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The Effects of Mist Cannon Trucks on Human Health and Reducing Dust

Yihan Xu

Capbridge Education, Changsha, 410000, China

Abstract. More and more attention has been paid to dust removal by Mist Cannon Trucks (MCT). It is necessary to study the effect and influencing factors of dust removal by MCT. This study discusses the effectiveness and hazards of using MCT to reduce airborne dust by conducting lead testing, color identification, pH testing, and chlorine testing on collected samples. The results show that dust can be significantly reduced by MCT, and the effect of fog cannon decreases with the increase of distance. The MCT is currently safe for pedestrians because it has very few corrosive and toxic substances, and the lead content is also very low, which is below the safe value. At the same time, the sprayed water captured a lot of dust compared to the water in the tank. The main harm to the human body is the excessive lead content in water..

Keywords: Mist Cannon Trucks; air quality; dust; human health.

1. Introduction

Air quality is being paid attention to all over the world because of its potential damage to human health. Air Quality Index (AQI) is a widely known index that indicates the level of pollution in the air. The national ambient air quality standard in China, GB3095-2012, encompasses six primary air pollutants, namely sulfur dioxide, nitrogen dioxide, particulate matter, carbon monoxide, ozone, and lead. (National Standard of the People's Republic of China, 2012). There are some properties of the substances that affects air quality, sulfur, dioxide, nitrogen dioxide, particular matter, and lead, additionally, sulfuric acid and nitric acid, products that form from nitrogen dioxide and sulfur dioxide reacting to water, should be discussed. As to sulfur dioxide, and nitrogen dioxide, they are harmful air pollutants that can cause respiratory and cardiovascular diseases, as well as other health effects, upon inhalation by humans (Schraufnagel et al., 2019). As to PM, can cause various health effects such as respiratory and cardiovascular diseases. According to a study by Dockery et al. (1993), an increase of 10 μg/m³ of PM2.5 is associated with an estimated 6% increase in all-cause mortality (Brook et al., 2010). As to lead, breathing in lead can cause inflammation and damage to the lung tissue, leading to respiratory symptoms such as coughing, wheezing, and shortness of breath (Laidlaw et al., 2017). On the other hand, lead also causes damage to skin by oxidative stress (Miao et al., 2018). Additionally, lead particles can accumulate in the lungs and remain there for long periods, causing ongoing damage to lung tissue (Laidlaw et al., 2017). As to nitric acid and sulfuric acid, the presence of them in water is due to the fact that they are formed from nitrogen dioxide and sulfur dioxide reacting with water. they denature and coagulate proteins, leading to tissue damage and cell death (Agency for Toxic Substances and Disease Registry, 2003).

There are various ways to reduce dust and particles in the air. A mist cannon truck, also known as a dust suppression truck or fog cannon truck, is a vehicle equipped with a large water tank and a high-pressure pump that sprays a fine mist of water into the air to suppress dust particles. The mist created by the cannon attaches to the dust particles, causing them to become heavier and fall to the ground, effectively reducing air pollution and improving air quality in the surrounding area (CPCB, 2020). According to my measurement and consulting the local operator, in the area where I conducted research, Changsha, the speed of spraying water by the mist cannon truck is 12 liters per one-meter square per minute, with a coverage radius of approximately 5 meters, and the speed of the truck is 20 km per hour. Since 2014, mist cannon trucks, have been deployed in numerous cities in northern China, including Xi'an in Shaanxi province and Zhangjiakou in Hebei province (China Daily, 2016). However, the merits and jeopardize of using mist cannon truck is controversial.

This essay aims to investigate the effectiveness of the mist cannon truck in reducing dust in the air and the harmfulness of using the mist cannon truck, hence, I will analyze if the merits of widely using mist cannon truck overwhelm the defects of using mist cannon truck. I will experiment with collected samples in lead tests, color identification, pH tests, and chlorine tests. I hypothesize that the degree of health harmfulness is under safe standards since the amount of water sprayed on a person can be relatively small, and the harmful particles in the air can be relatively few.

2. Materials and methods

2.1 Experimental equipment

The equipment used in this experiment and its parameters are shown in Table 1.

Table 1 Experimental equipment

Items	Properties
Volumetric flask x30	500 cm^3, ±0.25 cm^3, made of glass
Measuring cylinder x5	50 cm^3, ±0.1 cm^3, made of glass
C-level chemical protective clothing	Consists of a chemical-resistant suit and a full-face air-purifying respirator
Timer x1	± 0.01 s
Funnel x1	Made of plastic
Lead tester x1	Indicate value from 0 to 500 mg/dm^3, with correction error of ±0.01 mg/dm^3
pH tester x1	Indicate pH value from 0 to 14, with correction error of ±0.01.
Dropper x5	Made of plastic
Chlorine tester x1	Indicate value from 0 to 2.0 mg/dm^3, with correction error of ±0.01 mg/dm^3.
Beaker x30	50 cm^3, ±0.25 cm^3, transparent, made of glass
Colorimeter x1	$\triangle E<0.05$, value for RGB is ±3
Light x1	r: 255, g: 255, b:255
Photography white box x1	r: 255, g: 255, b:255

2.2 Experimental design

I chose to collect samples in the way of placing one collector very 1 meter away from the mist cannon truck because this can show whether the effectiveness of spraying water declines with distance. I identify the color via placing the sample under pure white, r: 255, g: 255, b:255, box and light so that the room light and the light reflected from other place are isolated to minimize the system errors in color identification. I conducted other experiment by using tester because they are the available instruments that has the highest accuracy in the school's laboratory, which other more accurate apparatus like IR spectrum are not accessible and indicators are not that accurate.

Therefore, an applicable methodology is created as following:

Collecting samples. Collect five 500 ml of water samples in the tank with the 500 ml volumetric flasks and droppers, and name this group of samples as group 0. Horizontal to the right side of the truck, place five collectors, made by placing a funnel above a 500 ml volumetric flask, every one meter away from the truck, and collect five 500ml of water samples for each collector in each interval, and name them as groups 1, 2, 3, 4, and 5 respective to the distance away from the truck.

Rinsing the containers. Rinse all the 50 ml beakers by soap water for three times and use tap water to rinse the beakers until no more bubbles occurred, then, use distilled water to rinse the beakers for three times. Repeat this step after step 3, 4, 5, and 6.

Identifying the color of each sample. Using measuring cylinder, take 50 ml of water into a 50 ml transparent beaker, then put the beaker into the photography white box with a white light, and use a colorimeter to identify its color. Repeat the experiment for all the 30 collected samples.

Conducting pH test. Using measuring cylinder, take 50 ml of water into a 50 ml beaker, then immerge probe of pH tester and record data after 3 minutes and repeat the experiment for all the collected samples.

Conducting lead tests. Using measuring cylinder, take 50 ml of water into a 50 ml beaker, then immerge probe of lead tester and record data after 3 minutes and repeat the experiment for all the collected samples.

6) Conducting chlorine test. Using measuring cylinder, take 50 ml of water into a 50 ml beaker, then immerge probe of chlorine tester and record data after 3 minutes and repeat the experiment for all the collected samples.

2.3 Experimental variable selection and the condition for the growth

2.3.1 Independent Variables

The horizontal distance away from the truck is the independent variable of each group of samples. The samples are collected from the collectors placed every one meter on the right side of the vehicle, start from one meter.

2.3.2 Dependent Variables

The value of pH, lead concentration, color, and chlorine concentration are the dependent variables. Since the sprayed water, in the form of mist, can easily be inhaled by humans, hence, the Chinese national standard for tap water, GB 5749-2006, (National Standards of the People's Republic of China, 2006) is used to state the legal range of the following properties.

Table 2 The range of pH, lead concentration, color, and chlorine concentration

Variables	Measurable Range by instruments	Legal Range	Explanation
pH	0 to 14	6.5 to 8.5	-
Lead concentration	0 to 500 mg/dm³	<0.01 mg/dm³	-
Color	R: 0, G:0, B:0 to R:255, G:255, B:255	R: 255, G: >230, B: >0	GB 5749-2006 stated that the color should not exceed 15 degrees on the platinum-cobalt scale. But it can be turned into RGB value. (U.S. Environmental Protection Agency, 2017)
Chlorine	0 to 2.0 mg/dm³	<0.5 mg/dm³	-

2.3.3 Controlled Variables

1) The source of the samples. Each group of water is collected from one truck.

2) The methods of collection. Each group of water is collected, stored, and examined in the same ways, which are mentioned in part 6.2, methodology.

3) The condition of collection, each sample are collected under the following environmental condition (Tianqishi, 2022).

Table 3 Experimental condition

Condition	Information
Date	15:00, 28th of February, 2023
Location	Changsha, Hunan China

AQI	119 (Webmasterhome, n.d.)
Wind Speed	9 m/s
Wind direction	West
Atmospheric pressure	1013 hPa
Temperature	22℃
Humidity	45%
Weather	Cloudy

2.4 Safety and Environmental Considerations

Referencing human safety issues, there could be unknown substances and micro-biotics contained in the mist. Therefore, I wore C-level chemical protective clothing, consisting of a chemical-resistant suit and a full-face air-purifying respirator to make sure the safety and decrease contamination from the operator, me. Concerning the environmental considerations, the mixture remained after test and unused samples were sent to the professional companies that specialized in treating chemical hazardous substances.

3. Results and discussion

3.1 Total Extent of Harmfulness

Concerning the harmfulness of using a mist cannon truck, the only factor in excess to the national standard is lead, while there is little existence of chlorine, sulfur dioxide and nitrogen dioxide, which their values are nearly 3 times lower than the maximum value specified in the Chinese national standard. Therefore, the extent of the harmfulness can be mainly presented by the lead concentration.

The average skin surface area of an adult under casual clothes is estimated to be about 1.5 to 2 square meters (Cole, 2003). The width of an adult is 40-46 centimeters at the shoulders (Schuntermann, 2005). According to my measurement mentioned in part 3.1, the speed of spraying water by the mist cannon truck is 12 liters per one-meter square per minute, with coverage radius approximately 5 meters, and the speed of the truck is 20 km per hour. Taking the average value, we can get the amount of water being sprayed on an adult.

$$\text{Average exposued skin area} \times \text{Speed of spraying water} \times \text{Average wideth of shoulder} \times \text{Speed of the truck} = \text{the amount of water sprayed on an adult pedestrian}$$

Bring in the value and change the units

$$\frac{1.5+1.2}{2} \times 12 \times \frac{40+46}{\frac{2}{100}} \times \frac{20 \times 1000}{60} = 0.02646\ \text{dm}^3$$

In this case, when the truck passes a standing adult, the adult will be covered with 0.02646 dm^3 of water on the skin of the person.

Multiplying in the collected data on the concentration of lead, 50 mg/dm^3, we can get the value of lead intake when passing a mist cannon truck.

$$50 \times 0.02646 = 1.323\ \text{dm}^3$$

Referencing the information given in part 3.3 that says the maximum amount of intake of lead via skin under casual clothing is 58.06mg. This means that we can let the mist cannon truck pass us 43 times in a day still within the maximum daily intake value.

3.2 Total Extent of Air Quality Improvement

Concerning the positive effects of using a mist cannon truck in reducing dust in the air. According to Table 3, there is an observable amount of dust being collected, resulting in the change in color of the water sample in the water samples. In the meantime, there could be a little amount of nitrogen dioxide and sulfur dioxide being collected but under correction error, due to there being no decrease in the pH value. Therefore, the significance can mainly be presented by the color change.

As to the observed color change, there is an observable trend. All samples in group 0 showed a color of almost pure white, all samples in group 1 showed a light reddish brown, r:254, g:233, b:195 in average, and the color in group 2 to group 5 gradually transited from light reddish brown to almost pure white, r:255, g:254, b:254 in average. The average difference of the gradual change, from group 1 to group 5, between each group are r:0, g:5, b:7 after calculation and rounding up to integer, since there is no decimal allowed in the value of RGB.

Using the nearly pure white color of samples in group 0, samples of water in the water tank, as reference, the significant presence of color in the other groups indicated capture of substances on air by the mist. In the meantime, the gradual fading of color from group 1 to 5 indicated that the effectiveness of the mist cannon truck decline with distance.

Table 4 The concentration of lead in the samples taken from water tank, group 0, and the mist, group 1.

Lead mg/dm³	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Group 0	49.55	52.08	49.03	50.91	50.25
Group 1	52.14	48.29	51.20	51.29	49.25
Group 2	48.85	52.75	48.95	50.92	49.43
Group 3	50.75	50.71	51.92	49.26	51.23
Group 4	48.47	51.23	50.23	50.56	52.30
Group 5	49.35	51.51	50.34	48.28	52.35

Notes: Correction error: ± 0.01; The data in this is round to 2 decimals, and the value of each sample in each group is similar, which has an average value of 50.00.

Table 5 The pH test results of the samples taken from the water tank, group 0, and the mist, group 1.

pH	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Group 0	7.00	7.02	7.01	6.99	7.01
Group 1	6.91	6.92	6.85	6.92	6.89
Group 2	6.97	6.93	6.98	6.92	6.94
Group 3	7.00	6.92	6.93	6.92	6.94
Group 4	6.97	6.92	6.95	6.96	6.94
Group 5	6.94	6.95	6.94	6.91	6.97

Notes: The data is round to 2 decimals. The mean value is 6.96. The lower the value is, the more sulfuric acid and nitric acid captured. Correction error: ± 0.01

Table 6 Color of water samples under white background and a white light.

Color (RGB)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Group 0	255, 254, 255	255, 253, 251	255, 253, 254	253, 253, 254	254, 255, 254
Group 1	253, 234, 194	255, 235, 193	255, 232, 198	251, 230, 193	253, 233, 195
Group 2	254, 241, 210	254, 240, 207	255, 243, 209	252, 240, 211	253, 242, 210
Group 3	253, 247, 219	252, 246, 220	254, 248, 223	254, 246, 217	255, 250, 225
Group 4	255, 247, 240	254, 248, 245	255, 250, 243	254, 245, 240	254, 248, 242
Group 5	254, 250, 247	254, 253, 251	255, 252, 249	255, 253, 248	254, 254, 249

Notes: The RGB value can only be integers. The lower the value is, the darker the color is, indicating the amount of dusts being captured. Correction error: ±3

Table 7 Chlorine concentration test results of samples taken from water tank, group 0, and the mist, group 1.

Chlorine mol/dm³	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Group 0	0.14	0.16	0.14	0.15	0.12
Group 1	0.11	0.12	0.12	0.15	0.11
Group 2	0.18	0.20	0.18	0.15	0.13
Group 3	0.17	0.14	0.14	0.12	0.18
Group 4	0.18	0.18	0.15	0.19	0.19

Group 5	0.15	0.18	0.15	0.17	0.15

Notes: The values are round to 2 decimals, and the mean is 0.15. The higher the value is, the higher amount of chlorine contained in it. Correction error: ± 0.01

3.3 Test reliability and practical value

One strength is that there is a relatively low amount of systemic errors. For instance, I wore C-level chemical protective clothing to reduce impurities on humans dropping into the water samples. Another strength is that nearly all the major air and water quality factors are examined, which increases the reliability of my experiment, for example, carbon dioxide is present in the air and it forms carbonic acid when reacted with water. However, since the pH was measured to be 7, the effects of such substances are quite minor.

Of course, this experiment still has some shortcomings. One weakness is that the result and conclusion obtained in this experiment might not be applicable under other conditions. For example, if the experiment is conducted in some industrial area and there is the existence of sulfur dioxide, this can affect the result in errors in pH calculating because SO2 reacts with water to form an acid. Another major weakness is that there was no apparatus in my laboratory, which does not allow me to be able to separate large particles and PM, which has diameter of less than 10 μm, from dust, therefore, it was not possible to calculate AQI. Another weakness is that the components of water used by the mist cannon truck is different, which can also make the result and conclusion from this experiment to be not applicable. One region may have higher levels of metals in its water, while another region may have lower levels of metals in its water. Furthermore, since there are limited studies in such fields, the data and theory used in this essay are not from studies conducted in the local area where I collected the samples. Therefore, there might be a small extent of inaccuracy during the calculation.

The extension could be made by considering the economical issues in further research, which can make the outcome of this research to be more referencing to the government and the society when considering using a mist cannon truck in reducing air pollution. Another extension that could be made is to repeat this experiment in different regions that have different water and air quality, this can expand the applicability of my research.

4. Conclusion

From the analysis above, it can be drawn that the mist cannon truck is currently safe for pedestrians due to little corrosive and toxic substances presenting and a little amount of lead presenting under safe value. In the meantime, a large amount of dust is being captured by the sprayed water compared to the water in the tank. It is exemplified that using the mist cannon truck is a valid in improving air quality and harmless to humans in large extent. However, since this essay only researched the short-term effect of using mist cannon truck, more research on the long term-effects should be conducted to draw a more certain conclusion.

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