ATMOSPHERIC EXPOSURE TO CHLORAMINES IN INDOOR SWIMMING POOLS

Alain PERSON, Anne-Marie LAURENT, Yvon LE MOULLEC
Laboratoire d'Hygiène de la Ville de Paris
yvon.lemoullec@mairie-paris.fr

INTRODUCTION

Swimming pools constitute a particular environment where volatile by-products generated by chlorination of water [1] can depreciate the air quality. Chloramines are dominant air pollutants whose irritant effects are well-known. Atmospheric high levels affect the comfort of users and can cause harmful health effects particularly for workers chronically exposed [2]. Last few years consciousness of the authorities and facilities owners has raised; a better quality of the swimming pools environment is whished. Consequently, preliminary investigations were undertaken in a set of public Parisian covered swimming pools. The objectives were to assess atmospheric chloramines levels and to evaluate the influence of the main factors related to facilities management.

MATERIAL AND METHODS

More than 30 public indoor swimming pools located in Paris were studied in 2003.

Swimming pools characteristics

Most of buildings contain either a large pool (300 –1,000 m^2) or a large pool and a small pool (60 - 150 m^2). The water is chlorinated with hypochlorous acid. The same principle of air mechanical ventilation is used in all cases : the air in the hall is exchanged at constant flow, depending on the building volume. A variable proportion of indoor air is recirculated and mixed with outdoor air to maintain a theoretically constant level of humidity inside the hall. Different type of people frequent the pools : public and school children are the main swimmers during the measurements .

Sampling and analysis

The swimming pools were visited once a year, during morning (~ 9:00-11:30 am) or afternoon (~ 2:00-4:30 pm) periods. Air quality was evaluated at the poolside, generally ~1-2 m from edge of pools and ~ 1.5 m from floor level. 2 or 3 sampling points were selected depending on the number of pools in the building. Air chloramines levels were determined by integrated air sampling (2 hours) followed by analysis in laboratory. Sampling device is a Millipore cassette containing a cellulose filter (37 mm diameter) treated with carbonate and diarsenic trioxide to trap mono, di and trichloramine. Air is drawing through the sampling device using a calibrating pump operating at 4 L/min. After sampling, filters were desorbed in demineralized water and the resulting solutions were analysed by electrophoresis to quantify chloride concentrations. Air relative humidity and temperature were measured with a small portable analyser equipped with capacitive and thermistance sensors.
Water samples were collected in glass bottles at a depth of about 50 cm. Aliquot of water were mixed with ready-to-use products to develop conventional colorimetric reaction. PH (red phenol) , free chlorine and total chlorine (Diethyl Para Phenylene Diamine reaction) were analyzed with a portable spectrophotometer.
Complementary data on pools frequentation were collected during the air sampling by counting the number of swimmers every 30 minutes.

RESULTS AND DISCUSSION

Distribution of water data

The table 1 includes the distribution of data. The temperature of water varies from 27°C up to 33 °C in case of babies swimmers. Free Chlorine (mean:1.6 mg/L) and PH (mean:7.3-7.4) satisfy the French lawful requirements to minimize the bacteriological contamination. The combined chlorine derived from chlorination of nitrogen contaminants brought by swimmers is often slightly higher in small basins (mean : 0.54 mg/L) than in large ones (0.46 mg/L). Sometimes the allowable limit is exceeded (0.6 mg/L).

	Temperature °C	PH	Free chlorine Cl_2 mg/L	Combined chlorine Cl_2 mg/L
	Large basins (n=35)			
Min	27.0	6.9	0.8	0.12
Median	28.0	7.3	1.6	0.40
Percentile 90	29.7	7.6	2.1	0.70
Max	33.0	7.8	2.8	1.10
Mean	28.5	7.4	1.6	0.46
CV%	4	3	30	47
	Small basins (n=12)			
Min	27.0	6.9	0.7	0.17
Median	29.0	7.4	1.6	0.48
Percentile 90	30.0	7.7	2.6	0.85
Max	30.0	8.0	3.4	1.05
Mean	29.0	7.4	1.7	0.54
CV%	4	4	46	51

Table 1 : Water parameters distribution data

Distribution of air data

The indoor total chloramines mean levels vary from 83 to 600 µg/m^3 with a median level of 229 µg/m^3. The temperature and humidity comply generally with the criteria defined by the owner of facilities : RH : 65-70 % and 26 °C which corresponds to 14-15 g of water per kg dry air. In some cases, abnormal thermal conditions are noticed (min : 22.7 °C) and high levels of humidity (RH : 78 %) mean insufficient ventilation rate.

	Temperature °C	Relative humidity %	Absolute humidity g/kg dry air	Chloramines NCL_3 µg/m^3
Min	22.7	40.0	9.3	83
Median	26.7	61.0	13.0	229
Percentile 90	28.8	68.0	16.2	440
Max	29.2	78.0	16.9	660
Mean	26.8	60.3	13.2	258
CV%	6	14	16	51

Table 2 : Air parameters distribution data (n=35)

Spatial distribution of the air chloramines

Case of one pool : Two sampling points are located as shown on figure 1. The graph illustrates the values related to couples of sampling points in each building (1 to 24). The relative variation between the air chloramines levels measured in each hall, is generally lower than 30 %. Except some cases, differences are not significant and may be easily explained by the precision of the measurement.

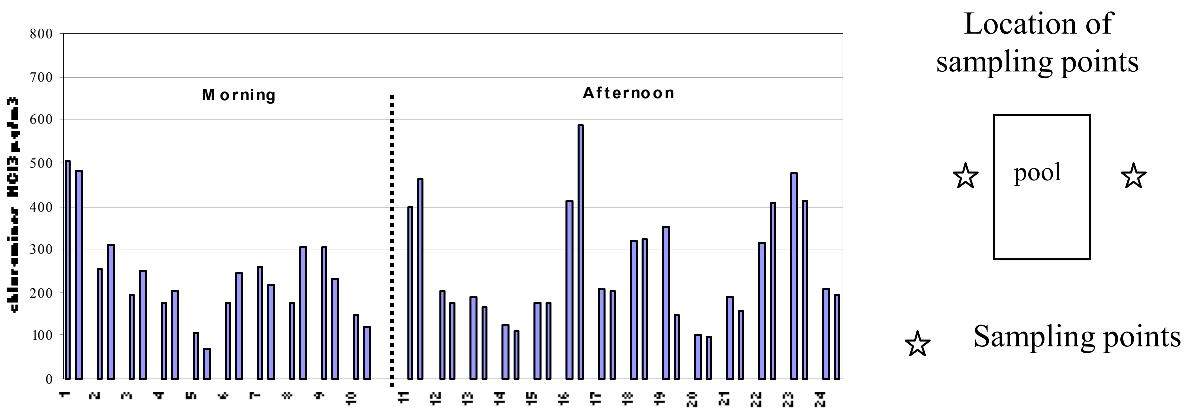

Figure 1 :   Location of sampling points and air chloramines levels in swimming pools with one basin

Case of two pools : Three sampling points are located as shown on figure 2. Chloramines levels close to the small basin are often higher than the one associated to the large pool (see red bars on figure 2) . The discrepancy between the minimum and maximum values can exceed 40 % .

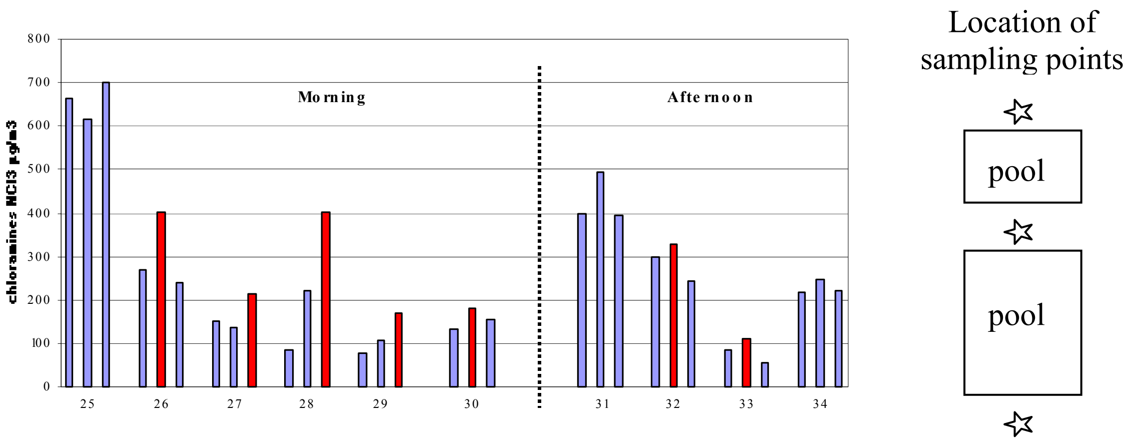

Figure 2 : Location of sampling points and air chloramines levels in swimming pools with two basins

This results highlight the risk of insufficient representativeness of data to assess the atmospheric human exposure. The variation of air concentrations may be due to the heterogeneity of chloramines emissions from the water surface because the frequentation activity pattern is typical for each pool. In addition, the airflow is not always equally distributed in large air volume space.

Temporal variation of the air chloramines

The figure 3 illustrates significant time variations of chloramines levels during a day which are explained by many factors.

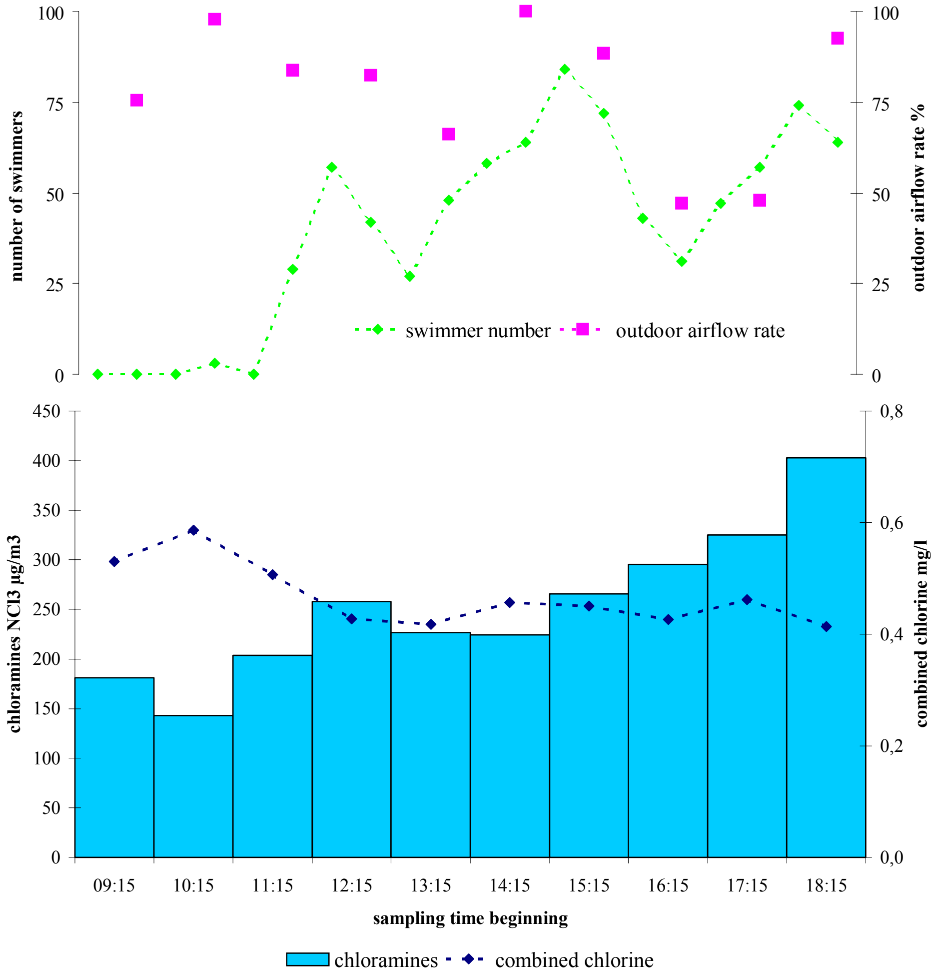

Figure 3 : Temporal evolution of air chloramines level in a swimming pool during a day related to combined chlorine level, outdoor airflow rate and number of swimmers

The temporal variation of chloramines levels was studied during a warm day in July in one swimming pool with two basins. 60 minutes consecutive integrated air sampling was carried out in a midpoint. In each basin, every 30 minutes, the swimmers were counted and the combined chlorine was measured in the water of the two pools. In addition the recirculation airflow rate was continuously recorded which allows to know the outdoor air ventilation rate.

The variations of air chloramines level seems to be independent of the combined chlorine concentrations in the basins that were nearly constant all along the day. According to other parameters, four periods can be distinguished during the day :
-early in the morning, before occupation of the basins, the air supplied in the hall was nearly 100 % of outdoor air and chloramines level was minimum (~ 150 µg/m^3);
-later in the morning, the level of chloramines increased caused by occupation of basins (up to 80 swimmers at ~ 4 pm) while the outdoor air proportion is quite constant until 4 pm;
-from 4 to 6 pm, despite the decrease of the swimmer number, the chloramines level increased again due to significant reduction of outdoor airflow rate ;
-finally, after 6 pm, despite the decrease of the swimmer number and a maximum outdoor airflow rate, the chloramines levels continued to increase probably explained by a more intensive agitation of water surface induced by a aqua-gym training.

Influence of different factors on air quality

How to interpret the air chloramines variation in the different pools studied during a short period once a year ?
Theoretically, two main parameters govern the level of indoor air pollutants : the emissions of the source in relation with water composition and volatilization rates of mono, di and trichloramine and the conditions of ventilation.
The air chloramines level are not correlated with the combined chlorine measured in the water (R^2 = 0.01, n = 25). The air chloramines level apparent independence of the water composition is probably due to the insufficient representativeness of combined chlorine because nitrogen trichloride, the dominant chloramine specie in air (> 80 %), is likely to represent a minor part of combined chlorine.
It is easier to investigate the influence of the ventilation because the outdoor airflow rate may be approximately estimated from humidity measurements by considering two equations.

$$Q \times W_i \times \rho_i - Q \times W_o \times \rho_o = E \qquad E = 16 \times S \times (Ws - Wi) \qquad (1)(2)$$

Q (m^3/h): outdoor airflow rate S (m^2) : water area E (g/h) : water emission rate
ρ_i, ρ_e (kg/m^3): respectively indoor, outdoor air density
Wi, We, Ws (g water/Kg dry air): respectively indoor, outdoor and saturation absolute humidity

The first equation means that the quantity of water brought by ventilation equals the water losses from basins; In the second, we suppose a weak agitation of water.

By taking into account the set of experiments in all swimming pools, the figure 4 graphically illustrates as a scatterplot the relationship between air chloramines level (Y-axis) and Q/S (X-axis). The pattern of the points indicates a negative correlation between the two variables clearly. The general trend is to observe high level of chloramines associated with low airflow rate available per basin area. Logically this trend is observed more often in winter; during this period, ventilation rate is reduced because the outdoor air is more drying.

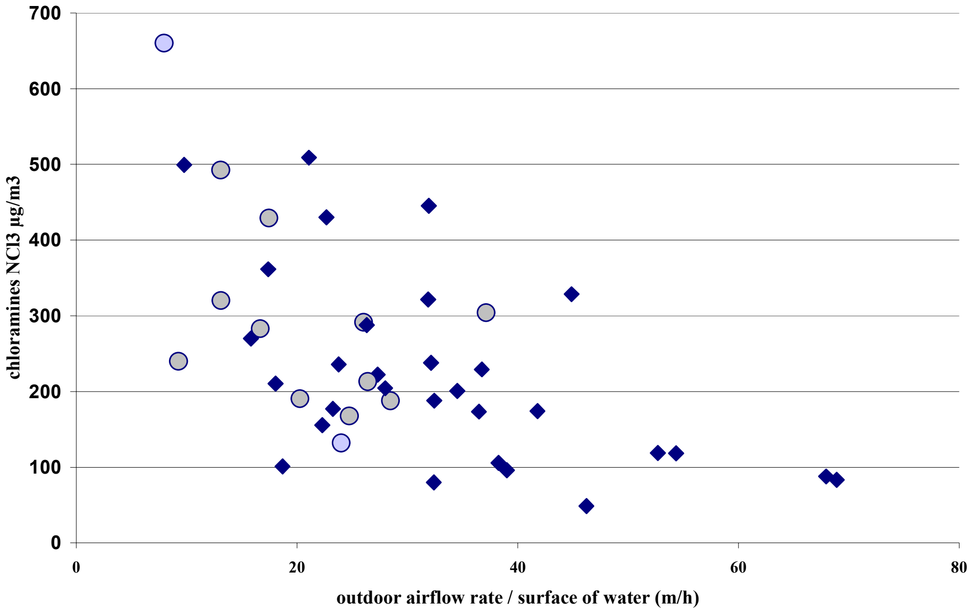

Figure 4 : Air chloramines level in relationship between outdoor air flowrate/surface of water

CONCLUSION

The air chloramines levels in the Parisian public indoor swimming pools comply with the ones published by other authors. Recently the guideline of 500 µg/m^3 was proposed [3] to reduce the risk of incomfort and irritation effects. For few cases, this value was exceeded. But we have to keep in mind that most measurements were carried out during periods of moderate activity in the pools. A specific study showed the chloramines level are likely to increase significantly particularly when the activity in the pools are intensive.

The sampling strategy need to be improved because in certain buildings significant differences appear between results related to different point of sampling. The difficulty is to select a minimum of sampling sites so that the results are representative on the scale of the environment.

If the results clearly highlight the importance of ventilation, it is necessary to continue nevertheless the investigations to quantify the respective role of the water quality and that of ventilation. From this point of view, tests are in progress to substitute the measurement of the combined chlorine by that of nitrogen trichloride which is theoretically a more relevant indicator of the water quality in the swimming pools.

REFERENCES

[1] Judd S.J., Bullock G. (2003). The fate of chlorine and organic materials in swimming pools. Chemosphere. 51, 869-879.

[2] Thickett K.M., McCoach J.S., Gerber J.M. et al. (2002). Occupational asthma caused by chloramines in indoor-pool air. Eur Respir. 19, 827-832.

[3] Massin N., Bohadana A.B., Wild P., Hery M. et al. (1998). Respiratory symptoms and bronchial responsiveness in lifeguards exposed ti nitrogen trichloride in indoor swimming pools. Occup Environ Med. April, 55(4), 258-263.