Dilution 10	25	10.18045	0.407218	0.270784
Dilution 20	25	11.09383	0.443753	0.159649

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.64122	3	4.547075	20.43737	2.53E-10	2.699393
Within Groups	21.35887	96	0.222488			
Total	35.0001	99				

Table B. 21 Data analysis for dilution rates - Mixing Setup: Linoleum & Paint

Mixing Setup: Linoleum & Paint

SUMMARY

Groups	Count	Sum	Average	Variance
Dilution 1	25	-9.44927	-0.37797	0.238134
Dilution 2.5	25	-5.36	-0.2144	0.215351
Dilution 10	25	6.283002	0.25132	0.119314
Dilution 20	25	7.184595	0.287384	0.159381

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.346512	3	2.782171	15.19938	3.61E-08	2.699393
Within Groups	17.57232	96	0.183045			
Total	25.91883	99				

Table B. 22 Data analysis for dilution rates - Combination Setup: Linoleum & Paint

Combination Setup: Linoleum & Paint

SUMMARY

Groups	Count	Sum	Average	Variance
Dilution 1	25	-6.62077	-0.26483	0.203734
Dilution 2.5	25	-6.49007	-0.2596	0.207859
Dilution 10	25	5.628191	0.225128	0.175131
Dilution 20	25	6.35	0.254	0.156733

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6.305359	3	2.101786	11.30818	2.04E-06	2.699393
Within Groups	17.84297	96	0.185864			
Total	24.14832	99				

Table B. 23 Data analysis for dilution rates - Mixing Setup: Linoleum, Carpet & paint

Mixing Setup: Linoleum, Carpet & paint

SUMMARY

Groups	Count	Sum	Average	Variance

Dilution 1	25	-4.48527	-0.17941	0.206979
Dilution 2.5	25	-5.03	-0.2012	0.098953
Dilution 10	25	9.60899	0.38436	0.165409
Dilution 20	25	9.228017	0.369121	0.225933

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.047354	3	2.682451	15.38822	2.99E-08	2.699393
Within Groups	16.73458	96	0.174318			
Total	24.78193	99				

Table B. 24 Data analysis for dilution rates - Combination Setup: Linoleum, Carpet & Paint

Combination Setup: Linoleum, Carpet & paint

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Dilution 1	25	-3.46323	-0.13853	0.204119
Dilution 2.5	25	-2.78311	-0.11132	0.130379
Dilution 10	25	9.358499	0.37434	0.216938
Dilution 20	25	11.39	0.4556	0.152084

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.379007	3	2.459669	13.98493	1.23E-07	2.699393
Within Groups	16.88448	96	0.17588			
Total	24.26348	99				

B.2.2 Data Analysis for Difference between Single Materials

Table B. 25 Data analysis for difference between single materials - Carpet & paint

SUMMARY	Paint	carpet	Total			
0						
Count	25	25	50			
Sum	-6.65026	-9.55444	-16.2047			
Average	-0.26601	-0.38218	-0.32409			
Variance	0.168701	0.219869	0.193762			
0.916290732						
Count	25	25	50			
Sum	-5.67838	-7.71852	-13.3969			
Average	-0.22714	-0.30874	-0.26794			
Variance	0.179934	0.240388	0.207571			
2.302585093						
Count	25	25	50			
Sum	2.829588	11.37181	14.2014			
Average	0.113184	0.454872	0.284028			
Variance	0.193147	0.102686	0.174681			
2.995732274						
Count	25	25	50			
Sum	7.48	15	22.48			
Average	0.2992	0.6	0.4496			
Variance	0.168749	0.13605	0.172371			
Total						
Count	100	100				
Sum	-2.01905	9.098844				
Average	-0.02019	0.090988				
Variance	0.228576	0.365204				
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	22.73137	3	7.577122	43.0053	2.63636E-21	2.65164
Columns	0.618037	1	0.618037	3.50778	0.062601153	3.890348
Interaction	2.224291	3	0.74143	4.20812	0.00654884	2.65164
Within	33.82856	192	0.17619			
Total	59.40226	199				

Table B. 26 Data analysis for difference between single materials – Linoleum & paint

SUMMARY	Paint	Linoleum	Total

0			
Count	25	25	50
Sum	-6.65026	-7.54811	-14.1984
Average	-0.26601	-0.30192	-0.28397
Variance	0.168701	0.268043	0.214244

0.916290732			
Count	25	25	50
Sum	-5.67838	-6.84	-12.5184
Average	-0.22714	-0.2736	-0.25037
Variance	0.179934	0.204049	0.188624

2.302585093			
Count	25	25	50
Sum	2.829588	6.407811	9.237399
Average	0.113184	0.256312	0.184748
Variance	0.193147	0.146815	0.171738

2.995732274			
Count	25	25	50
Sum	7.48	7.547676	15.02768
Average	0.2992	0.301907	0.300554
Variance	0.168749	0.141562	0.151991

Total		
Count	100	100
Sum	-2.01905	-0.43262
Average	-0.02019	-0.00433
Variance	0.228576	0.265867

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	13.35923	3	4.453076	24.21797	2.45569E-13	2.65164
Columns	0.012584	1	0.012584	0.068436	0.793908238	3.890348
Interaction	0.286692	3	0.095564	0.519723	0.669200418	2.65164
Within	35.30398	192	0.183875			
Total	48.96248	199				

Table B. 27 Data analysis for difference between single materials – Linoleum & Carpet

SUMMARY	linoleum	carpet	Total			
0						
Count	25	25	50			
Sum	-7.54811	-9.55444	-17.1026			
Average	-0.30192	-0.38218	-0.34205			
Variance	0.268043	0.219869	0.24062			
0.916290732						
Count	25	25	50			
Sum	-6.84	-7.71852	-14.5585			
Average	-0.2736	-0.30874	-0.29117			
Variance	0.204049	0.240388	0.217998			
2.302585093						
Count	25	25	50			
Sum	6.407811	11.37181	17.77962			
Average	0.256312	0.454872	0.355592			
Variance	0.146815	0.102686	0.132262			
2.995732274						
Count	25	25	50			
Sum	7.547676	15	22.54768			
Average	0.301907	0.6	0.450954			
Variance	0.141562	0.13605	0.158641			
Total						
Count	100	100				
Sum	-0.43262	9.098844				
Average	-0.00433	0.090988				
Variance	0.265867	0.365204				
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	26.20369	3	8.734565	47.87831	3.78103E-23	2.65164
Columns	0.454244	1	0.454244	2.48993	0.116222931	3.890348
Interaction	1.245267	3	0.415089	2.2753	0.081208302	2.65164
Within	35.02706	192	0.182433			
Total	62.93026	199				

B.2.3 Data Analysis for Difference between Mixing, Combination and Single Set Ups

Table B. 28 Data analysis for difference between mixing and combination set ups – Paint & Carpet

Carpet & Paint SUMMARY	combination	Mixing	Total
0			
Count	25	25	50
Sum	-6.77241981	-9.3397	-16.112
Average	-0.27089679	-0.3736	-0.3222
Variance	0.16741614	0.21937	0.19213
0.916290732			
Count	25	25	50
Sum	-13.3632992	-4.75	-18.1133
Average	-0.53453197	-0.19	-0.36227
Variance	0.20823561	0.16285	0.21204
2.302585093			
Count	25	25	50
Sum	6.66140083	5.69431	12.3557
Average	0.26645603	0.22777	0.24711
Variance	0.20916072	0.24345	0.22207
2.995732274			
Count	25	25	50
Sum	0.87	10.1132	10.9832
Average	0.0348	0.40453	0.21967
Variance	0.12323433	0.14426	0.16589
Total			
Count	100	100	
Sum	-12.6043181	1.71782	
Average	-0.12604318	0.01718	
Variance	0.26451938	0.28514	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	16.6271849	3	5.54239	30.0002	5.9553E-16	2.65164
Columns	1.02561761	1	1.02562	5.55152	0.01947253	3.89035
Interaction	2.31743976	3	0.77248	4.18132	0.00678306	2.65164
Within	35.4711229	192	0.18474			
Total	55.4413652	199				

Table B. 29 Data analysis for difference between mixing set up of Paint & Carpet with single set up of Paint

SUMMARY	Mixing	Paint	Total
0			
Count	25	25	50
Sum	-9.339733799	-6.65026	-15.99
Average	-0.373589352	-0.26601	-0.3198
Variance	0.219364712	0.168701	0.193025
0.916290732			
Count	25	25	50
Sum	-4.75	-5.67838	-10.4284
Average	-0.19	-0.22714	-0.20857
Variance	0.16285	0.179934	0.168246
2.302585093			
Count	25	25	50
Sum	5.69430504	2.829588	8.523893
Average	0.227772202	0.113184	0.170478
Variance	0.243445997	0.193147	0.217191
2.995732274			
Count	25	25	50
Sum	10.1132446	7.48	17.59324
Average	0.404529784	0.2992	0.351865
Variance	0.144255942	0.168749	0.156139
Total			
Count	100	100	
Sum	1.717815841	-2.01905	
Average	0.017178158	-0.02019	
Variance	0.285134635	0.228576	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	14.93174283	3	4.977248	26.89591	1.44247E-14	2.65164
Columns	0.069820659	1	0.069821	0.377295	0.539781689	3.890348
Interaction	0.394894441	3	0.131631	0.711306	0.546337773	2.65164
Within	35.5307407	192	0.185056			
Total	50.92719863	199				

Table B. 30 Data analysis for difference between mixing set up of Paint & Carpet with single set up of Carpet

SUMMARY	Mixing	carpet	Total
0			
Count	25	25	50

Sum	-9.339733799	-9.55444	-18.8942
Average	-0.373589352	-0.38218	-0.37788
Variance	0.219364712	0.219869	0.215154
0.916290732			
Count	25	25	50
Sum	-4.75	-7.71852	-12.4685
Average	-0.19	-0.30874	-0.24937
Variance	0.16285	0.240388	0.201101
2.302585093			
Count	25	25	50
Sum	5.69430504	11.37181	17.06611
Average	0.227772202	0.454872	0.341322
Variance	0.243445997	0.102686	0.182691
2.995732274			
Count	25	25	50
Sum	10.1132446	15	25.11324
Average	0.404529784	0.6	0.502265
Variance	0.144255942	0.13605	0.14704
Total			
Count	100	100	
Sum	1.717815841	9.098844	
Average	0.017178158	0.090988	
Variance	0.285134635	0.365204	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	28.10262398	3	9.367541	51.01767	2.70034E-24	2.65164
Columns	0.27239785	1	0.272398	1.483538	0.224716439	3.890348
Interaction	1.027055498	3	0.342352	1.864523	0.13697757	2.65164
Within	35.2538216	192	0.183614			
Total	64.65589893	199				

Table B. 31 Data analysis for difference between combination set up of Paint & Carpet with single set up of Paint

SUMMARY	combination	Paint	Total
0			
Count	25	25	50
Sum	-6.772419812	-6.65026	-13.4227
Average	-0.270896792	-0.26601	-0.26845
Variance	0.167416135	0.168701	0.164635

0.916290732			
Count	25	25	50
Sum	-13.36329915	-5.67838	-19.0417
Average	-0.534531966	-0.22714	-0.38083
Variance	0.208235612	0.179934	0.214229

2.302585093			
Count	25	25	50
Sum	6.661400829	2.829588	9.490988
Average	0.266456033	0.113184	0.18982
Variance	0.209160724	0.193147	0.203042

2.995732274			
Count	25	25	50
Sum	0.87	7.48	8.35
Average	0.0348	0.2992	0.167
Variance	0.123234333	0.168749	0.160846

Total		
Count	100	100
Sum	-12.60431813	-2.01905
Average	-0.126043181	-0.02019
Variance	0.264519382	0.228576

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	12.98188647	3	4.327295	24.40357	2.01236E-13	2.65164
Columns	0.560239996	1	0.56024	3.159446	0.077071768	3.890348
Interaction	1.788717023	3	0.596239	3.362461	0.019823776	2.65164
Within	34.04586443	192	0.177322			
Total	49.37670791	199				

Table B. 32 Data analysis for difference between mixing set up of Paint & Carpet with single set up of Carpet

SUMMARY	combination	carpet	Total
0			
Count	25	25	50
Sum	-6.772419812	-9.55444	-16.3269
Average	-0.270896792	-0.38218	-0.32654
Variance	0.167416135	0.219869	0.19285
0.916290732			
Count	25	25	50
Sum	-13.36329915	-7.71852	-21.0818
Average	-0.534531966	-0.30874	-0.42164

Variance	0.208235612	0.240388	0.232739
2.302585093			
Count	25	25	50
Sum	6.661400829	11.37181	18.03321
Average	0.266456033	0.454872	0.360664
Variance	0.209160724	0.102686	0.161798
2.995732274			
Count	25	25	50
Sum	0.87	15	15.87
Average	0.0348	0.6	0.3174
Variance	0.123234333	0.13605	0.208489
Total			
Count	100	100	
Sum	-12.60431813	9.098844	
Average	-0.126043181	0.090988	
Variance	0.264519382	0.365204	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	25.69982269	3	8.566608	48.70714	1.87049E-23	2.65164
Columns	2.355136136	1	2.355136	13.39059	0.000326691	3.890348
Interaction	2.873823011	3	0.957941	5.446563	0.001292948	2.65164
Within	33.76894533	192	0.17588			
Total	64.69772716	199				

Table B. 33 Data analysis for Difference between mixing and combination set ups – Linoleum & Carpet

Linoleum & Carpet			
SUMMARY	Combination	Mixing	Total
0			
Count	25	25	50
Sum	-11.4309404	-8.1909	-19.622
Average	-0.45723762	-0.3276	-0.3924
Variance	0.23837166	0.18284	0.21059
0.916290732			
Count	25	25	50
Sum	-1.33	-8.0762	-9.4062
Average	-0.0532	-0.3231	-0.1881
Variance	0.22114767	0.21669	0.23303

2.302585093			
Count	25	25	50
Sum	10.1804495	11.7106	21.8911
Average	0.40721798	0.46842	0.43782
Variance	0.27078420	0.21291	0.23786
2.995732274			
Count	25	25	50
Sum	11.0938250	9.9	20.9938
Average	0.443753	0.396	0.41988
Variance	0.15964946	0.17828	0.16609
Total			
Count	100	100	
Sum	8.51333406	5.34353	
Average	0.08513334	0.05344	
Variance	0.35353632	0.33727	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	26.9089791	3	8.96966	42.6959	3.4738E-21	2.65164
Columns	0.05023828	1	0.05024	0.23914	0.62538897	3.89035
Interaction	1.14525889	3	0.38175	1.81716	0.14540217	2.65164
Within	40.3358254	192	0.21008			
Total	68.44030167	199				

Table B. 34 Data analysis for difference between mixing set up of Linoleum & Carpet with single set up of Carpet

SUMMARY	Linoleum & Carpet(mixing)	carpet	Total
0			
Count	25	25	50
Sum	-8.190922976	-9.55444	-17.7454
Average	-0.327636919	-0.38218	-0.35491
Variance	0.182837014	0.219869	0.198003
0.916290732			
Count	25	25	50
Sum	-8.076150993	-7.71852	-15.7947
Average	-0.32304604	-0.30874	-0.31589
Variance	0.216697382	0.240388	0.223931
2.302585093			
Count	25	25	50
Sum	11.71060441	11.37181	23.08241

Average	0.468424176	0.454872	0.461648
Variance	0.212905347	0.102686	0.154622
2.995732274			
Count	25	25	50
Sum	9.9	15	24.9
Average	0.396	0.6	0.498
Variance	0.178266667	0.13605	0.164567
Total			
Count	100	100	
Sum	5.343530439	9.098844	
Average	0.053435304	0.090988	
Variance	0.337272406	0.365204	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	33.30063937	3	11.10021	59.6105	2.7878E-27	2.65164
Columns	0.070511883	1	0.070512	0.378664	0.539047917	3.890348
Interaction	0.491725284	3	0.163908	0.880223	0.452344374	2.65164
Within	35.75277582	192	0.186212			
Total	69.61565236	199				

Table B. 35 Data analysis for difference between mixing set up of Linoleum & Carpet with single set up of Linoleum

SUMMARY	Linoleum & Carpet(mixing)	Linoleum	Total
0			
Count	25	25	50
Sum	-8.190922976	-7.54811	-15.739
Average	-0.327636919	-0.30192	-0.31478
Variance	0.182837014	0.268043	0.221008
0.916290732			
Count	25	25	50
Sum	-8.076150993	-6.84	-14.9162
Average	-0.32304604	-0.2736	-0.29832
Variance	0.216697382	0.204049	0.206704
2.302585093			
Count	25	25	50
Sum	11.71060441	6.407811	18.11842
Average	0.468424176	0.256312	0.362368
Variance	0.212905347	0.146815	0.187667

2.995732274			
Count	25	25	50
Sum	9.9	7.547676	17.44768
Average	0.396	0.301907	0.348954
Variance	0.178266667	0.141562	0.158909

Total		
Count	100	100
Sum	5.343530439	-0.43262
Average	0.053435304	-0.00433
Variance	0.337272406	0.265867

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	21.93755903	3	7.31252	37.71346	3.3002E-19	2.65164
Columns	0.166819854	1	0.16682	0.860354	0.354804261	3.890348
Interaction	0.545066439	3	0.181689	0.937039	0.423832805	2.65164
Within	37.22819023	192	0.193897			
Total	59.87763555	199				

Table B. 36 Data analysis for difference between combination set up of Linoleum & Carpet with single set up of Carpet

SUMMARY	Linoleum & Carpet(comb.)	carpet	Total
0			
Count	25	25	50
Sum	-11.43094043	-9.55444	-20.9854
Average	-0.457237617	-0.38218	-0.41971
Variance	0.238371658	0.219869	0.225882
0.916290732			
Count	25	25	50
Sum	-1.33	-7.71852	-9.04852
Average	-0.0532	-0.30874	-0.18097
Variance	0.221147667	0.240388	0.242717
2.302585093			
Count	25	25	50
Sum	10.18044949	11.37181	21.55226
Average	0.407217979	0.454872	0.431045
Variance	0.270784201	0.102686	0.183504
2.995732274			
Count	25	25	50
Sum	11.09382501	15	26.09383

Average	0.443753	0.6	0.521877
Variance	0.159649456	0.13605	0.15106
Total			
Count	100	100	
Sum	8.513334061	9.098844	
Average	0.085133341	0.090988	
Variance	0.353536315	0.365204	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	31.80204706	3	10.60068	53.37216	3.90701E-25	2.65164
Columns	0.001714107	1	0.001714	0.00863	0.926080938	3.890348
Interaction	1.218526781	3	0.406176	2.045007	0.108979327	2.65164
Within	38.13469355	192	0.198618			
Total	71.1569815	199				

Table B. 37 Data analysis for difference between mixing set up of Linoleum & Carpet with single set up of Linoleum

SUMMARY	Linoleum & Carpet(comb.)	Linoleum	Total
0			
Count	25	25	50
Sum	-11.43094043	-7.54811	-18.9791
Average	-0.457237617	-0.30192	-0.37958
Variance	0.238371658	0.268043	0.254193
0.916290732			
Count	25	25	50
Sum	-1.33	-6.84	-8.17
Average	-0.0532	-0.2736	-0.1634
Variance	0.221147667	0.204049	0.220651
2.302585093			
Count	25	25	50
Sum	10.18044949	6.407811	16.58826
Average	0.407217979	0.256312	0.331765
Variance	0.270784201	0.146815	0.210348
2.995732274			
Count	25	25	50
Sum	11.09382501	7.547676	18.6415
Average	0.443753	0.301907	0.37283
Variance	0.159649456	0.141562	0.152665

Total		
Count	100	100
Sum	8.513334061	-0.43262
Average	0.085133341	-0.00433
Variance	0.353536315	0.265867

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	20.66609715	3	6.888699	33.39123	2.05324E-17	2.65164
Columns	0.40015091	1	0.400151	1.939631	0.165319282	3.890348
Interaction	1.04473751	3	0.348246	1.688034	0.170962159	2.65164
Within	39.61010795	192	0.206303			
Total	61.72109352	199				

Table B. 38 Data analysis for difference between mixing and combination set ups – Linoleum & Paint

paint & Linoleum						
SUMMARY	Combination	Mixing	Total			
0						
Count	25	25	50			
Sum	-6.62077242	-9.4493	-16.07			
Average	-0.26483089	-0.3779	-0.3214			
Variance	0.20373418	0.23813	0.21969			
0.916290732						
Count	25	25	50			
Sum	-6.49007201	-5.36	-11.8501			
Average	-0.25960288	-0.2144	-0.237			
Variance	0.20785874	0.21535	0.20781			
2.302585093						
Count	25	25	50			
Sum	5.62819114	6.28300	11.9112			
Average	0.22512765	0.25132	0.23822			
Variance	0.17513067	0.11931	0.14439			
2.995732274						
Count	25	25	50			
Sum	6.35	7.18459	13.5346			
Average	0.254	0.28738	0.27069			
Variance	0.15673333	0.15938	0.15512			
Total						
Count	100	100				
Sum	-1.13265328	-1.34167				
Average	-0.01132653	-0.01342				
Variance	0.24392247	0.26181				
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	14.4440334	3	4.81468	26.1022	3.3136E-14	2.65164
Columns	0.00021844	1	0.00022	0.00118	0.97258347	3.89035
Interaction	0.20783721	3	0.06928	0.37559	0.77070739	2.65164
Within	35.4152872	192	0.18446			
Total	50.0673762	199				

Table B. 39 Data analysis for difference between mixing set up of Linoleum & Paint with single set up of Linoleum

SUMMARY	mixing	Linoleum	Total

0			
Count	25	25	50
Sum	-9.449269038	-7.54811	-16.9974
Average	-0.377970762	-0.30192	-0.33995
Variance	0.238133711	0.268043	0.249398

0.916290732			
Count	25	25	50
Sum	-5.36	-6.84	-12.2
Average	-0.2144	-0.2736	-0.244
Variance	0.215350667	0.204049	0.206314

2.302585093			
Count	25	25	50
Sum	6.2830024	6.407811	12.69081
Average	0.251320096	0.256312	0.253816
Variance	0.119314495	0.146815	0.130355

2.995732274			
Count	25	25	50
Sum	7.184595243	7.547676	14.73227
Average	0.28738381	0.301907	0.294645
Variance	0.159381174	0.141562	0.147454

Total		
Count	100	100
Sum	-1.341671394	-0.43262
Average	-0.013416714	-0.00433
Variance	0.261806392	0.265867

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	16.30121058	3	5.433737	29.12267	1.451E-15	2.65164
Columns	0.004131827	1	0.004132	0.022145	0.881858327	3.890348
Interaction	0.114912191	3	0.038304	0.205295	0.892645988	2.65164
Within	35.82355752	192	0.186581			
Total	52.24381212	199				

Table B. 40 Data analysis for difference between mixing set up of Linoleum & Paint with single set up of Paint

SUMMARY	mixing	Paint	Total
0			
Count	25	25	50
Sum	-9.449269038	-6.65026	-16.0995
Average	-0.377970762	-0.26601	-0.32199
Variance	0.238133711	0.168701	0.202464

0.916290732			
Count	25	25	50
Sum	-5.36	-5.67838	-11.0384
Average	-0.2144	-0.22714	-0.22077
Variance	0.215350667	0.179934	0.19365
2.302585093			
Count	25	25	50
Sum	6.2830024	2.829588	9.11259
Average	0.251320096	0.113184	0.182252
Variance	0.119314495	0.193147	0.15791
2.995732274			
Count	25	25	50
Sum	7.184595243	7.48	14.6646
Average	0.28738381	0.2992	0.293292
Variance	0.159381174	0.168749	0.160753
Total			
Count	100	100	
Sum	-1.341671394	-2.01905	
Average	-0.013416714	-0.02019	
Variance	0.261806392	0.228576	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	13.52613046	3	4.50871	25.00132	1.06268E-13	2.65164
Columns	0.002294178	1	0.002294	0.012721	0.910315245	3.890348
Interaction	0.396689287	3	0.13223	0.733229	0.533355871	2.65164
Within	34.62506222	192	0.180339			
Total	48.55017614	199				

Table B. 41 Data analysis for difference between combination set up of Linoleum & Paint with single set up of Linoleum

SUMMARY	combination	Linoleum	Total
0			
Count	25	25	50
Sum	-6.62077242	-7.54811	-14.1689
Average	-0.264830897	-0.30192	-0.28338
Variance	0.203734177	0.268043	0.231425
0.916290732			
Count	25	25	50
Sum	-6.490072005	-6.84	-13.3301
Average	-0.25960288	-0.2736	-0.2666

Variance	0.207858742	0.204049	0.201801
2.302585093			
Count	25	25	50
Sum	5.628191141	6.407811	12.036
Average	0.225127646	0.256312	0.24072
Variance	0.175130668	0.146815	0.157936
2.995732274			
Count	25	25	50
Sum	6.35	7.547676	13.89768
Average	0.254	0.301907	0.277954
Variance	0.156733333	0.141562	0.146689
Total			
Count	100	100	
Sum	-1.132653284	-0.43262	
Average	-0.011326533	-0.00433	
Variance	0.243922474	0.265867	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	14.31692722	3	4.772309	25.38589	7.06219E-14	2.65164
Columns	0.002450199	1	0.00245	0.013034	0.909226384	3.890348
Interaction	0.058042712	3	0.019348	0.102918	0.95826873	2.65164
Within	36.09420248	192	0.187991			
Total	50.4716226	199				

Table B. 42 Data analysis for difference between combination set up of Linoleum & Paint with single set up of Paint

SUMMARY	combination	Paint	Total
0			
Count	25	25	50
Sum	-6.62077242	-6.65026	-13.271
Average	-0.264830897	-0.26601	-0.26542
Variance	0.203734177	0.168701	0.182418
0.916290732			
Count	25	25	50
Sum	-6.490072005	-5.67838	-12.1684
Average	-0.25960288	-0.22714	-0.24337
Variance	0.207858742	0.179934	0.190208
2.302585093			
Count	25	25	50
Sum	5.628191141	2.829588	8.457779

Average	0.225127646	0.113184	0.169156
Variance	0.175130668	0.193147	0.183578

2.995732274			
Count	25	25	50
Sum	6.35	7.48	13.83
Average	0.254	0.2992	0.2766
Variance	0.156733333	0.168749	0.159941

Total		
Count	100	100
Sum	-1.132653284	-2.01905
Average	-0.011326533	-0.02019
Variance	0.243922474	0.228576

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	11.69021935	3	3.89674	21.44029	5.07292E-12	2.65164
Columns	0.003928455	1	0.003928	0.021615	0.883270744	3.890348
Interaction	0.191447555	3	0.063816	0.351122	0.788378476	2.65164
Within	34.89570717	192	0.181748			
Total	46.78130253	199				

Table B. 43 Data analysis for difference between mixing and combination set ups – Linoleum, Carpet & Paint

Linoleum, Carpet & Paint

SUMMARY	Combination	Mixing	Total
0			
Count	25	25	50
Sum	-3.46323369	-4.48527	-7.9485
Average	-0.13852934	-0.17941	-0.1589
Variance	0.20411868	0.20698	0.20178
0.916290732			
Count	25	25	50
Sum	-2.78311149	-5.03	-7.8131
Average	-0.11132446	-0.2012	-0.1563
Variance	0.13037882	0.09895	0.11439
2.302585093			
Count	25	25	50
Sum	9.3584988	9.60899	18.9675
Average	0.37433992	0.38436	0.37935
Variance	0.21693838	0.16541	0.1873
2.995732274			
Count	25	25	50
Sum	11.39	9.22802	20.6180
Average	0.4556	0.36912	0.41236
Variance	0.152084	0.22593	0.18706
Total			
Count	100	100	
Sum	14.5021536	9.32174	
Average	0.14502154	0.09322	
Variance	0.245085699	0.250323	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	15.3439453	3	5.11465	29.21	1.3275E-15	2.65164
Columns	0.13418370	1	0.13418	0.76633	0.38244876	3.89036
Interaction	0.08241605	3	0.02747	0.15689	0.92514398	2.65164
Within	33.6190519	192	0.17509			
Total	49.1795970	199				

Table B. 44 Data analysis for difference between mixing set up of Linoleum, Carpet & Paint with single set up of Paint

SUMMARY	Linoleum, Carpet &	Paint	Total

	Paint(mixing)		
0			
Count	25	25	50
Sum	-4.485271656	-6.65026	-11.1355
Average	-0.179410866	-0.26601	-0.22271
Variance	0.206979373	0.168701	0.18592
0.916290732			
Count	25	25	50
Sum	-5.03	-5.67838	-10.7084
Average	-0.2012	-0.22714	-0.21417
Variance	0.098952667	0.179934	0.136769
2.302585093			
Count	25	25	50
Sum	9.608989745	2.829588	12.43858
Average	0.38435959	0.113184	0.248772
Variance	0.165408579	0.193147	0.194378
2.995732274			
Count	25	25	50
Sum	9.228016583	7.48	16.70802
Average	0.369120663	0.2992	0.33416
Variance	0.225933341	0.168749	0.194561
Total			
Count	100	100	
Sum	9.321734672	-2.01905	
Average	0.093217347	-0.02019	
Variance	0.250322516	0.228576	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	13.18426043	3	4.394753	24.97365	1.09446E-13	2.65164
Columns	0.643066461	1	0.643066	3.654293	0.057414024	3.890348
Interaction	0.439401667	3	0.146467	0.832315	0.477592592	2.65164
Within	33.78731611	192	0.175976			
Total	48.05404466	199				

Table B. 45 Data analysis for difference between mixing set up of Linoleum, Carpet & Paint with single set up of Linoleum

SUMMARY	Linoleum, Carpet & Paint(mixing)	Linoleum	Total
0			
Count	25	25	50

Sum	-4.485271656	-7.54811	-12.0334
Average	-0.179410866	-0.30192	-0.24067
Variance	0.206979373	0.268043	0.236493
0.916290732			
Count	25	25	50
Sum	-5.03	-6.84	-11.87
Average	-0.2012	-0.2736	-0.2374
Variance	0.098952667	0.204049	0.149746
2.302585093			
Count	25	25	50
Sum	9.608989745	6.407811	16.0168
Average	0.38435959	0.256312	0.320336
Variance	0.165408579	0.146815	0.157108
2.995732274			
Count	25	25	50
Sum	9.228016583	7.547676	16.77569
Average	0.369120663	0.301907	0.335514
Variance	0.225933341	0.141562	0.18115
Total			
Count	100	100	
Sum	9.321734672	-0.43262	
Average	0.093217347	-0.00433	
Variance	0.250322516	0.265867	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	16.07813916	3	5.35938	29.41195	1.08088E-15	2.65164
Columns	0.475737655	1	0.475738	2.610819	0.10777889	3.890348
Interaction	0.038825959	3	0.012942	0.071025	0.975379462	2.65164
Within	34.98581141	192	0.182218			
Total	51.57851418	199				

Table B. 46 Data analysis for difference between mixing set up of Linoleum, Carpet & Paint with single set up of Carpet

SUMMARY	Linoleum, Carpet & Paint(mixing)	carpet	Total
0			
Count	25	25	50
Sum	-4.485271656	-9.55444	-14.0397
Average	-0.179410866	-0.38218	-0.28079
Variance	0.206979373	0.219869	0.219557

0.916290732			
Count	25	25	50
Sum	-5.03	-7.71852	-12.7485
Average	-0.2012	-0.30874	-0.25497
Variance	0.098952667	0.240388	0.169158
2.302585093			
Count	25	25	50
Sum	9.608989745	11.37181	20.9808
Average	0.38435959	0.454872	0.419616
Variance	0.165408579	0.102686	0.13258
2.995732274			
Count	25	25	50
Sum	9.228016583	15	24.22802
Average	0.369120663	0.6	0.48456
Variance	0.225933341	0.13605	0.190896
Total			
Count	100	100	
Sum	9.321734672	9.098844	
Average	0.093217347	0.090988	
Variance	0.250322516	0.365204	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	26.03999348	3	8.679998	49.73261	7.88549E-24	2.65164
Columns	0.000248402	1	0.000248	0.001423	0.969945492	3.890348
Interaction	1.386710825	3	0.462237	2.648417	0.050209064	2.65164
Within	33.51039701	192	0.174533			
Total	60.93734971	199				

Table B. 47 Data analysis for difference between combination set up of Linoleum, Carpet & Paint with single set up of Paint

SUMMARY	Linoleum, Carpet & paint (comb.)	Paint	Total
0			
Count	25	25	50
Sum	-3.46323369	-6.65026	-10.1135
Average	-0.138529348	-0.26601	-0.20227
Variance	0.204118677	0.168701	0.186751
0.916290732			
Count	25	25	50

Sum	-2.783111499	-5.67838	-8.46149
Average	-0.11132446	-0.22714	-0.16923
Variance	0.130378815	0.179934	0.155411
2.302585093			
Count	25	25	50
Sum	9.3584988	2.829588	12.18809
Average	0.374339952	0.113184	0.243762
Variance	0.216938381	0.193147	0.218257
2.995732274			
Count	25	25	50
Sum	11.39	7.48	18.87
Average	0.4556	0.2992	0.3774
Variance	0.152084	0.168749	0.163383
Total			
Count	100	100	
Sum	14.50215361	-2.01905	
Average	0.145021536	-0.02019	
Variance	0.245085699	0.228576	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	12.7909763	3	4.263659	24.12167	2.72334E-13	2.65164
Columns	1.364750081	1	1.36475	7.721081	0.006000171	3.890348
Interaction	0.16433902	3	0.05478	0.309916	0.818203473	2.65164
Within	33.93721803	192	0.176756			
Total	48.25728343	199				

Table B. 48 Data analysis for difference between combination set up of Linoleum, Carpet & Paint with single set up of Linoleum

SUMMARY	Linoleum, Carpet & paint (comb.)	Linoleum	Total
0			
Count	25	25	50
Sum	-3.46323369	-7.54811	-11.0113
Average	-0.138529348	-0.30192	-0.22023
Variance	0.204118677	0.268043	0.238073
0.916290732			
Count	25	25	50
Sum	-2.783111499	-6.84	-9.62311
Average	-0.11132446	-0.2736	-0.19246
Variance	0.130378815	0.204049	0.170519

2.302585093			
Count	25	25	50
Sum	9.3584988	6.407811	15.76631
Average	0.374339952	0.256312	0.315326
Variance	0.216938381	0.146815	0.181719
2.995732274			
Count	25	25	50
Sum	11.39	7.547676	18.93768
Average	0.4556	0.301907	0.378754
Variance	0.152084	0.141562	0.149852
Total			
Count	100	100	
Sum	14.50215361	-0.43262	
Average	0.145021536	-0.00433	
Variance	0.245085699	0.265867	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	15.43156464	3	5.143855	28.10873	4.10171E-15	2.65164
Columns	1.115238049	1	1.115238	6.094247	0.014436513	3.890348
Interaction	0.017053708	3	0.005685	0.031063	0.99261636	2.65164
Within	35.13571334	192	0.182999			
Total	51.69956973	199				

Table B. 49 Data analysis for difference between combination set up of Linoleum, Carpet & Paint with single set up of Carpet

SUMMARY	Linoleum, Carpet & paint (comb.)	carpet	Total
0			
Count	25	25	50
Sum	-3.46323369	-9.55444	-13.0177
Average	-0.138529348	-0.38218	-0.26035
Variance	0.204118677	0.219869	0.222811
0.916290732			
Count	25	25	50
Sum	-2.783111499	-7.71852	-10.5016
Average	-0.11132446	-0.30874	-0.21003
Variance	0.130378815	0.240388	0.191542
2.302585093			
Count	25	25	50
Sum	9.3584988	11.37181	20.73031

Average	0.374339952	0.454872	0.414606
Variance	0.216938381	0.102686	0.158205
2.995732274			
Count	25	25	50
Sum	11.39	15	26.39
Average	0.4556	0.6	0.5278
Variance	0.152084	0.13605	0.146446

Total		
Count	100	100
Sum	14.50215361	9.098844
Average	0.145021536	0.090988
Variance	0.245085699	0.365204

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	25.33340389	3	8.444468	48.16766	2.95564E-23	2.65164
Columns	0.145978798	1	0.145979	0.83267	0.362645883	3.890348
Interaction	1.42495364	3	0.474985	2.709335	0.046400109	2.65164
Within	33.66029894	192	0.175314			
Total	60.56463526	199				

B.2.4 Data Analysis for Evaluating the Addition Theory

Table B. 50 Data analysis for evaluating the addition theory – Linoleum & Paint (comb.)

Paint & Linoleum

SUMMARY	sum/2	combination	Total
0			
Count	25	25	50
Sum	35.693066	33.897974	69.59104
Average	1.4277226	1.355919	1.3918208
Variance	0.7006896	1.1117144	0.8890233
0.916290732			
Count	25	25	50
Sum	32.765724	34.451101	67.216825
Average	1.310629	1.378044	1.3443365
Variance	0.5289297	1.1669918	0.8318148
2.302585093			
Count	25	25	50
Sum	11.843073	11.528776	23.371849
Average	0.4737229	0.4611511	0.467437
Variance	0.3111415	0.4783433	0.3867267
2.995732274			
Count	25	25	50
Sum	9.8025769	9.3371908	19.139768
Average	0.3921031	0.3734876	0.3827954
Variance	0.2302325	0.1706461	0.1964371
Total			
Count	100	100	
Sum	90.10444	89.215042	
Average	0.9010444	0.8921504	
Variance	0.6532646	0.9385185	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	44.694386	3	14.898129	25.365593	7.216E-14	2.6516403
Columns	0.0039551	1	0.0039551	0.006734	0.9346835	3.8903477
Interaction	0.1236092	3	0.0412031	0.0701524	0.9758127	2.6516403
Within	112.76853	192	0.5873361			
Total	157.59048	199				

Table B. 51 Data analysis for evaluating the addition theory – Linoleum & Paint (mix.)

Paint & Linoleum

SUMMARY	sum/2	mixing	Total
0			
Count	25	25	50
Sum	35.693066	39.792358	75.485424
Average	1.4277226	1.5916943	1.5097085
Variance	0.7006896	1.2382384	0.9565379
0.916290732			
Count	25	25	50
Sum	32.765724	31.290835	64.056559
Average	1.310629	1.2516334	1.2811312
Variance	0.5289297	1.1388043	0.8177372
2.302585093			
Count	25	25	50
Sum	11.843073	7.9021056	19.745178
Average	0.4737229	0.3160842	0.3949036
Variance	0.3111415	0.1047739	0.2100529
2.995732274			
Count	25	25	50
Sum	9.8025769	9.9749176	19.777494
Average	0.3921031	0.3989967	0.3955499
Variance	0.2302325	0.4062378	0.3117527
Total			
Count	100	100	
Sum	90.10444	88.960216	
Average	0.9010444	0.8896022	
Variance	0.6532646	1.0015527	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	51.325512	3	17.108504	29.376826	1.12E-15	2.6516403
Columns	0.0065462	1	0.0065462	0.0112405	0.9156762	3.8903477
Interaction	0.6842621	3	0.2280874	0.3916463	0.7591504	2.6516403
Within	111.81714	192	0.582381			
Total	163.83346	199				

Table B. 52 Data analysis for evaluating the addition theory – Carpet & Paint (Comb.)

Carpet & Paint

SUMMARY	Sum/2	Combination	Total
0			
Count	25	25	50
Sum	36.461125	36.232923	72.694048
Average	1.458445	1.4493169	1.453881
Variance	0.5664028	0.9984511	0.7664803
0.916290732			
Count	25	25	50
Sum	34.118969	49.589828	83.708797
Average	1.3647588	1.9835931	1.6741759
Variance	0.6874564	1.1203653	0.9831565
2.302585093			
Count	25	25	50
Sum	9.1505496	9.88014	19.03069
Average	0.366022	0.3952056	0.3806138
Variance	0.2113687	0.3379954	0.2692936
2.995732274			
Count	25	25	50
Sum	6.1849697	16.311726	22.496695
Average	0.2473988	0.652469	0.4499339
Variance	0.1590353	0.4850798	0.3573426
Total			
Count	100	100	
Sum	85.915614	112.01462	
Average	0.8591561	1.1201462	
Variance	0.7049248	1.1167602	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	67.315235	3	22.438412	39.312574	7.476E-20	2.6516403
Columns	3.4057897	1	3.4057897	5.9670158	0.0154806	3.8903477
Interaction	3.4438713	3	1.1479571	2.0112452	0.1137574	2.6516403
Within	109.58771	192	0.5707693			
Total	183.75261	199				

Table B. 53 Data analysis for evaluating the addition theory – Carpet & Paint (Mix.)

Carpet & Paint

SUMMARY	sum/2	Mixing	Total
0			
Count	25	25	50
Sum	36.46113	39.94728	76.4084
Average	1.458445	1.597891	1.528168
Variance	0.566403	1.140681	0.841083
0.916291			
Count	25	25	50
Sum	34.11897	28.00424	62.12321
Average	1.364759	1.12017	1.242464
Variance	0.687456	0.985078	0.834461
2.302585			
Count	25	25	50
Sum	9.15055	13.50763	22.65818
Average	0.366022	0.540305	0.453164
Variance	0.211369	0.674131	0.441463
2.995732			
Count	25	25	50
Sum	6.18497	5.539175	11.72414
Average	0.247399	0.221567	0.234483
Variance	0.159035	0.125612	0.13959
Total			
Count	100	100	
Sum	85.91561	86.99832	
Average	0.859156	0.869983	
Variance	0.704925	0.992439	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	57.47157	3	19.15719	33.6847	1.54E-17	2.65164
Columns	0.005861	1	0.005861	0.010306	0.919245	3.890348
Interaction	1.373026	3	0.457675	0.804745	0.492628	2.65164
Within	109.1944	192	0.568721			
Total	168.0448	199				

Table B. 54 Data analysis for evaluating the addition theory – Linoleum & Carpet (comb.)

Linoleum & Carpet

SUMMARY	sum/2	Combination	Total
0			
Count	25	25	50
Sum	37.237335	46.245244	83.482579
Average	1.4894934	1.8498098	1.6696516
Variance	0.8120775	1.0333848	0.9370192
0.916290732			
Count	25	25	50
Sum	35.294612	21.670125	56.964738
Average	1.4117845	0.866805	1.1392948
Variance	0.7772591	0.9436783	0.9186741
2.302585093			
Count	25	25	50
Sum	6.4835409	9.7740793	16.25762
Average	0.2593416	0.3909632	0.3251524
Variance	0.0942143	0.5702051	0.3298494
2.995732274			
Count	25	25	50
Sum	5.5699756	5.0479188	10.617894
Average	0.222799	0.2019168	0.2123579
Variance	0.1225179	0.0857653	0.1021275
Total			
Count	100	100	
Sum	84.585464	82.737368	
Average	0.8458546	0.8273737	
Variance	0.8082246	1.049569	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	71.842796	3	23.947599	43.157551	2.302E-21	2.6516403
Columns	0.0170773	1	0.0170773	0.0307761	0.8609257	3.8903477
Interaction	5.5403076	3	1.8467692	3.3281849	0.0207318	2.6516403
Within	106.53846	192	0.5548878			
Total	183.93864	199				

Table B. 55 Data analysis for evaluating the addition theory – Linoleum & Carpet (mix.)

Linoleum & Carpet

SUMMARY	sum/2	Mixing	Total
0			
Count	25	25	50
Sum	37.237335	38.063206	75.300541
Average	1.4894934	1.5225282	1.5060108
Variance	0.8120775	0.9458249	0.8612918
0.9162907			
Count	25	25	50
Sum	35.294612	40.047904	75.342516
Average	1.4117845	1.6019161	1.5068503
Variance	0.7772591	1.0676668	0.9128591
2.3025851			
Count	25	25	50
Sum	6.4835409	5.9610931	12.444634
Average	0.2593416	0.2384437	0.2488927
Variance	0.0942143	0.3063371	0.1962999
2.9957323			
Count	25	25	50
Sum	5.5699756	6.5208792	12.090855
Average	0.222799	0.2608352	0.2418171
Variance	0.1225179	0.2974479	0.2060666
Total			
Count	100	100	
Sum	84.585464	90.593082	
Average	0.8458546	0.9059308	
Variance	0.8082246	1.0704195	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	79.516863	3	26.505621	47.937689	3.595E-23	2.6516403
Columns	0.1804574	1	0.1804574	0.3263727	0.568471	3.8903477
Interaction	0.3086029	3	0.1028676	0.1860449	0.905802	2.6516403
Within	106.1603	192	0.5529182			
Total	186.16622	199				

Table B. 56 Data analysis for evaluating the addition theory – Linoleum, Paint & Carpet (Comb.)

Linoleum, Paint & Carpet

SUMMARY	sum/3	combination	Total
0			
Count	25	25	50
Sum	36.012579	29.907632	65.920211
Average	1.4405031	1.1963053	1.3184042
Variance	0.5169748	1.0523584	0.7838654
0.9162907			
Count	25	25	50
Sum	34.296544	26.241487	60.538031
Average	1.3718618	1.0496595	1.2107606
Variance	0.6504942	0.6800681	0.6781872
2.3025851			
Count	25	25	50
Sum	9.3474532	7.8447048	17.192158
Average	0.3738981	0.3137882	0.3438432
Variance	0.13052	0.3616894	0.2420039
2.9957323			
Count	25	25	50
Sum	6.7253042	5.1777583	11.903063
Average	0.2690122	0.2071103	0.2380613
Variance	0.1259589	0.1369386	0.1297437
Total			
Count	100	100	
Sum	86.38188	69.171582	
Average	0.8638188	0.6917158	
Variance	0.6443131	0.7328834	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	47.967213	3	15.989071	34.996576	4.338E-18	2.6516403
Columns	1.4809718	1	1.4809718	3.2415229	0.0733635	3.8903477
Interaction	0.6551776	3	0.2183925	0.4780134	0.6979528	2.6516403
Within	87.720058	192	0.4568753			
Total	137.82342	199				

Table B. 57 Data analysis for evaluating the addition theory – Linoleum, Paint & Carpet (Mix.)

Linoleum, Paint & Carpet

SUMMARY	sum/3	mixing	Total
0			
Count	25	25	50
Sum	36.01258	29.01257	65.02515
Average	1.440503	1.160503	1.300503
Variance	0.516975	1.000779	0.76339
0.916291			
Count	25	25	50
Sum	34.29654	29.97289	64.26943
Average	1.371862	1.198915	1.285389
Variance	0.650494	0.705433	0.671758
2.302585			
Count	25	25	50
Sum	9.347453	6.352143	15.6996
Average	0.373898	0.254086	0.313992
Variance	0.13052	0.115758	0.124288
2.995732			
Count	25	25	50
Sum	6.725304	8.937418	15.66272
Average	0.269012	0.357497	0.313254
Variance	0.125959	0.332794	0.226693
Total			
Count	100	100	
Sum	86.38188	74.27502	
Average	0.863819	0.74275	
Variance	0.644313	0.716765	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	47.95936	3	15.98645	35.73678	2.14E-18	2.65164
Columns	0.732881	1	0.732881	1.638312	0.202102	3.890348
Interaction	0.898309	3	0.299436	0.669372	0.57181	2.65164
Within	85.88908	192	0.447339			
Total	135.4796	199				

APPENDIX C

SUPPORTING DOCUMENTS

Table C. 1 Instruments specification used in experimental procedure

Type of Instrument	Specification
Anemometer	Flow master 54N60, Precision Anemometer. DANTEC
Multi Gas Monitor	Bruel and Kjær. Type 1302. Dinitrogen Oxide measurement Detection limit: 0.03 ppm
Mass Flow Meter/Controller	HI-TEC series F-100/200 Bronkhorst Flow 200 mlN/min Air T=20 C

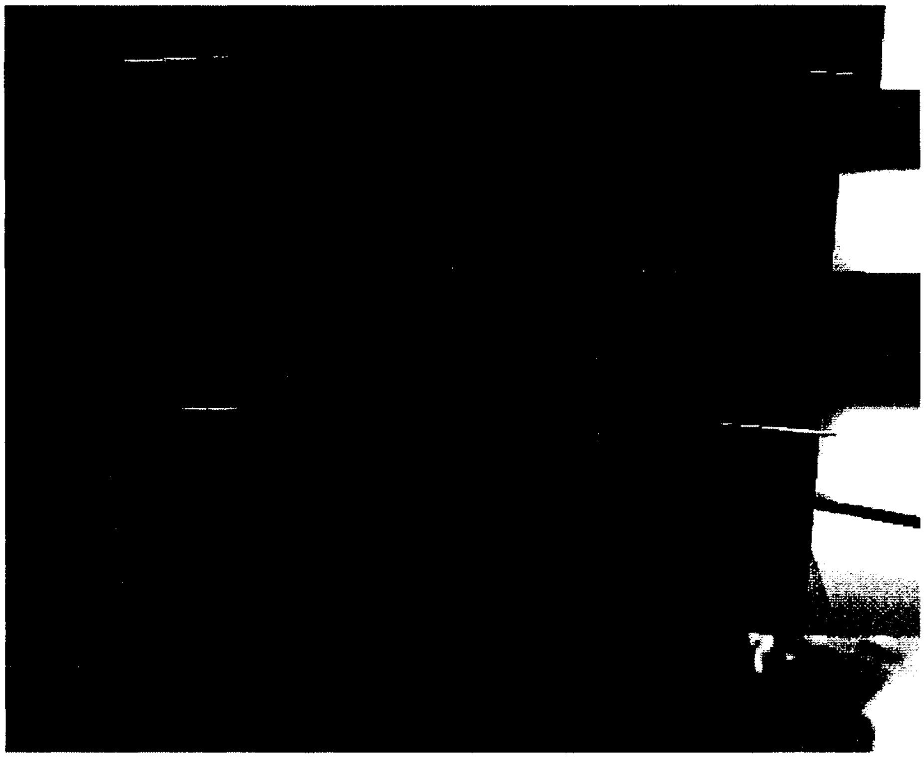

Figure C. 1. Preconditioning period

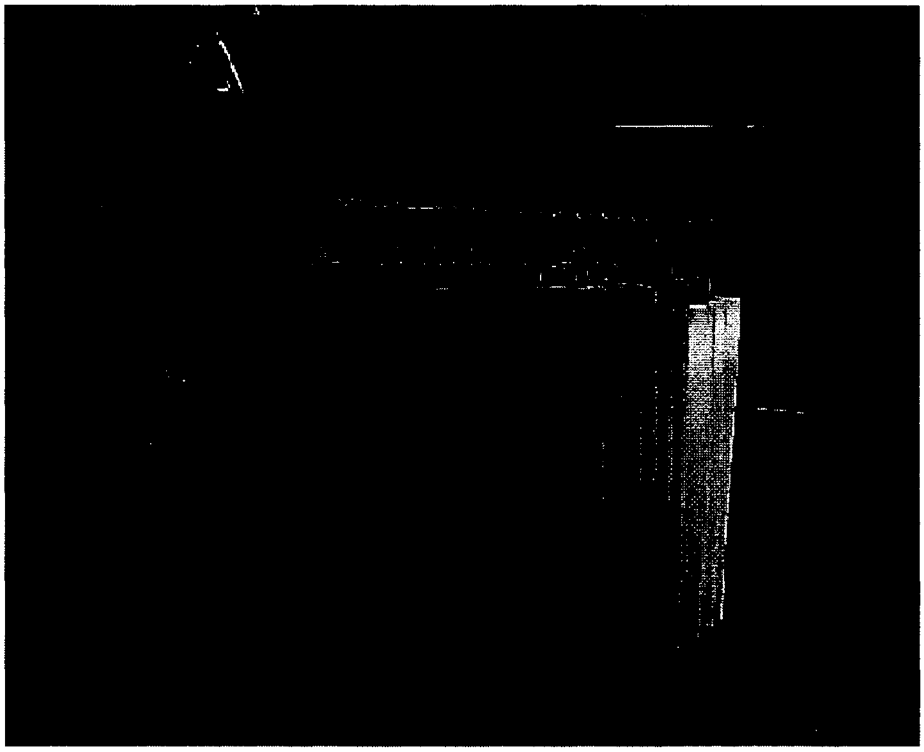

Figure C. 2. Preconditioning period

Figure C. 3. Single set up of an individual building material

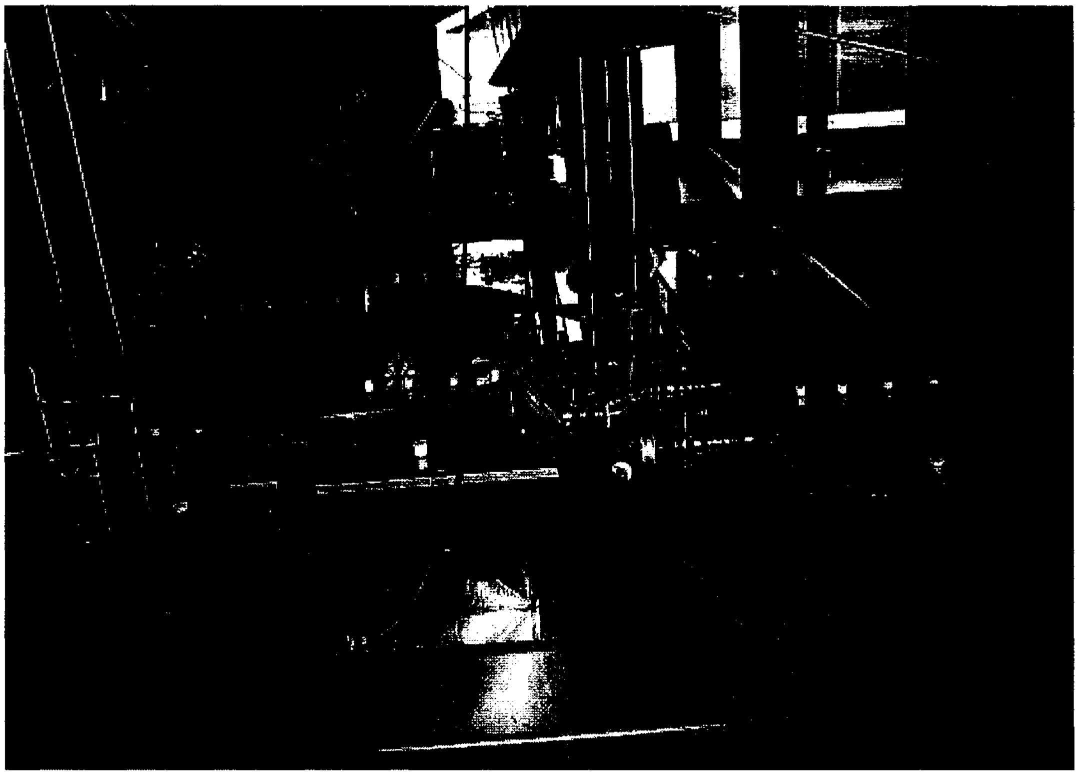

Figure C. 4. Mixing set up of two building materials

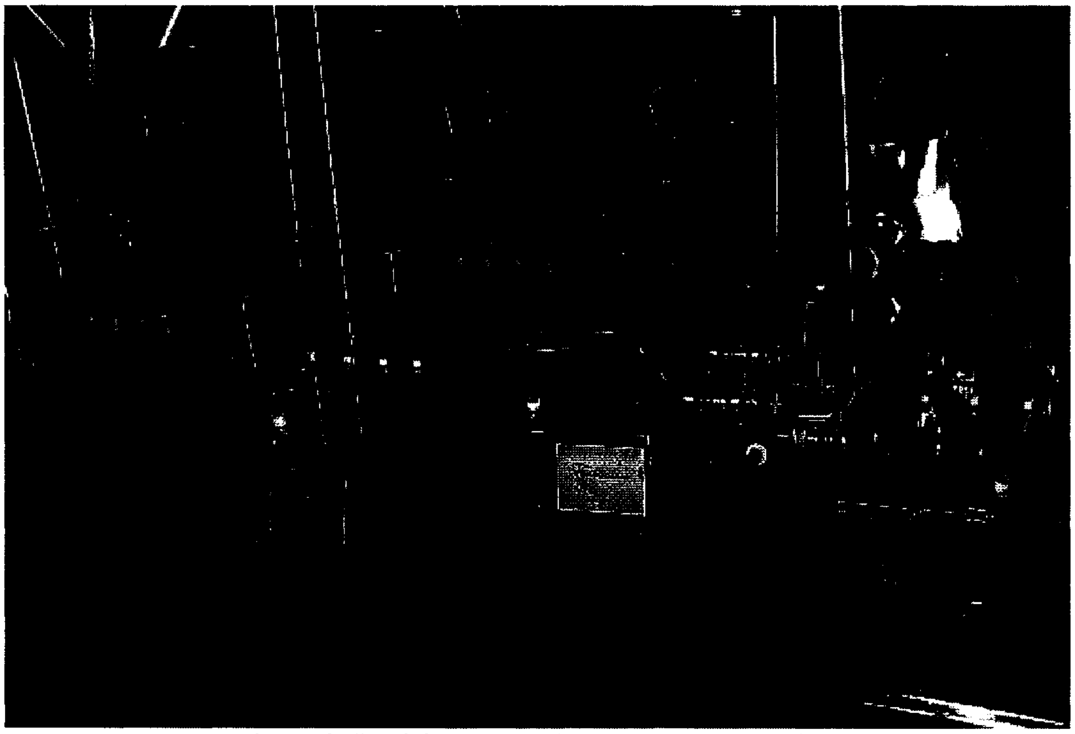

Figure C. 5. Mixing set up of three building materials

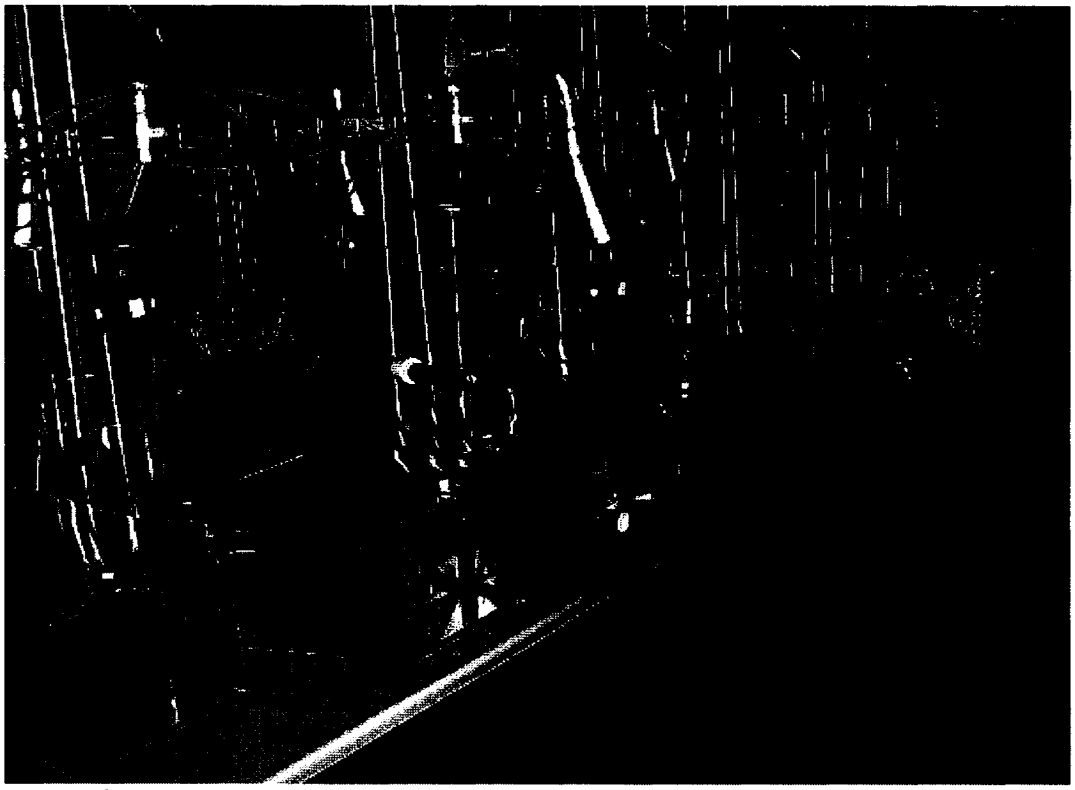

Figure C. 6. CLIMPAQs were covered from outside with aluminium plates to hide the building products from the view of sensory panel.

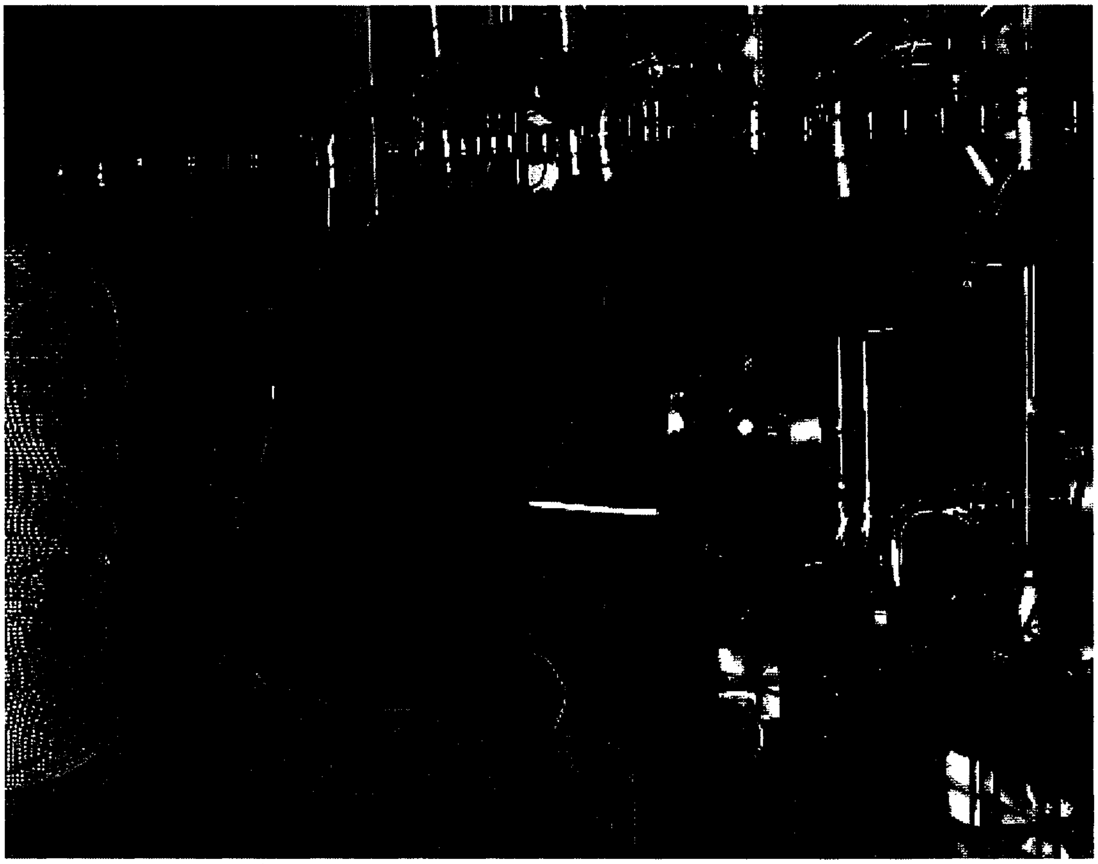

Figure C. 7. Sensory panel performing the assessments