EFFECT OF PAINT ON LOCAL AIR QUALITY

4 readily available brands in the Hong Kong market; HCHO and TVOC investigated

Testing period: February - April 2019

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Summary:

Experiments carried out in enclosed and isolated environment in order to reduce noise in the data. The aim was to find out if there is a measurable difference in air quality beside an open tin of paint, painted board or painted box, more importantly we sought to find out the difference between four brands of paint (readily available for sale in Hong Kong) and their respective TVOC and HCHO emissions. TVOC means total VOC, or volatile organic compound. HCHO is the chemical formula for formaldehyde and is used to refer to formaldehyde in this report.

We anticipated that of the four brands tested (which shall not be named in this report) the European imported brand will have the lowest TVOC/HCHO output and will have far safer air quality in the immediate surroundings of firstly an open tin of the paint and a painted surface/painted box. Additionally, in order to provide another point of comparison (in the case that all tested products performed similarly) the time taken for the surrounding area to return to a safe value according to the apparatus was also recorded and analysed.

The experimental procedure used an air quality monitor, referred to as the detector. This is capable of measuring TVOC and HCHO levels in real-time. We opened a tin of each brand of paint (referred to as A, B, C & D) blindly (logos were covered) and had the detector beside the open tin at a distance of 10cm. Each tin was tested with at least a day in between such that the baseline air quality was comparable. For the painting board test the detector was at the same distance to a box as it was painted, increasing rate of dissipation of VOCs and HCHO.

After 7 trials data was processed and analysed. The results showed that paint D had far lower VOCs and HCHO than the other paints. Additionally, the time to return to safe levels was less than half that of the next best paint after the box painting experiment. Paint D was more than 12 times less harmful than the worst performer and approximately 4 times less harmful than the other two products tested (where VOCs and HCHO levels correspond to harmfulness, their effect on a human is not part of the scope of this investigation).

We found that paint of all kinds released VOCs and some HCHO, though not all at the same rate. Paints A, B and C performed very poorly (according to the detector the air quality nearby a tin of these paints would be considered to harmful to work in without significant PPE and ventilation).

To take this test further a detector with a broader VOC and HCHO measuring range would allow for more comparison between the worse performing paints (as they hit the maximum measurable by the detector in certain tests). Also comparing these results to stated VOC and formaldehyde content within the respective tins would also be an interesting area of further investigation.

Contents

Aim:

This report aims to identify if there is a measurable change in the concentration of HCHO and TVOC beside an open tin of paint, a painted board, and a painted box (varying surface area).

Secondly, the aim is to find the difference in potentially harmful compound released into the air by differing paint brands in a blind test in order to ascertain appreciable difference in their respective safety.

Additionally, another aim is to find the time to return to safety of these different paint brands and whether there is a difference due to the level of saturation of these components in the air surrounding a drying source.

Hypothesis:

It is known that the stated VOC levels differ and that a certain brand (an imported European paint brand) has significantly lower VOC as well as no HCHO (formaldehyde) added to their paint. As such it is hypothesised that the air surrounding the sources of paint (open tin and painted board/box) will both produce significantly lower readings on the detector in this brand's test than in the tests of the other generic brands. It is also hypothesised that due to this lower saturation the return to "safe" levels, according to the detector, will also take significantly less time if the European paint does reach "unsafe" levels, again according to the detector.

Tools & Materials:

Tools:

1. Temtop LKC-1000S+ PM2.5 Air Quality Detector, referred to as the detector.
2. Brush (x4)
3. Stopwatch
4. Tin opener
5. Air conditioners (and fans)
6. Ruler
7. Tin opener
8. Marker
9. Table

Materials:

1. 1 litre tins of paint (4 differing brands, 14 tins of each brand [same batch number], standard non pigmented white wall paint, each brand's "flagship" product)
2. Cardboard board A4 size (x4)
3. Cardboard box (approx. 20L volume) (x4)
4. Tape (opaque i.e. duct tape)
5. Carboard cutting (5cm x 5cm)

Method:

Steady state will be defined as 1 minute without significant fluctuation (no more than +/- 0.02)

Preparation

1. Have someone cover the decals of the paint tins with tape to ensure the person carrying out the experiment cannot identify the brand with ease.
2. Once this is done label the tins from A-D.
3. The experiment location should be well ventilated to ensure identical starting points for all measurements.
4. The tins should be stored in separate sealable boxes to ensure no cross contamination prior to testing. This should be in a separate area (different room/unit) to the test bed.

Open tin test:

1. Start detector and record steady state TVOC and HCHO levels in empty clean room. This will be baseline reading and comparatively 0 added compounds from paint.
2. The experimental setup should be as follows:
    a. Collect one tin from its storage container.
    b. Leave it closed on a table in a previously well-ventilated room (air conditioner switched off for the duration of one trial).
    c. The tin's location and a 10cm length thence should be marked on the table such that all subsequent tests can be done from the same location.
    d. The detector should be placed 10cm away from the tin, on the marking.
    e. A stopwatch should be nearby ready to record time to ensure steady state is reached before noting down any data.
3. Once background TVOC and HCHO is established and detector and tin are in place, open the tin using the tin opener if required.
4. Place the lid on the other side of the tin from the detector, paint side up.
5. Wait for at least one minute to allow diffusion into the air.
6. After this point monitor the detector for any change in the HCHO and TVOC levels.
7. Once steady state has once again been reached, and no the detector value is not rising/fluctuating appreciably (using the stopwatch to ensure 1 minute of no change) record the values for TVOC and HCHO as experimental data for experiment 1, trial 1, Brand "X".
8. Upon recording the data, close the tin again and return it to its storage location.
9. Turn on all ventilation sources which were previously on to ensure room is once more well ventilated.
10. Leaving the detector on ensure the levels return close to previous baseline values before switching off any ventilation and the detector.
11. Waiting until the next day, repeat steps 1-10 for another brand of paint (4 tests total)
12. Repeat steps 1-11 for as many trials as required (7 in the case of this report)

Painted board test:

1. Ensure ventilated room with ventilation (fans/air conditioners) now switched off.
2. Start detector and record steady state TVOC and HCHO levels in empty clean room. This will be baseline reading and comparatively 0 added compounds from paint.
3. Collect one A4 cardboard sheet, a clean brush and one tin of paint to be tested.
4. Place the detector and the board on the table, (10cm separation as in the previous experiment).

5. Open the tin with the tin opener and begin to paint the board, being careful not to move the board from its 10cm marker from the detector.
6. Keep the open tin on the far side of the board when in use.
7. Once the board has been entirely covered with an appropriate coat of paint (thickness should be identical across all trials and brands to ensure a fair test) seal the tin and return it to its storage location.
8. Monitor the detector while the board is drying, record the maximum value seen over the course of this period (will likely be very early on during the drying process, perhaps even during the painting time). The detector can record maximums, using this function can help if there are not enough people to monitor the detector and paint at the same time.
9. Once a maximum is observed, record this data as the "after" value in a results table for this trial, for both HCHO and TVOC.
10. When this is recorded, remove the board and allow it to dry in a different location such that the test bed area may return to baseline (again start air conditioners or fans or whatever ventilation was previously running before the test began.
11. Confirm using the detector the concentration of contaminants is falling back to background levels.
12. Wait one day and perform steps 1-11 again, once for each of the 4 brands.
13. Repeat steps 1-12 for as many trials as is required for reliability (and such that anomalous data can be identified) (5 in the case of this report).

Painted box test:

1. Ensure room is well ventilated by making sure detector reads similar background level to previously established level (+/- 0.01).
2. Switch off any sources of ventilation for the duration of the trial.
3. Collect one brand paint tin, one carboard box, one brush, the stopwatch and the detector.
4. In the testing area record the background HCHO and TVOC levels ("before" data in this report).
5. Using the tin opener, open the tin to be tested and paint the inside walls of the entire box.
6. Place a 5cm x 5cm cutting of card on the bottom of the box on the painted surface.
7. With the detector running place it in an upright position inside the box on the cardboard cutting, ensuring the detector does not get paint on it.
8. As before, await maximum steady state values on the detector for HCHO and TVOC.
9. Once steady state maximums have been observed, record these data points ("after" data).
10. Now remove the box from the room, allow it to dry away from the test area.
11. Restarting any ventilation in the room (air conditioner or fan if available) start the stopwatch.
12. Monitor the detector's displayed readings, once the concentration is deemed as "safe" or near baseline (below 0.09 for HCHO and 0.45 for TVOC) (steady state conditions) stop the stopwatch and record the time on the stopwatch.
13. Allow ventilation to continue for true background levels to be returned to for at least one day.
14. Repeat steps 1-13 for each paint brand.
15. Repeat steps 1-14 for as many trials as is required.

Results and analysis:

*For full raw data please see tables in appendix.

Experiment 1; Detector exposure to open tin

Table showing average HCHO and TVOC in the air for the open tin of paint test

	Average Air Pollutants (mg/m^3)			
Paint brand	Before		After	
	HCHO	TVOC	HCHO	TVOC
A	0.06	0.30	0.30	1.00
B	0.06	0.30	0.15	0.68
C	0.06	0.30	0.14	0.60
D	0.07	0.32	0.09	0.43

Table 1: Table of air quality metrics before and after open paint tin in immediate vicinity

From Table 1, of data taken from the open tin test we can see there is a clear consistent baseline value across all tested brands, with only brand "D" having some slight deviation. From the 'after' data we can see that formaldehyde increased drastically in the case of brand "A" and less drastically for brands "B" and "C". Brand "D" test returned very slight increase in formaldehyde concentration in the air nearby. Similar results were experienced with regards to VOC levels. In this case, brand "A" again had the largest increase going from 0.3 to 1, a rise of 271%, more than tripling the value. In the case of brands "B" and "C", VOCs doubled or more, where brand "D" only saw a rise of 0.11 (35%).

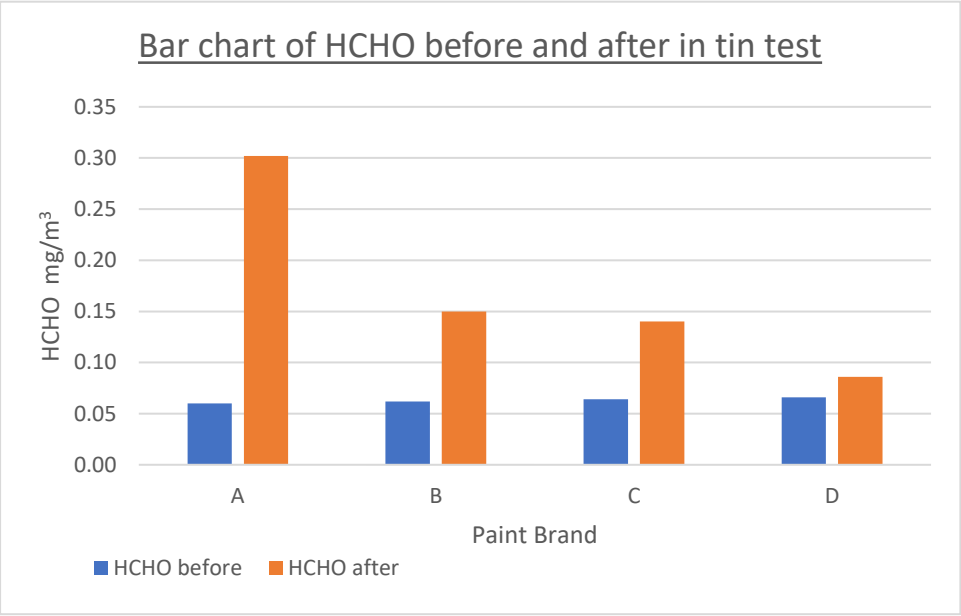

Figure 1: Graph showing formaldehyde level change after open paint tin in vicinity

As we can see from the above graph, Figure 1, there is a large difference in HCHO emission from differing paint brands. Only in the case of brand "D" is the after level of HCHO in an acceptable range (according to the detector's internal rating system). The chart for TVOC is similar in the trend shown, though scaling (systematic difference in the results). This is not shown for the sake of space in the report.

Table of air pollutant deltas with relative colour grading

Paint brand	Change in air pollutants (higher is worse) mg/m^3	
	HCHO	TVOC
A	0.24	0.70
B	0.09	0.38
C	0.08	0.30
D	0.02	0.11

Table 2: Open tin Processed data showing air pollutant deltas

From the above table, Table 2, we can see that though in the raw data (please see appendix I) the before values were not always identical in each trial, the average as seen above in table 1 was identical. This makes this comparison a fair one and these delta values offer a precise look at how much of a change the respective paint brands caused in HCHO and TVOC levels in the air. Again, here it is clear "A" performed worst with "B" and "C" not performing well either, whereas "D" had near negligible change in HCHO and a relatively very small change in TVOC. It is important to remember that though we are using both of these values to represent changes in air quality, because of increased air pollutants, TVOC includes many compounds which are in fact harmless and present in, for example, tap water.

Experiment 2; Detector exposure to painted board

Table of average air pollutants before and after a nearby board is painted

	Average Air Pollutants (mg/m^3)			
Paint brand	Before		After	
	HCHO	TVOC	HCHO	TVOC
A	0.064	0.334	0.568	1.676
B	0.062	0.326	0.776	2.674
C	0.060	0.314	0.604	1.526
D	0.066	0.332	0.170	0.698

Table 3: Painted board average results

These results, seen in Table 3, follow the trend set by the measurements taken from the open tin test. Though we can see from these results that there is a likely connection between emissivity characteristics due to movement/action on the paint and the air pollutants the detector can detect. That is to say, likely due to viscosities and other paint qualities, it seems different paints emit different amounts of compound depending on if they are stationary or being used at the time. This is clear from the fact that paint "B" is in this case produced a significantly higher air pollutant result than all the other three, even with high readings from both "A" and "C". Consistent with the previous experiment, paint "D" had significantly lower HCHO and TVOC after exposure to the painted board. This represents a difference in the contents of the paint brand, as well as much improved safety characteristics when this brand is in use.

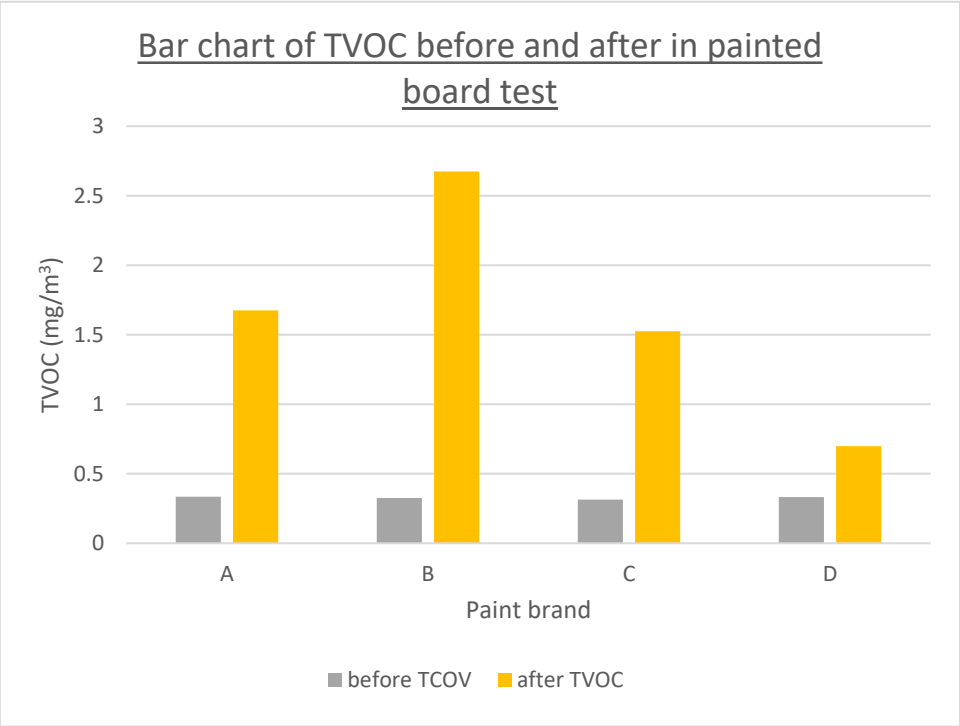

Figure 3: Bar chart of TVOC in painted board test

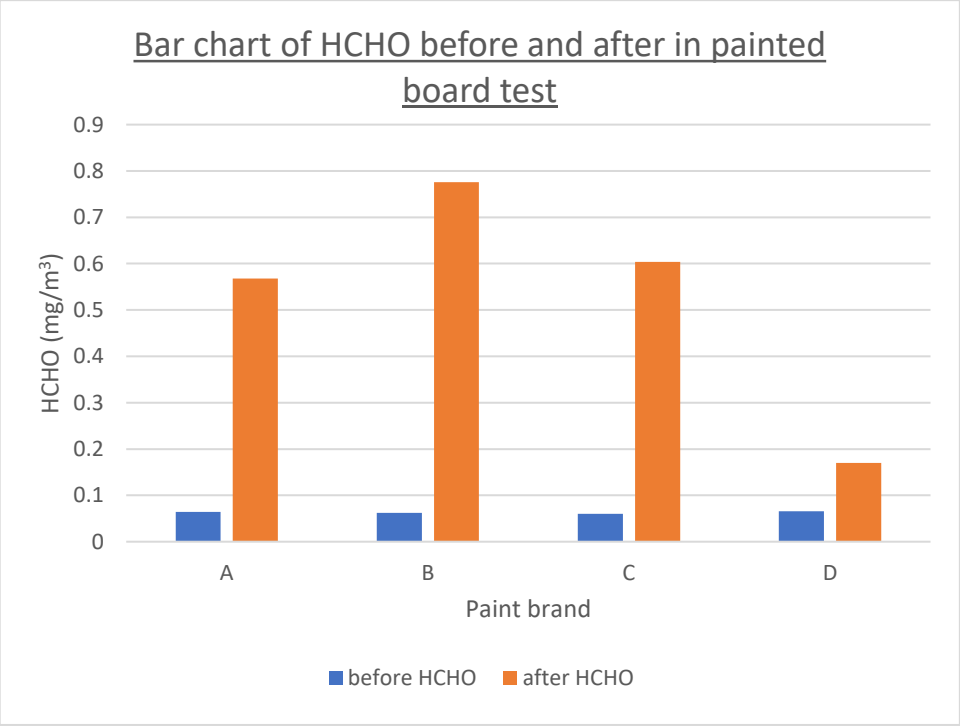

Figure 2: bar chart of HCHO in painted board test

In Figure 2 and Figure 3 we can see that this test for TVOC and HCHO had very similar trends and that even though brand “B” had the highest results, the separation between the results from brands “A”, “B”, and “C” and those from brand “D” are more significant than the differences between the first three brands.

Experiment 3; Detector within a freshly painted box

Table of processed data collected from painted box test, simulating worst case scenario for compound to air emission

Paint brand	before		after		Change		Time to background level	
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC	min	sec
A	0.08	0.44	5*	5*	4.92	4.56	23	15
B	0.06	0.27	5*	5*	4.94	4.73	36	31
C	0.08	0.42	5*	5*	4.92	4.58	43	44
D	0.08	0.38	1.62	4.43	1.54	4.05	9	52

Table 4: Mean data pertaining to painted box test

**in the above table some data points hit the maximum readable by the detector. In this case the detector value is shown however, it is clear the actual concentration of these compounds in the air are likely significantly higher. As such, further processing was done using previous data relationships in order to approximate the real values.*

In this test a worst-case scenario is tested. Not only is the detector relatively close to the source of the paint (the painted box not the open tin), but it is surrounded on all sides (with open top) with the paint products in their wet state before drying. If we look at the above table, Table 4, we can identify that there are clear differences between the three first brands “A”, “B” and “C” and the fourth brand, brand “D”. Brand “D” was the only product not to reach a maximum measurable on the detector in both tests. In fact, it did not reach maximum in either case, only reaching 4.43 mg/m^3 of TVOC and as low as 1.62 mg/m^3 of formaldehyde. This demonstrates the separation between this product and the other three in the test group.

In Table 4 we can also see “Time to acceptable level”. This refers to the removal of any paint source from the area and allowing full ventilation to reduce the concentration of compounds in the air. When the detector was reading at a steady state a value below what is considered “unsafe” according to the detector. This has practical implications; if a newly painted room is unsafe for longer then there is higher risk of dangerous effects on the users of the room. Ideally a paint should never give any significant unsafe emissions, and in the case where some is given off, the speed for it to dissipate (based on the combination of VOCs, the saturation of the air in the room and the ventilation of the room) will be an important comparison. Faster dissipation means less time exposed to VOCs and formaldehyde.

In Table 4, one brand (“D”) clearly stands out as returning to background significantly faster, only taking 9 minutes and 52 seconds. The other brands are more than two, three or four times as much in each case, with brand “C” taking the longest time at 43 minutes and 44 seconds.

In the case of the detector reaching its maximum displayable data point of 5mg/m^3, some calculations were done to approximate the theoretical peak values as compared to the painted board test. It is important to note these values will have some systematic error based on the different relative performances we've observed across the three test types.

Because brand "D" did not reach the maximum readable value, the ratio between its results for experiment 2 and three was calculated, as the data is collected in the same steady state situations.

Table of compounds measured in air after both experiment 2 & 3 for brand "D"

Brand "D"	HCHO	TVOC
box	1.62	4.43
Painted board	0.17	0.70

Table 5: Results from experiments two and three, for brand "D"

From the above table, Table 5, the box to board ratios (result from box experiment divided by result from painted board experiment) were found to be R_f = 9.529 and R_v = 6.347 for HCHO and TVOC respectively. This means that the concentration of formaldehyde in the air from experiment 3 was almost 10 times larger than in experiment 2, the TVOC was over 6 times as concentrated as well.

Using these proportions and the results for all brands from experiment 2, we were able to generate an approximation of what the top end values were which could not be collated by the detector. Using the results in "Table 3: Painted board average results" and the R_f and R_v values defined earlier to find predicted maximums outside of detector's measurable range. The following equations show how to find $HCHO_{x3}$, the theoretical formaldehyde levels from the third experiment and $TVOC_{x3}$ the theoretical TVOC from the third experiment, where "x3" refers to brand A/B/C's result from experiment 3, "x2" refers to brand A/B/C's result from experiment 2. Equation 1 and Equation 2 show how the predicted maximums are found.

$$HCHO_{x3} = R_f \times HCHO_{x2}$$

Equation 1: Theoretical formaldehyde from experiment 3

$$TVOC_{x3} = R_v \times TVOC_{x2}$$

Equation 2: Theoretical TVOC from experiment 3

Table of paint brand's theoretical calculated maximum compound concentrations in air

Paint brand	Compounds in air (mg/m^3)	
	HCHO	TVOC
A	5.41	10.64
B	7.39	16.97
C	5.76	9.69
D (Control)	1.62	4.43

Table 6: theoretical maximums from the painted box experiment

From Table 6 we can see the control values (brand "D") are identical to the experimental results (which shows there was no error in the calculation). Additionally, from these results we can predict that the difference between brand "D" and the other three tested was much more significant than the detector could indicate. Predicted TVOC from brand "B" for example was as high as almost $17mg/m^3$, which is approximately 4 times as high as brand "D", with the other brands being approximately twice the concentration of brand "D". Although the formaldehyde concentrations were only slightly exceeding the measurable range for the detector there was still a significant difference between the brands. Again, brand "D" was the safest paint considering both the measured detector maximum values and the predicted maximums from the afore calculations. Below is a graph of these theoretical data points, where the difference in results is clear to see.

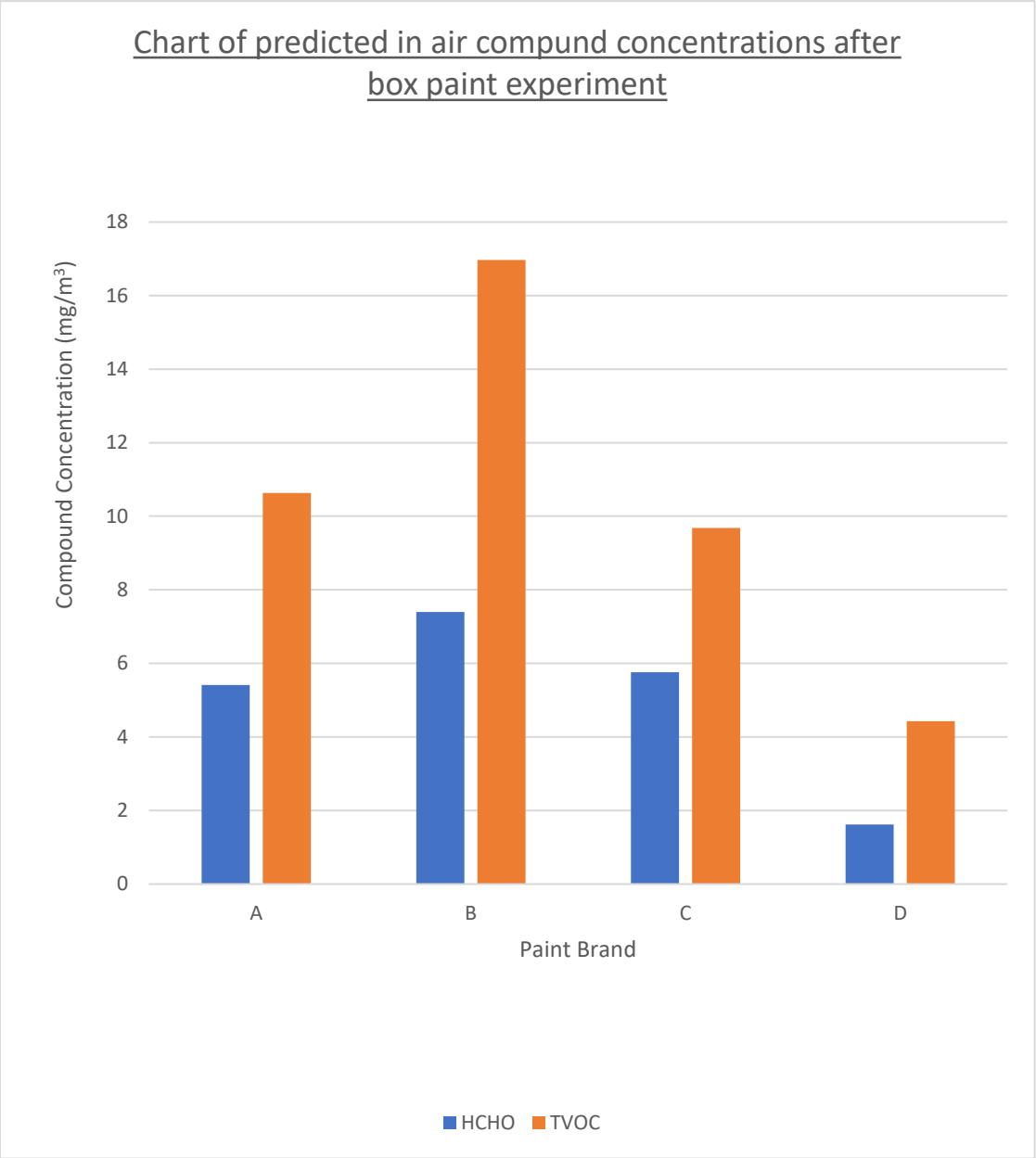

Figure 4: Theoretical and actual data bar chart from experiment 3

In the above graph, Figure 4, brand "D"'s values are measured average values processed from experimental data, whereas the other brands are showing theoretical data from the calculations described afore. In both HCHO and TVOC the trend is similar to the previous two experiments. Brand "D" was safest by a significant margin in all areas and was also the only brand of paint not to be considered dangerous by the temtop detector's grading system.

Conclusion:

Firstly, we can conclude that yes, there is an impact on the surrounding area on TVOC and HCHO concentration beside firstly an open tin of paint, secondly a painted board, and also a painted box.

Additionally, in conclusion there is a clear trend across all testing and each of the three experiments that indicates that brand "D" is significantly safer in all scenarios than the other three brand's flagship products.

With regards to experiment 1, being around an open tin of any of the three first brands (A/B/C) would result in being exposed to higher concentrations of HCHO and TVOCs, with a concentration of 0.14mg/m^3 to 0.3mg/m^3 of HCHO and from 0.60mg/m^3 to 1.00mg/m^3 of TVOC. Contrary to this brand "D" was a mere 0.09mg/m^3 of HCHO and 0.43mg/m^3 TVOCs.

In experiment 2 the trend is similar though where brand "A" performed the worst by some margin in experiment 1, in this case it was brand "B" that had a slightly higher concentration than the other two poor performers. Again, brand "D" test experienced significantly better results, with far lower total in-air compound concentrations for both formaldehyde and TVOC.

Experiment 3 returned the most concentrated readings, with three of the four brands reading 5mg/m^3, the top end of the measurable range with the detector used in this set of experiments. Owing to this, some processing of these results was done, and the predicted results generated (as well as the measured results) show the same trend between brand "D" and the other three brands. A/B/C were all reading higher than 5mg/m^3 which means the air in the immediate vicinity of the painted box is, according to the detector, unsafe or even dangerous. On the other hand, brand "D" was within the measurable range, even in these extreme worst-case scenario conditions of experiment 3. This further proves the difference in compounds emitted from the paint.

It is appropriate to conclude that brand "D" has the best characteristics when considering air contamination during use and while stationary. While stationary brand "A" produced the highest concentration in the air, whereas in use, brand "B" seems to produce the highest concentration of compounds in the air. Based on the "return to safe" duration brand "C" was also the worst performer in a certain category. It is perhaps appropriate to conclude that brand "D" was the safest brand and the other three, though with some variation amongst them, produced significantly higher concentrations of formaldehyde and total volatile organic compounds in the air surrounding the various sources according to the detector.

Evaluation:

Overall the experiments are reliable and fair tests. Multiple trials (as many as 7) were done for all experiments which provided a reliable mean from which to draw comparisons between the different brands. Additionally, between each reading baselines were established, ensuring that random error from previous trials was as low as reasonably practicable. One area for improvement in the test would be testing location, as Hong Kong (where the tests occurred) has very high pollution which can vary. This would have been a source of some random error in the experimental data, though from the variance in trials we can see that in the controlled testing environment it had little or perhaps no effect.

In order to improve the experiment further, a detector with significantly higher testing range would be needed. This would mean that the theoretical data from experiment 3 would not be needed and empirical data could be gathered in its stead. Additionally, this would mean experimental scope would improve and other tests could be done. Another area for further investigation would be a comparison of stated VOC contents and TVOC measured in air, to see if there is correlation between these numbers and TVOC released is based purely on VOC levels or on some other characteristics of the paint itself.

Appendix:

Appendix I

Raw data from test of near open tin air quality

Open tin 1 min		T1						
Paint brand	before		after		**change**		% change	
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC
A	0.08	0.43	0.19	0.65	0.11	0.22	137.50%	51.16%
B	0.08	0.44	0.1	0.61	0.02	0.17	25.00%	38.64%
C	0.08	0.43	0.1	0.55	0.02	0.12	25.00%	27.91%
D	0.09	0.44	0.08	0.43	-0.01	-0.01	-11.11%	-2.27%

Table 7: Tin opening test, Trial 1

Open tin 1 min		T2						
Paint brand	before		after		**change**			
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC		
A	0.06	0.31	0.21	0.79	0.15	0.48	250.00%	154.84%
B	0.07	0.33	0.14	0.69	0.07	0.36	100.00%	109.09%
C	0.07	0.33	0.14	0.62	0.07	0.29	100.00%	87.88%
D	0.07	0.37	0.11	0.54	0.04	0.17	57.14%	45.95%

Table 8: Tin opening test, Trial 2

Open tin 1 min		T3						
Paint brand	before		after		**change**			
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC		
A	0.05	0.24	0.16	0.67	0.11	0.43	220.00%	179.17%
B	0.05	0.2	0.21	0.78	0.16	0.58	320.00%	290.00%
C	0.05	0.23	0.08	0.38	0.03	0.15	60.00%	65.22%
D	0.05	0.2	0.08	0.38	0.03	0.18	60.00%	90.00%

Table 9: Tin opening test, Trial 3

Open tin 1 min		T4						
Paint brand	before		after		**change**			
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC		
A	0.06	0.26	0.47	1.42	0.41	1.16	683.33%	446.15%
B	0.05	0.23	0.19	0.74	0.14	0.51	280.00%	221.74%
C	0.06	0.26	0.29	0.98	0.23	0.72	383.33%	276.92%
D	0.06	0.29	0.09	0.45	0.03	0.16	50.00%	55.17%

Table 10: Tin opening test, Trial 4

Open tin 1 min		T5						
Paint brand	before		after		**change**			
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC		
A	0.05	0.25	0.48	1.46	0.43	1.21	860.00%	484.00%
B	0.06	0.29	0.11	0.57	0.05	0.28	83.33%	96.55%
C	0.06	0.27	0.09	0.48	0.03	0.21	50.00%	77.78%
D	0.06	0.29	0.07	0.34	0.01	0.05	16.67%	17.24%

Table 11: Tin opening test, Trial 5

Open tin 1 min		T6						
Paint brand	before		after		**change**			
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC		
A	0.05	0.21	0.12	0.52	0.07	0.31	140.00%	147.62%
B	0.04	0.18	0.07	0.32	0.03	0.14	75.00%	77.78%
C	0.04	0.19	0.09	0.49	0.05	0.3	125.00%	157.89%
D	0.04	0.19	0.05	0.23	0.01	0.04	25.00%	21.05%

Table 12: Tin opening test, Trial 6

Open tin 1 min		T7						
Paint brand	before		after		**change**			
	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC		
A	0.05	0.2	0.33	1.07	0.28	0.87	560.00%	435.00%
B	0.05	0.2	0.09	0.45	0.04	0.25	80.00%	125.00%
C	0.04	0.19	0.07	0.34	0.03	0.15	75.00%	78.95%
D	0.04	0.19	0.05	0.22	0.01	0.03	25.00%	15.79%

Table 13: Tin opening test, Trial 7

Appendix II

Painted board experimental raw data

T1				
Painted board				
Paint brand	before		after	
	HCHO	TVOC	HCHO	TVOC
A	0.07	0.37	0.57	1.62
B	0.07	0.34	0.8	2.73
C	0.04	0.18	0.56	1.36
D	0.07	0.35	0.18	0.72

Table 14: Painted board test, Trial 1

T2				
Painted board				
Paint brand	before		after	
	HCHO	TVOC	HCHO	TVOC
A	0.07	0.33	0.6	1.65
B	0.06	0.32	0.81	2.51
C	0.07	0.36	0.67	1.42
D	0.06	0.34	0.17	0.69

Table 15: Painted board test, Trial 2

T3				
Painted board				
Paint brand	before		after	
	HCHO	TVOC	HCHO	TVOC
A	0.07	0.3	0.59	1.59
B	0.07	0.3	0.82	2.91
C	0.06	0.34	0.58	1.62
D	0.07	0.31	0.16	0.71

Table 16: Painted board test, Trial 3

T4				
Painted board				
Paint brand	before		after	
	HCHO	TVOC	HCHO	TVOC
A	0.05	0.31	0.54	1.81
B	0.05	0.36	0.75	2.74
C	0.07	0.37	0.62	1.64
D	0.07	0.35	0.19	0.7

Table 17: Painted board test, Trial 4

T5				
Painted board				
Paint brand	before		after	
	HCHO	TVOC	HCHO	TVOC
A	0.06	0.36	0.54	1.71
B	0.06	0.31	0.7	2.48
C	0.06	0.32	0.59	1.59
D	0.06	0.31	0.15	0.67

Table 18: Painted Board test, Trial 5

Appendix III

Box paint experiment raw data

	before		after		Change		Time to "safe" level	
Product	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC	min	sec
A	0.08	0.39	5	5	4.92	4.61	24	35
B	0.08	0.31	5	5	4.92	4.69	31	20
C	0.07	0.32	5	5	4.93	4.68	40	1
D	0.07	0.4	1.65	4.31	1.58	3.91	9	48

Table 19: raw data from trial 1 of experiment 3

	before		after		Change		Time to "safe" level	
Product	HCHO	TVOC	HCHO	TVOC	HCHO	TVOC	min	sec
A	0.08	0.49	5	5	4.92	4.51	21	55
B	0.07	0.23	5	5	4.93	4.77	41	42
C	0.08	0.44	5	5	4.92	4.56	47	27
D	0.08	0.48	1.59	4.55	1.51	4.07	9	56

Table 20: raw data from trial 2 of experiment 3

Appendix IV

Ratios from experiments 2:3

box to board ratio	
HCHO	TVOC
9.529412	6.346705

Table 21: box to board ratio derived from brand "D" in experiments 2 & 3