INVESTIGATION OF THE INTERIOR AIR QUALITY OF THE LIGHT RAIL TRANSIT TRAINS IN METRO MANILA

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Abstract: This study investigated the interior air quality of air-conditioned trains of the Light Rail Transit (LRT) in Metro-Manila. The air contaminants assessed include chemical and biological contaminants and particulate matters (PM2.5). The chemical contaminants considered include carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen oxide and volatile organic compounds such as toluene and benzene. A survey is conducted to determine the sicknesses/illnesses contracted by the passengers which may be due to poor interior air quality. The study recommended some interventions to maintain good interior air quality of the trains.

The concentration of chemical contaminants is measured using colorimetric method while the concentration of particulate matter is measured by gravimetric method using IOM sampler. The measurement of biological contaminants is determined by sedimentation test using a bio-stage compactor.

Preliminary results indicated a high concentration of carbon dioxide during peak time but it was still within the acceptable limit as set by the standard. There was no trace of the other chemical contaminants found in the trains. Generally, the concentration of biological contaminant exceeded the acceptable level of 1000 cfu/m^3 set by the American Conference of Governmental Industrial Hygienist.

Keywords: interior air quality, chemical and biological contaminants, particulate matter.

1. INTRODUCTION

As years pass by, air pollution problem has become worse all around the world. Due to the overwhelming air pollution in environment, human's health and comfort are affected. According to scientific studies, frequent exposure to air contaminants can increase the risk of acquiring health-related problems specifically respiratory problems. Developments in the Heating, Ventilation and Air-conditioning (HVAC) industry show a concern for good Indoor Air Quality (IAQ). The health hazards are caused by poor IAQ that contained air contaminants such as chemicals, particulate matter and airborne bacteria. These contaminants are generally formed by many electric power plants, automotive industry for transportation, other industrial processes, construction and agriculture. It is for the reason that this study is undertaken with the health of the commuters in the Light Rail Transit (LRT) trains in Metro

Manila as the main concern.

2. OBJECTIVES OF THE STUDY

The study investigated the interior air quality of the LRT trains and surveyed the common health problems of the commuters which may be related to respiratory problems caused by the air contaminants.

Specific Objectives

The study accomplished the following specific objectives.
(1) The concentration of the air contaminants in the LRT trains was assessed. The air contaminants included particulate matter (PM2.5) and chemical contaminants such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxide (NO_2) and volatile organic compounds such as benzene (C_6H_6) and toluene (C_7H_8). (2) Biological contaminants in the form of airborne bacteria, molds and fungi were assessed. (3) The group conducted a survey to determine the common sickness/illness contracted by the passengers which may be due to the poor interior air quality in the LRT trains.

3. RELATED LITERATURE

Indoor air quality studies in building and surface transportation have been undertaken in the mechanical engineering departments of Mapua Institute of Technology and De La Salle University-Manila. These studies include investigation of indoor air quality of classrooms, libraries, shopping malls, cafeteria, buses and ship cabins.

Three mechanical engineering undergraduate theses on interior air quality of surface transportation such as buses and ships which were undertaken at De La Salle University-Manila are cited in this study.

Bosshard et al. (2003) assessed the interior air quality of air-conditioned buses plying the route Moonwalk (Las Piñas) to Lawton (Manila) and vice-versa. The study considered chemical contaminants such as CO_2, CO, SO_2, NO_2, C_6H_6 and C_7H_8 and particulate matter PM 2.5. The results of the study indicated that CO and CO_2 concentrations were at acceptable levels while NO_2, SO_2 and C_6H_6 concentrations exceeded the acceptable level based on the Canadian Indoor Air Quality Standard. There was no trace of C_7H_8 in all the sampling done. The concentration of particulate matter (PM 2.5) is also within the acceptable level based on the same standard.

In addition to the chemical contaminants assessed by the previous research group, Austria et al. (2004) included assessment of biological contaminants found in the air-conditioned buses plying the same route. The result of this study showed that the concentration of the chemical contaminants were within the acceptable levels while the airborne bacterial count exceeded the recommended level by the American Conference of Governmental Industrial Hygienist (ACGIH).

Pea et al. (2006) investigated the interior air quality of air-conditioned ship cabins of motor vessels traversing the route Manila-Cebu and vice-versa. Except for CO_2, there was no trace of CO, SO_2, NO_2, C_6H_6 and C_7H_8 found in the cabins using colorimetric method. The concentration of CO_2 and particulate matter (PM 2.5) were within the acceptable level based

on the Canadian Indoor Air Quality Standard. However, the biological contaminants exceeded the limit set forth by the ACGIH.

In all these studies, the CO_2 level and particulate matter (PM 2.5) were all within the acceptable level based on the Canadian Indoor Air Quality Standard. On the other hand, the airborne bacterial count exceeded the allowable limit set by the ACGIH. These studies made some recommendations to improve the interior air-quality such as using better filter materials, activated carbon and ultra-violet light.

3. METHODOLOGY

The assessment of the chemical contaminants was done by the use of a direct measurement device for CO_2 and colorimetric tubes for the other chemicals such as CO, SO_2, NO_2, C_6H_6 and C_7H_8.Sampling test of particulate matter (PM5) was done using gravimetric method. Sedimentation test was applied to determine the bacterial count using a postage compactor. The tests were conducted mostly on dry-weather conditions between May and August. Two LRT lines namely Line 1 or yellow line (Baclaran to Monumento Stations) and Line 2 or purple lane (Santolan to Recto Stations) were considered in the study. The sampling time was set at 8:00AM , 1:00PM and 6:00PM and the sampling points were at the middle and both ends of the LRT train. In the absence of an interior air quality standard for surface transportation, the Canadian Indoor Air Quality Standard for buildings and American Conference of Governmental Industrial Hygienist (ACGIH)

4. DISCUSSION OF RESULTS

The following summarizes the results of the air sampling test done for the chemical contaminants, airborne bacteria and particulate matter.

Sampling test for chemical contaminants such as CO_2, CO, SO_2, NO_2, C_6H_6 and C_7H_8 were conducted for two days (morning and afternoon on dry-weather condition) on LRT Lines 1 and 2 plying the routes Baclaran to Monumento and vice versa and Santolan to Recto and vice-versa, respectively. With the exception of CO_2, there was no trace of the other chemical contaminants seen in the detector (colorimetric) tubes. The CO_2 concentration was observed to increase during the time when the volume of the passengers increased. Tables 1 and 2 summarize the data obtained during the air sampling test conducted for the different chemical contaminants, in LRT Line 2, while Tables 3 and 4 summarize the data obtained in LRT Line 1.

Table 1: Concentration of Chemical Contaminants taken at LRT Line 2 (May 2 and 12)

DATE/TIME	STATION	CHEMICAL CONTAMINANT CONCENTRATION (PPM)					
		CO_2	CO	SO_2	NO_2	C_6H_6	C_7H_8
2 May AM	(*end part)*						
8:42	Santolan	588					
8:44	Santolan-Katipunan		0				
8:45	Santolan-Katipunan			0			
8:47	Katipunan				0		
8:49	Katipunan-Anonas					0	
8:50	Katipunan-Anonas						0
	(middle part)						
8:55	Cubao	2130					
8:57	Cubao-Betty Go		0				
9:00	Gilmore			0			
9:01	Gilmore – J.Ruiz				0		
9:02	Gilmore – J.Ruiz					0	
9:03	J. Ruiz						0
	(front part)						
9:05	V. Mapa	2870					
9:06	V.Mapa - Pureza		0				
9:07	Pureza			0			
9:09	Legarda				0		
9:10	Legarda-Recto					0	
9:11	Recto						0
12 May PM							
1:33	Pureza	619					
1:35	V.Mapa		0				
1:25	Recto			0			
1:30	Legarda				0		
1:32	Legarda-Pureza					0	
1:28	Recto-Legarda						0
	(middle part)						
1:40	Betty Go	903					
1:42	Cubao		0				
1:39	Gilmore-Betty Go			0			
1:38	Gilmore				0		
1:36	J.Ruiz					0	
1:43	Cubao-Anonas						0
	(front part)						
1:47	Katipunan	593					
1:44	Anonas		0				
1:51	Santolan			0			
1:46	Katipuna-Santolan				0		
1:49	Katipunan-Santolan					0	
1:45	Anonas-Katipunan						0

Table 2: Concentration of Chemical Contaminants taken at LRT Line 2 (May 30)

DATE/TIME	STATION	CHEMICAL CONTAMINANT CONCENTRATION (PPM)					
		CO_2	CO	SO_2	NO_2	C_6H_6	C_7H_8
30 May AM	(*end part)*						
10:35	Santolan	1210					
10:37	Santolan-Katipunan		0				
10:39	Katipunan			0			
10:40	Katipunan-Anonas				0		
10:42	Anonas					0	
10:43	Anonas-Cubao						0
	(middle part)						
10:45	Cubao	2071					
10:48	Betty Go-Gilmore		0				
10:51	J. Ruiz			0			
10:52	J.Ruiz-V.Mapa				0		
10:54	V.Mapa-Pureza					0	
10:56	Pureza						0
	(front part)						
10:57	Pureza-Legarda	2870					
10:58	Legarda		0				
10:59	Legarda-Recto			0			
11:00	Recto				0		
11:02	Recto					0	
11:03	Recto-Recto						0
30 May PM	(*end part)*						
2:00	Pureza	619					
2:02	V.Mapa		0				
2:03	Recto			0			
2:05	Legarda				0		
2:06	Legarda-Pureza					0	
2:07	Recto-Legarda						0
	(middle part)						
2:09	Betty Go	1268					
2:10	Cubao		0				
2:11	Gilmore-Betty Go			0			
2:12	Gilmore				0		
2:14	J.Ruiz					0	
2:16	Cubao-Anonas						0
	(front part)						
2:18	Katipunan	593					
2:19	Anonas		0				
2:20	Santolan			0			
2:22	Katipuna-Santolan				0		
2:23	Katipunan-Santolan					0	
2:24	Anonas-Katipunan						0

Table 3: Concentration of Chemical Contaminants taken at LRT Line 1 (August 5)

DATE/TIME	STATION	CHEMICAL CONTAMINANT CONCENTRATION (PPM)					
		CO_2	CO	SO_2	NO_2	C_6H_6	C_7H_8
5 August AM	(front *part)*						
6:45	Baclaran	2100					
6:50	Edsa		0				
6:55	Libertad			0			
7:00	Gil Puyat				0		
7:05	Vito Cruz					0	
7:10	Qurino						0
5 August PM	*(middle part)*						
12:43	Pedro Gil	2200					
12:47	U.N. Avenue		0				
12:49	Central Terminal			0			
12:51	Carriedo				0		
12:54	Doroteo Jose					0	
12:58	Bambang						0
	(end part)						
6:30	Tayuman	2300					
6:32	Blumentritt		0				
6:35	Jose Abad Santos			0			
6:37	R.Papa				0		
6:39	5^{th} Avenue					0	
6:41	Monumento						0

Table 4: Concentration of Chemical Contaminants taken at LRT Line 1 (August 11)

DATE/TIME	STATION	CHEMICAL CONTAMINANT CONCENTRATION (PPM)					
		CO_2	CO	SO_2	NO_2	C_6H_6	C_7H_8
11 August AM	(front *part)*						
9:40	Baclaran	1100					
9:44	Edsa		0				
9:46	Libertad			0			
9:48	Gil Puyat				0		
9:51	Vito Cruz					0	
9:54	Quirino						0
5 August PM	*(middle part)*						
12:41	Pedro Gil	2450					
12:45	U.N. Avenue		0				
12:48	Central Terminal			0			
12:51	Carriedo				0		
12:54	Doroteo Jose					0	
12:57	Bambang						0
	(end part)						
6:30	Tayuman	2250					
6:34	Blumentritt		0				
6:36	Jose Abad Santos			0			
6:38	R.Papa				0		
6:40	5^{th} Avenue					0	
6:43	Monumento						0

Using a direct reading instrument to measure CO_2 concentration in ppm, the data obtained for CO_2 concentration taken at LRT line 2 for two days at various time of the day and at different stations of the LRT (Santolan to Recto and vice-versa) are plotted. Please see Figures 1 and 2 below. As can be observed, CO_2 concentration builds up overtime and reaches the highest at peak time when the number of passengers is at a maximum. On the other hand, the temperature in the train starts high then begins to decline until a stabilized condition is reached.

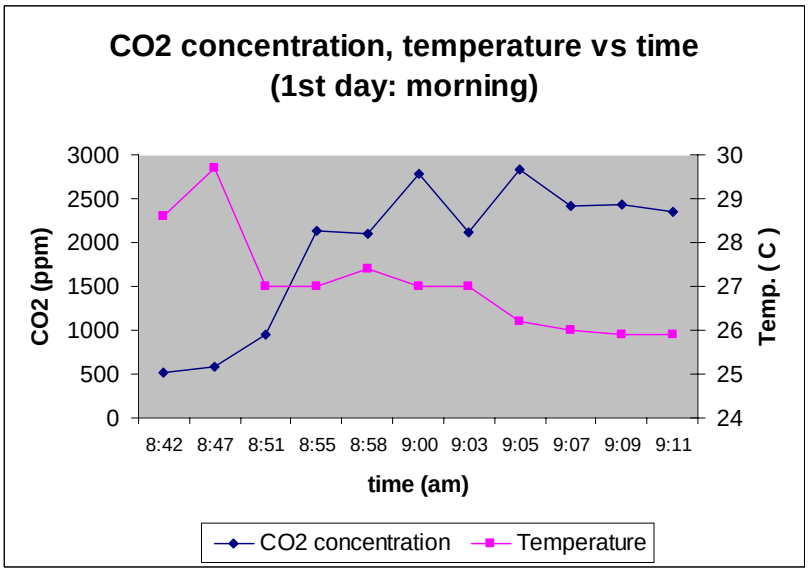

Figure 1. CO_2 concentration, temperature vs. time (first day)

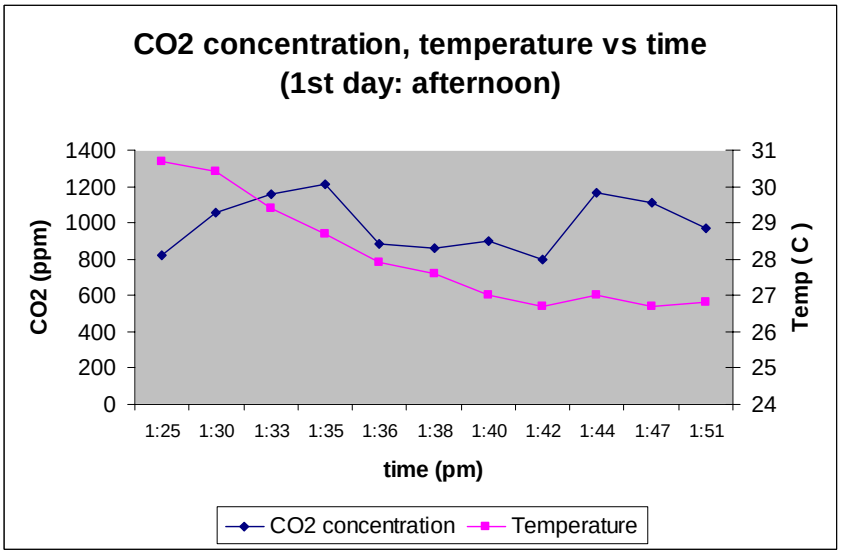

Figure 2. CO_2 concentration, temperature vs. time (second day)

As far as the airborne bacteria count is concerned, the highest value obtained is 229 cfu (5831 cfu/m^3) while the lowest is 8 cfu (203 cfu/m^3). Please see Table 5. For an acceptable level of 1000 cfu/m^3 as set by ACGHI. Line 1 couches and Line 2 couch Train #4 exceeded the limit for airborne bacteria. As observed, the concentration of airborne bacteria in the train depends on the number of passengers.

Table 5: Sampling Results of Biological Contaminants (August 5)

Sampling Point/Time	Colony forming unit	Colony forming unit per cubic meter (cfu/m3)
Line 1		
Front Couch(6:45am – 7:16am)	123	3132
Middle Couch(12:47pm – 1:16pm)	85	1804
Back Couch(6:30pm – 7:00pm)	51	1082
Line 2		
Couch Train #4 (6:45am – 7:16am)		
Front	94	2394
Middle	140	3565
Back	229	5831
Couch Train # 7(12:47pm – 1:16pm)		
Front	34	866
Middle	32	815
Back	31	789
Couch # 11(6:30pm – 7:00pm)		
Front	9	229
Middle	8	203
Back	16	407

5. CONCLUSION

Based on the discussion of the results, the only chemical contaminant found in the LRT trains was carbon dioxide with a concentration that was within the acceptable limit prescribed by the Canadian Indoor Air Quality Standard. Carbon dioxide ($CO_{2)}$ concentration varied at the different LRT stations, time of measurement and with the number of passengers. There was no trace of the other chemical contaminants found in the trains.

As for the biological contaminants, large number of bacterial colony forming unit was found. The amount exceeded the acceptable limit based on the American Conference of Government Industrial Hygienist. The concentration of biological contaminants varied at the different LRT stations, time of measurement and with the number of passengers.

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