# DRY-MIX PRODUCTS CONTRIBUTION TO INDOOR AIR QUALITY

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## ABSTRACT

A green, or sustainable, building is a structure that is designed, built, renovated, operated or reused in an ecological manner. Occupant health and safety are fundamental requisites for a construction to be called green: buildings with good overall environmental quality can reduce the rate of respiratory disease, sick building syndrome and enhance worker performance. Many building materials emit toxic gases such as volatile organic compounds and formaldehyde, which can have a detrimental impact on occupants' health. Several countries and international communities have imported various regulations mandating maximum VOC of products, thereby establishing indoor air quality standards and restricting certain chemicals from usage within construction industry. Emicode EC1 classification has gained increasing importance in the European Community, and establishes very tight constraints on Volatile Organics and carcinogenic chemicals, creating a significant selection criterion for dry-mix products to be used in truly sustainable buildings.

## 1. INTRODUCTION

Dry-mix products can provide significant contributions to the reduction of the impact of constructions on human health and environment, which is one of the fundamental requirements for a building to be called green. Buildings with good overall environmental quality can reduce the rate of respiratory disease, sick building syndrome and enhance worker performance. The use of dry-mix products compared to traditional building techniques per se allows a more efficient use of resources, as exemplified by the use of thin-layer adhesives to lay tiles vs. thick-bed application, requiring much lower material consumption. Furthermore dry-mix construction materials are formulated products that can be properly designed in order to make them more compliant to environmental concerns. For instance it is possible to add to the dry-mix product some additives capable of reducing the formation of dust – made by fine particulates, dangerous when breathed - when it is poured from the bag to be mixed with water, thereby protecting the health of jobsite workers.

Moreover many building materials emit toxic gases such as volatile organic compounds and formaldehyde, which can have a detrimental impact on occupants' health. A careful choice of the organic additive contained in the formulation and a properly optimized composition can reduce the impact of construction chemicals on the health of the final building occupants by greatly reducing the concentration of volatile organic compounds to the order of ppm, particularly those of potentially carcinogenic substances. This paper will discuss the above-mentioned means to develop dry-mix construction chemicals compatible with sustainable building concepts, dedicating special attention to products for tile-laying.

## 2. DUST REDUCTION IN DRY-MIX PRODUCTS

The use of additives to help reducing dust formation in Portland cement-based formulations has been virtually known in the patent literature for almost 50 years. Patent GB892015, published in 1962, reports of an improvement in the manufacture and properties of water-repellent Portland cement aimed to the reduction of their dust-formation tendency by intergrinding 0.2-1.5% by weight of mineral lubricating oil, mineral jelly or mineral wax [1]. Patent GB12273355 proposes a Portland cement-based mortar composition that includes the addition of a mineral oil with the goal of reducing the formation of dust [2]. Similar claims can be found in more recent patents [3-8]. Dust is formed by minute solid particles that persist in the environment for a very long time due to their very low settling velocity, as described by the following equation:

$$v_s = \sqrt{\frac{4}{3}\frac{\left(\rho_s - \rho_f\right)}{\rho_f}\frac{g}{C_w(\mathrm{Re})}}$$

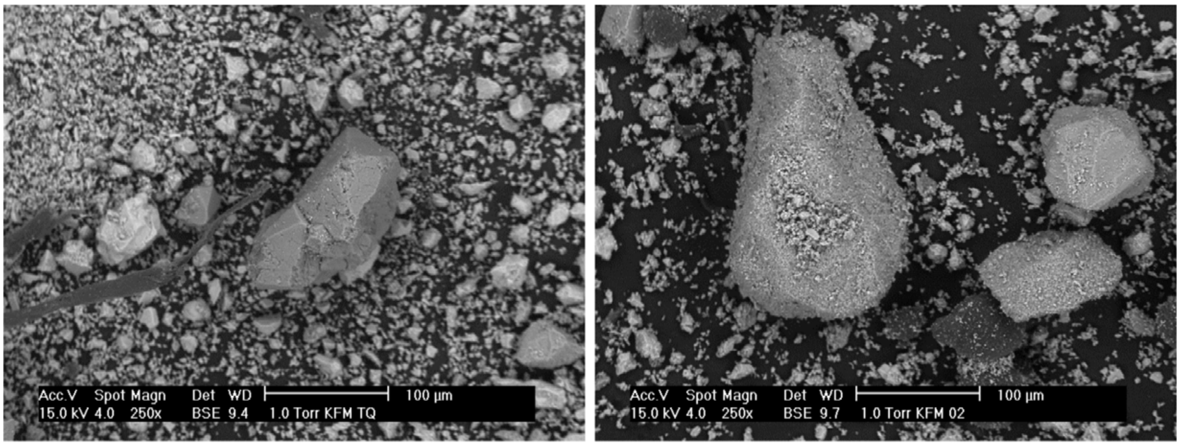
*Equation 1.*

where ρs is the density of the particles, $\rho_f$ is the density of air and $C_w$ is the drag coefficient (function of the Reynolds number). The equation allows calculation of the dependency of the fall velocity from particle size, as shown in table 1.

| Particle size (μm) | Settling time (1/m) |
|---|---|
| 0,5 | 28 h |
| 1 | 8 h |
| 5 | 21 min |
| 10 | 5 min |
| 50 | 14 s |
| 100 | 4 s |
| 1000 | 0,3 s |

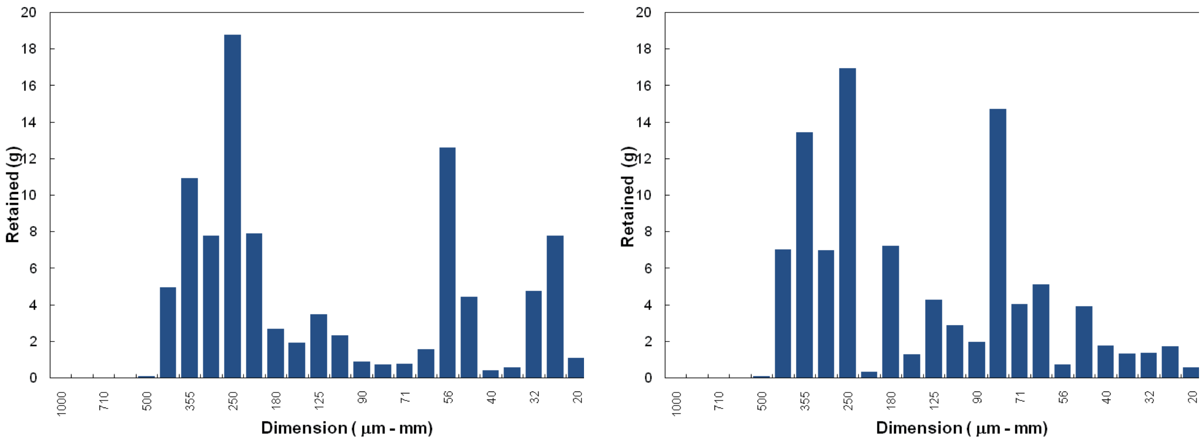
*Table 1. Settling time vs particle size (0 – 1000 μm).*

The idea of applying the concept to widely used dry-mix products is a recent innovation, but today tile-adhesives, self-levellers, levellers, grouts and patches provided with this property can be found, produced by many companies worldwide. Research has proved that various organic additives can play the role, which is clearly shown in the microscopic images reported in figures 1 and 2, comparing a conventional tile-adhesive with a low-dust one: that is, to help the agglomeration of fine particles.




*Figures 1 and 2. Comparison of SEM images of a normal and a dust-reduced product.*

The effect is also evidenced when one compares the sieving graphs of the two products (figure 3 and 4), clearly showing that where dust is reduced, the fine portion of the powder disappears. In principle, as soon as the powder is mixed with water the particles disaggregate and the fresh and hardened properties of the product are maintained unaltered, though the formulator needs to use some care since the organic additive might somehow interact with the other organic components. Further tests are necessary to assess the durability and stability of the dust reducing effect.




*Figures 3 and 4. Comparison of sieving analysis of a normal and a dust reduced products.*

Dust, when inhaled, can deposit itself on the various surfaces of the respiratory tract. EN 481 identifies different dust categories: particle sizes below 100 µm correspond to the E-fraction, which is inhalable into the lungs, whereas particle sizes below 10 µm correspond to the A-fraction, which is nearly invisible, remaining in the air for a very long time, and inhalable even into the alveoli. Fine cement particles are potentially damaging to human health due to the presence of alkaline compounds such as lime (calcium oxide), which are corrosive to human tissue, trace amounts of crystalline silica, which is abrasive to the skin and can damage lungs, and trace amounts of chromium, which can cause allergic reactions.

Apart from microscopy and sieving techniques, there are other laboratory instruments that allow dust content in powdery products to be measured. One of these is the so-called DustMon analyzer (manufactured by Anatec AS), which can be used in development laboratories or process control, shown in figure 5, consisting of a dosing control system, a sample collector chamber, a light source and a detector.

The sample is poured into the sample beaker. After starting the measurement the valve opens and the sample drops down through the tube into the sample collector. The sample dust will rise into the measurement area between the light source and the detector. Depending on the dust concentration, the light intensity will decrease. This is a direct indication of the amount of dust in a sample. The instrument provides the following parameters: maximum dust concentration in %, dust concentration after 30 seconds, dust index (maximum + concentration after 30 sec.), and shows a graph of dust concentration over time [9].

*Figure 5. Dustmon Machine.*

Figure 6 shows the comparison of DustMon graphs of a dust-reduced tile adhesive vs. a conventional mortar. Both measurements tend to an asymptote, so that the value after 30 seconds can be assumed to be an index of the concentration of persistent dust in the job site.

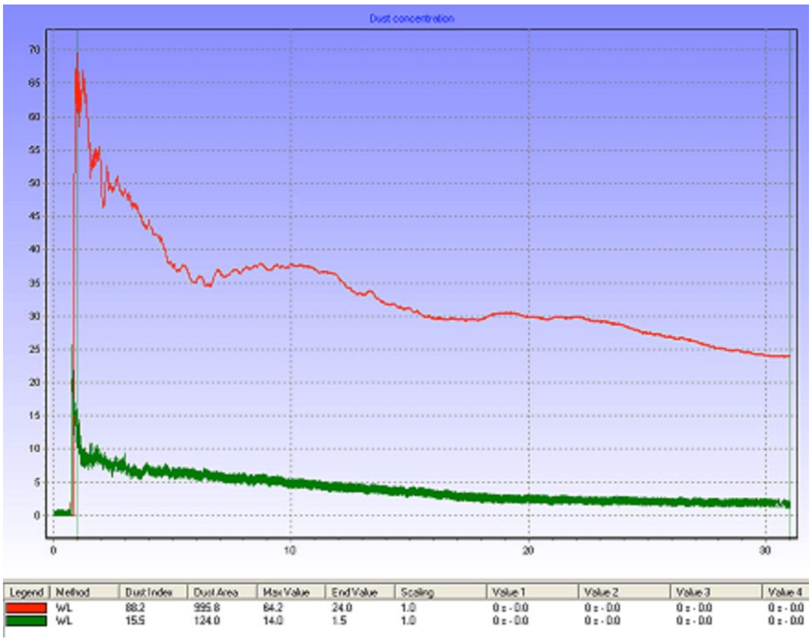



*Figure 6. DustMon Graph of a dust-reduced tile adhesive vs. conventional mortar.*

## 3. ORGANIC VOLATILE CONTENT IN DRY-MIX PRODUCTS

Indoor air quality can be strongly influenced by the presence of adhesives, mortars and in general all the building products in our houses, even if they are not in direct contact with indoor air. Emissions of volatile organic compounds can change in terms of quality and quantity as a function of the building materials applied. This concept has motivated the adoption in Europe of many voluntary systems for performance labels among which GEV (Gemeinschaft Emissionskontrollierter Verlegewerkstoffe) Emicode has acquired special importance particularly among products for flooring installation, licenses being granted to products that are classified in three categories, namely EC1, "very low emission", EC2, "low emission", EC3, "not low emission", based on the results of tests evaluating the concentration of cancerogenous substances 24 hours after application and evaluating residual total VOC after 10 days [10]. The testing of the flooring installation product in accordance with the defined GEV test methods uses emission chambers (as shown in Figure 7) made of stainless steel and glass, which have a volume of 210 l, controlled relative humidity and temperature (T=23 ± 2°C; RH= 50 ± 5%), and loading factor 0.45 $m^2/m^3$. This value is a typical ratio of exposed surface area of the test specimen to the test chamber volume.

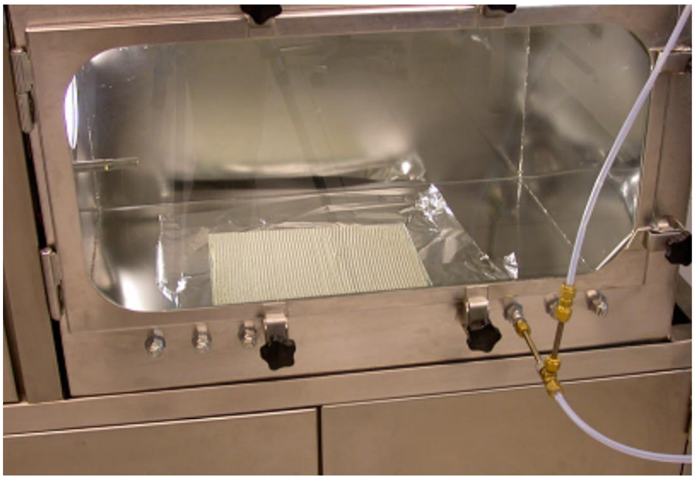


*Figure 7. Chamber for the VOC emission test.*

It simulates the situation in a common installation of a floor in a typical apartment. The chamber is fluxed by dry nitrogen (in this text we refer to this gas as "air"), with a flow rate of 0.5 $h^{-1}$, which allows a complete change of the air in the chamber every two hours. The sample is mixed uniformly, weighed and applied on to a non-adsorbent glass surface; the test specimen is transferred into the chamber immediately after preparation. At the test chamber outlet, exhaust air is passed trough a sample tube filled with a suitable adsorbent material (Tenax TA®). Tenax tubes are then desorbed by a thermo-desorber; volatile organic compounds are separated by gas-chromatography, identified by a MS detector and quantified by a FID detector. A scheme of the experimental device is shown in figure 8.

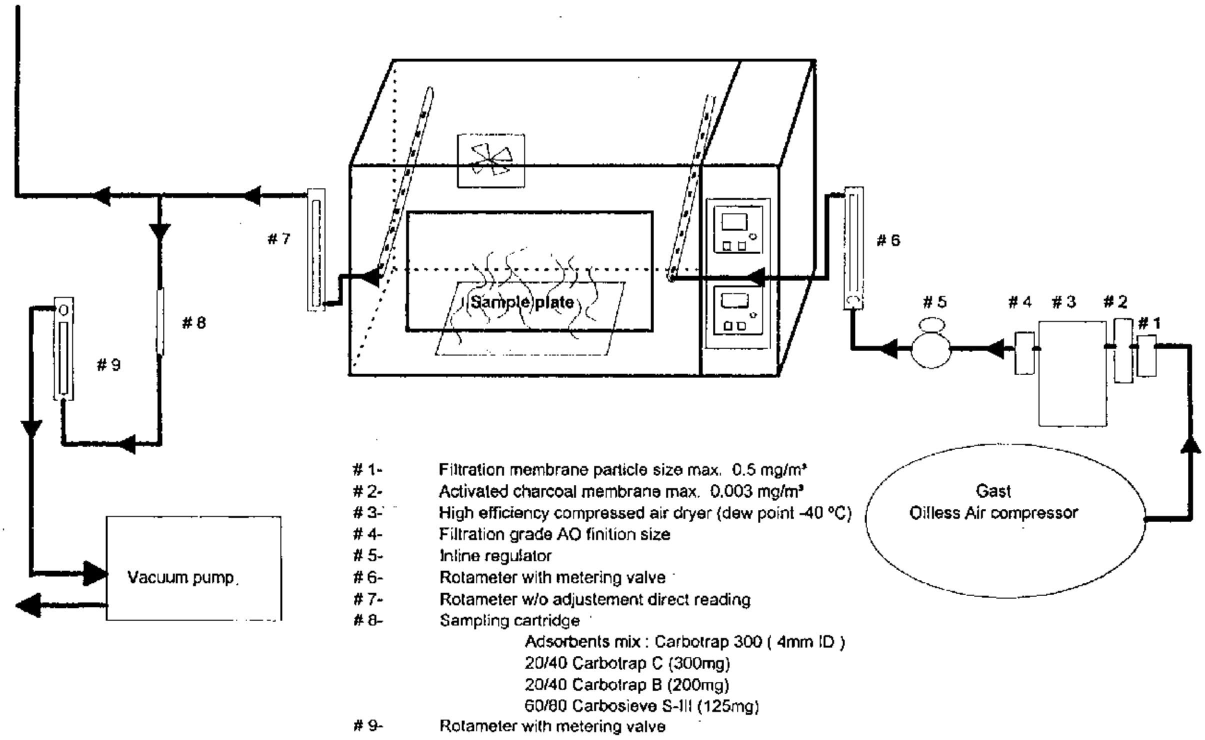



*Figure 8. Scheme of the experimental device for the VOC emission test.*

The limits for EC1 and EC2 on total VOC after 10 days are different, depending on product categories: powder based products with mainly inorganic binder, including levelling compounds, and tile mortars and joint fillers, should have a maximum concentration of 200 to be classified EC1, expressed in μg/m$^3$, and of 600 to be classified EC2.

A strict selection of raw materials should be applied to tile adhesives in order to satisfy the limits for EC1 classification. A potential source of volatile organics is redispersible polymer powders that might contain residual unreacted monomer. Furthermore, it was recently demonstrated [11] that the mortar substrate might interact with the VOC, and thereby it can not only limit their emission into the air but also adsorb, owing to its chemical and morphological characteristics, VOC coming from pollution, smoking, and paints. Different binders might behave quite differently, and novel eco-binders can be developed based on these findings.

## 4. DRY-MIX MORTARS AND GREEN CERTIFICATIONS

The above discussed relationships between dry-mix mortar properties and indoor air quality enable selection of a specific product for the "green" classification of a new building. The LEED certification applies only to building projects, not to products or services. However, while products cannot be LEED certified, they can help to contribute toward earning "green-building" status for a building. Dust reduction technology helps contribute to LEED EQ Credit 3.2 ("Construction IAQ Management Plan: Before Occupancy"). LVOC products contribute to LEED EQ Credit 4.1 ("Low-Emitting Materials: Adhesives and Sealants). Regarding the latter, however, there is an important issue to be discussed regarding the American Leed and "European philosophy" (followed by GEV) concerning VOC calculations in building materials. First of all, the definition of VOC: the US EPA's Terms of Environment (definition accepted by Leed) defines a VOC as any organic compound that participates in atmospheric photochemical reactions except those designated by the EPA as having negligible photochemical reactivity.

According to European standard EN 13999 VOC are defined as organic compounds whose boiling point ranges from (50 °C to 100 °C) to (240 °C to 260 °C) and generally have a saturation pressure of 25 °C greater than 102 kPa.

The USA is more sensitive to environmental pollution, while the European priority is human health.

Another difference is the VOC content concerning adhesives and sealants: GEV criteria measures the VOC emitted by the product in $\mu g/m^3$, while Rule 1168 (applied in LEED) considers the VOC contained in the product, measuring it in g/l. In this way, the Leed does not qualify the VOC: absurdly a product that is Leed compliant could contain benzene (for instance) which is a carcinogenic compound!

GEV quantifies and qualifies all the VOC emissions after 10 days the application of the product, considering also the carcinogenic compound evaluation.

Apart from the impact on air quality, there is another parameter the formulator can play on in order to make a product eligible for LEED points, which is the presence in the product of more than 20% of recycled material, for MR credits 4.1 and 4.2: "Recycled Content". These allow savings in natural resources, and the reduction in energy use and pollution associated with these activities. The beneficial use of industrial materials results in less waste sent to disposal sites, saving landfill space and further reducing greenhouse gas emissions and other pollutants. Several types of recycled material are, or can be used in dry-mix products: glass, rubber, slag, fly ash, etc. Furthermore, some of these recycled materials, namely glass and rubber, are also capable of reducing the specific weight of the product, thereby increasing the yield: that is, the square meters covered per kilogram product. This allows the weight of the bags to be reduced, and therefore also the cost of transportation and energy consumption, hence reducing the quantity of transportation $CO_2$.

## 5. CONCLUSIONS

The paper discusses the many ways by which dry-mix construction products, in particular those for tile-laying applications, can contribute to sustainable, or "green", construction practices, by improving the air quality in the jobsite, before building occupancy, by reducing the amount of dust produced during product mixing, and by decreasing the amount of VOC emitted during their lifecycle. Dry-mix products can further be instrumental in minimizing the environmental impact by using recyclable materials, which minimize the consumption of natural resources.

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