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Ultrasonically dispersed dyed water mists as a substitute for colored powders

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Colored powders such as colored corn starch are used in events such as The Color Run to blanket the air and surroundings with decorative color. Their use, however, presents a risk of dust explosion. The fact that such powders are used at events drawing large crowds makes any fire or explosion likely to result in a mass casualty incident. For instance, the Formosa Fun Coast explosion on June 27, 2015, resulted in multiple deaths and injuries. Development of alternatives to flammable/explosive colored powders would eliminate this hazard. We demonstrate as a proof-of-concept that an ultrasonically driven water mist can produce effects similar to those created by colored powders. Food coloring was dissolved in water, and the colored water was subsequently dispersed from various ultrasonic devices and photographed. Colored clouds were formed from the colored water. Colored clouds were visible under various conditions, and color combinations were possible. Possible risks of colored corn starch and water mists are discussed. An ultrasonic misting system is capable of safely replacing colored powders with regard to appearance.

1. Introduction

Various colored powders have been used to cover areas with color as part of festivals, events, and parties, with an example of such a scene illustrated in Fig. 1. Note how a variety of colors are present in the air due to the dispersion of colored powder. The photograph was taken by Mats Hagwall, "Party at the Big Stage," and reused under a Creative Commons 2.0 (CC BY 2.0) license.

The events have typically proceeded without mishap; however on June 27, 2015, a dust explosion and fire occurred at Formosa Fun Coast during the "Color Play Asia" event [1]. The disaster killed 15 [2], and injured 498 [3]. Subsequently, the government in Taiwan [4] has banned the use of flammable powders in such events. Shanghai and Shenyang subsequently cancelled their color runs, while the run planned in Singapore proceeded with additional precautions such as a prohibition on both smoking and machine dispersion of powder [5]. An excellent review [6] on dustiness notes that the behavior of dust/air mixtures is complex, and is not fully understood. Various investigators are studying dustiness as a metric for estimating the likelihood of an explosion occurring. However, progress in this area has resulted in the publication of standard NFPA

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Fig. 1. Photograph at the end of The Color Run at Lund, Skane, Sweden.

Table 1
Dyes used and concentrations (M – molar or equivalently mol/L).

Color	Dye name	Alternative name	Concentration (M)
Red	Red #6	New coccine	0.066
Yellow	Yellow #4	tartrazine	0.187
Blue	Blue #1	brilliant blue FCF	0.0189

Numbered dye names are provided by the manufacturer, and numbering schemes are country-specific (the same dye may be given different numbers depending on country).

(National Fire Protection Association) 652 [7], in an attempt to produce a single standard for flammable dusts across various industries [8].

The development of alternatives to colored powders would eliminate such hazards of fire and explosion. The use of approved food dyes for coloring water, rather than solid powder, provides an alternative to current approaches. Such water mists are not flammable, and are not prone to explosion. In fact, by increasing ambient humidity, they reduce explosion risk arising from other causes. They also provide a separate beneficial cooling effect [9] during warm weather. Here, we present data indicating that ultrasonically dispersed, dyed water mists can produce effects similar to that produced by previously used colored powders. Subsequently, the advantages and drawbacks of colored water mists in comparison to colored powders are discussed.

2. Experimental methods

Dyed water was prepared by dissolving the following food-grade dyes (Daiwa Dyestuff Mfg. Co. Ltd, Saitama, Japan) into separate water containers in the following concentrations (Table 1), producing water that was dyed red, yellow, and blue.

Shown in Fig. 2 is a chamber with restricted airflow constructed using an aluminum frame and clear plastic wrap. The chamber was used to test system performance in a restricted volume and had approximate dimensions of $25 \times 25 \times 50$ cm. The chamber was open at the top, and contained cutouts for nebulizer openings.

Two types of ultrasonic diffusers were used to generate water mist. The MUJI Nebulizer (Brisk Aroma Diffuser, Guangdong, China) operated at a fixed frequency of 1.7 MHz. It has a capacity of 500 mL, and was originally designed to be used as a room humidifier as well as a system for dispersing scented oils. It produces mist by dispersing water at a rate of 90–100 mL/h, at a mean particle size of 2 μm. The Mesh nebulizer WB-16A (Whirl Best International Co. Ltd, Taoyuan, Taiwan) operated at 104 ± 5 kHz, and disperses water at an adjustable rate between 30 and 120 mL/h, with a mean particle size of 7.5 μm. (All specifications obtained from manufacturers' documentation.) In the experiments performed, the maximum rate of 120 mL/h was used throughout. Colored mists were dispersed indoors and outdoors using both devices. Photographs and video recordings were obtained of the results using a camera-equipped mobile phone. Dispersion was performed both inside and outside of the restricted airflow chamber.