APPLICATION OF RELATIVE AIR POLLUTION INDEX (RAPI) – A NEW METHOD FOR AGGREGATE ASSESSMENT: CASE STUDY IN INDUSTRIAL ZONES, CLUSTERS AND TRADE VILLAGE AREA IN HANOI, VIETNAM

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TÓM TẮT

ÁP DỤNG CHỈ SỐ Ô NHIỄM KHÔNG KHÍ TƯƠNG ĐỐI (RAPI) MỘT PHƯƠNG PHÁP MỚI ĐỂ ĐÁNH GIÁ TỔNG HỢP: TRƯỜNG HỢP TẠI CÁC KHU, CỤM CÔNG NGHIỆP VÀ LÀNG NGHỀ TẠI HÀ NỘI, VIỆT NAM

Trong bài báo này, nhóm tác giả áp dụng Chỉ số ô nhiễm không khí tương đối (RAPI) do tác giả Phạm Ngọc Hồ đề xuất để đánh giá tổng hợp mức độ ô nhiễm không khí giờ (RAPIh) theo tiêu chuẩn trung bình ngày trong 1 giờ quy định tại Quy chuẩn kỹ thuật Việt Nam QCVN 05:2013/BTNMT về chất lượng không khí xung quanh. Số liệu do Viện Khoa học môi trường và Sức khỏe cộng đồng thu thập từ tháng 10 đến tháng 11 năm 2020. Các số liệu quan trắc định kỳ của môi trường không khí xung quanh tại 116 điểm quan trắc trong các khu, cụm công nghiệp và làng nghề xung quanh Hà Nội được sử dụng để tính toán chỉ số RAPIh. Kết quả cho thấy chất lượng không khí tại các các khu vực nêu trên nhìn chung đạt mức tốt hoặc trung bình (không ô nhiễm). Kết quả này phù hợp với số liệu quan trắc thực tế tại tất cả các điểm quan trắc, không có thông số nào có giá trị quan trắc vượt tiêu chuẩn cho phép quy định tại QCVN 05:2013/BTNMT về chất lượng không khí xung quanh.

Keywords: *Relative Air Pollution Index (RAPI), weighing factors, thresholds and hierarchical rating scale*

1. INTRODUCTION

The air pollution index (API) and the air quality index (AQI) have been commonly applied in Vietnam and abroad. These indices are aggregated from the individual indices (sub-indices), calculated from daily standards (1hr, 8hr and 24hr), or yearly standards (24hr, year), and employed for overall assessment of the level of pollution/air quality. There are three main methods to build the daily index API/AQI:

Using the highest value of the sub-indices (individual indices) (Ott *et al* 1976 [1]; Ott 1978 [2]; Wallace 1978 [3]). This method was used by the US Environmental Protection Agency (2006) [4]. Similar methods were also used by the Hong Kong Environmental Protection Department [5], the State Environmental Protection Administration of China [6], the Singapore National Environment

Agency 2014 [7], the Vietnam Environment Administration (VEA) (2019) [8], Hoang X. C. *et al* (2010) [9], and Nghiem T. D. *et al* (2012) [10]. However, these indices have several limitations as thresholds and hierarchy rating are self-regulated (5-7 levels); some indices take into account the weighing factor which is subjectively scored by the expert's criteria and some otherindices do not take into account the total amount of pollution from individual indices. When there are more parameters (the number of parameters $n \geq 2$), it is necessary to build up the lower and higher breakpoints, or complex search schemes that are not conducive to apply. The main advantage of these methods is that the daily aggregate index AQI_d, the highest value among individual indices, does not encounter eclipsing effect. However, because the AQI_d index does not take into account the total amount of pollution, in some cases, the ambiguity effect can lead to false warning.

Using the summation of the individual indices, according to the method of the former Soviet Union (Berliand 1985 [11]). There are only three levels of the rating hierarchy, no weighing factor.

Using the geometric means of the individual indices (Kyrkilis *et al* 2007) [12] or arithmetic means of the individual indicies (Vietnam Pollution Control Department 2010 [13]). Similar to the first method, the rating scale of this approach is also self-regulation. It does not take into account the total amount of pollution from individual indices. The weighing factor of each parameter is subjective to the expert grading method,. The index encounters "virtual" effect including eclipsing and ambiguity, which means that in some cases the index does not match the actual results. In order to overcome some limitations of the three above-mentioned methods, Pham Ngoc Ho has proposed a new method – the Relative Air Pollution Index (RAPI) [14, 15]. In this article, we applied the RAPI calculation to assess the current level of air pollution around industrial zones, clusters and trade village in Hanoi.

2. MATERIALS AND METHODS

2.1. Materials

The data was hourly monitored (1hr-average) in October and November in 2020 at 116 monitoring sites including 110 industrial zones/clusters and 06 trade villages in Hanoi.

Data used for $RAPI_h$ calculation: The selected basic parameters ($\mu g/m^3$) were SO_2, CO, NO_2 and TSP following Vietnam Technical Regulation QCVN 05:2015/MONRE and we only used the actual monitoring data series to ensure statistical stability of 70% or more of the surveyed parameters. Data processing was conducted according to regulations of the Ministry of Natural Resources and Environment 2013 [16].

2.2. Methods

Hourly Relative Air Pollution Index ($RAPI_h$) calculation

The $RAPI_h$ formula, temporary weighing factor W'_i, final weighing factor W_i, rating threshold and evaluation hierarchy of $RAPI_h$ were developed based on the following mathematical conditions: infimum (inf), supremum (sup), minimum value, maximum value, median value and mean value (Pham Ngoc Ho 2017 [14]). We applied the $RAPI_h$ calculation to a specific case, in which:

$$RAPI_h = 100 - \left(1 - \frac{P_m}{P_n}\right) \quad (1)$$

$$P_m = \sum_{i=1}^{m_1} W_i q_i + \sum_{i=1}^{m_2} W_i \left(1 - q_i\right) \quad (2)$$

$$P_k = \sum_{i=1}^{k} W_i \left(q_i - 1\right) \quad (3)$$

$P_n = P_m + P_k$ is the total amount of pollution of n surveyed parameters (4)

$$q_i = \frac{C_i}{C_i^*} \text{ (relatively individual index)} \quad (5)$$

In which: m_1 is the number of parameters with $q_i = 1$, m_2 is the number of parameters with $q_i < 1$, k is the number of parameters with $q_i > 1$;

C_i – monitoring concentration of parameter i;

C^*_i – permissible standard of parameter i according to each country's standard (1hr average)

W_i – weighing factor of parameter i (based on standard of 1 h, 8 h and 24 h);

Note: The smaller q_i is compared to 1, the better the air quality; q_i = 1 - moderate air quality and the greater q_i is compared to 1, the worse the air quality.

Temporary weighing factor W_i' is calculated by formula:

$$W_i'(S_j) = \frac{\sum_{j=1}^{m} C_i^*(S_j)}{m \times C_i^*(S_j)} \quad (6)$$

The final weighing factor W_i was calculated by this formula:

$$W_i(S_j) = \frac{W_i'(S_j)}{\sum_{i=1}^{n} W_i'(S_j)} \quad (7)$$

Easy to see: $\sum_{i=1}^{n} W_i = 1$ (8)

Where: S_j - standard of parameter i (1h / 8h / 24h), m - number of standards, m = 2 or m = 3, n - number of parameters having the same standard. For periodic data monitoring according to an average of 1 hour a day, set S_j = 1h.

The hierarchical rating scale of RAPI

Hierarchical rating scale of $RAPI_h$ with $n \geq 2$ is shown in Table 1.

Table 1. Hierarchical rating scale of $RAPI_h$ = I with n even and n odd (Pham Ngoc Ho 2017 [14])

n even	**n odd**	**Level of pollution**	**Color**	**Warning level to health**
$100\frac{n-1}{n} < I \leq 100$	$100\frac{n-1}{n} < I \leq 100$	Serious pollution (Dangerous)	Brown	Serious effect on health
$50 < I \leq 100\frac{n-1}{n}$	$50\frac{n-1}{n} < I \leq 100\frac{n-1}{n}$	Very heavy pollution (Very bad quality)	Red	Moderate effect on health
$\frac{100}{n} < I \leq 50$	$\frac{100}{n} < I \leq 50\frac{n-1}{n}$	Heavy pollution (Bad quality)	Orange	Unhealthy
$\frac{50}{n} < I \leq \frac{100}{n}$	$\frac{50}{n} < I \leq \frac{100}{n}$	Light pollution (Fair quality)	Yellow	Unhealthy for sensitive group
$0 \leq I \leq \frac{50}{n}$	$0 \leq I \leq \frac{50}{n}$	No pollution (Good or Moderate quality)	Green	No effects

Note*:* Special case

When n = 2 (even), there are no heavy and very heavy levels of pollution, Table 1 has three levels.

When n = 3 (odd), there is no heavy pollution level, table 1 has 4 levels.

In case all parameters have $q_i \leq 1 \rightarrow P_k = 0 \rightarrow P_m = P_k \rightarrow RAPI_h = 0$ coincides with the lower bound of the hierarchy of 0. In this case, we have:

$0 < q_i \leq 1 \rightarrow 0 < \sum_{i}^{n} W_i q_i < \sum_{i}^{n} W_i$ (according to formula (8))

Put $RAPI_h = \sum_{i}^{n} W_i q_i$ (9) → $0 < RAPI_h \leq 1$.

This inequality indicates the mean threshold is 1, the good threshold is the mean value of 1 and 0 - the lower bound of the scale, i.e. $\frac{1}{2}(1+0) = 0.5$

Therefore, there are 2 levels of rating:

Table 2. Hierarchical rating scale of RAPIh = I in case all parameters have qi < 1

Condition	***Conclusion***
$0 < RAPI_h \leq 0.5$	*No pollution (Good air quality)*
$0.5 < RAPI_h \leq 1$	*Pollution border (Moderate air quality)*

3. RESULTS AND DISCUSSION

3.1. Results

Place n = 4 in Table 1, resulting in the rating hierarchy for 4 parameter presented in Table 3. Using the formulas (6) – (8) with S_j = 1h, we have the weighing factors W'_i and W_i presented in Table 4.

Database to calculate the $RAPI_h$ at monitoring site S_2 (Gate of Dai Tu Industrial Park, Long Bien) presented in Table 5.

From the data provided in Table 5, we can calculate P_m, P_k, P_n and $RAPI_h$.

$P_m = \sum_1^4 W_i(1-q_i) = W_{SO2} \times (1-q_{SO2}) + W_{CO} \times (1-q_{CO}) + W_{NO2} \times (1-q_{NO2}) + W_{TSP} \times (1-q_{TSP}) = 0.255 \times (1-0.080) + 0.003 \times (1-0.088) + 0.445 \times (1-0.060) + 0.297 \times (1-0.244) = 0.88$

$P_k = \sum_1^4 W_i(q_i - 1) = 0$

$P_n = P_m + P_k = 0.88$

In this case, all parameters had $q_i < 1$. Therefore, using formula (9), we calculated:

$RAPI_h = \sum_i^n W_i q_i = 0.88$

From Table 2, it can be indicated that the ambient air at monitoring site S_2 was at pollution border, the air quality was moderate. Similar calculation was applied to other monitoring sites.

Table 3. Hierarchical rating scale of $RAPI_h$ = I with n = 4

n = 4 (even)	**No**	**Level of pollution**	**Color**	**Warning level to health**
$75 < I \leq 100$	V	Serious pollution (Dangerous)	Brown	Serious effect on health
$50 < I \leq 75$	IV	Very heavy pollution (Very poor quality)	Red	Moderate effect on health
$25 < I \leq 50$	III	Heavy pollution (Poor quality)	Orange	Unhealthy
$12.5 < I \leq 25$	II	Light pollution (Fair quality)	Yellow	Unhealthy for sensitive group
$0 \leq I \leq 12.5$	I	No pollution (Good quality)	Green	No effects

Table 4. Weighing factors of 4 surveyed parameters according to Vietnamese technical regulation QCVN 05:2013/MONRE for standard 1hr

No.	**Parameter (μg/m³)**	**Average standard 1-hr**	**W'(1-hr)**	**W(1-hr)**
1	SO_2	350	22.036	0.255
2	CO	30000	0.257	0.003
3	NO_2	200	38.563	0.445
4	TSP	300	25.708	0.297
$\sum W_i$				1

Table 5. Database to calculate the RAPIh at monitoring site S2 (Gate of Dai Tu Industrial Zone, Long Bien)

No	Parameters ($\mu g/m^3$)	C_i(1h)	q_i (Average standard 1-hr)
1	SO_2	28	0,080
2	CO	2650	0,088
3	NO_2	12	0,060
4	TSP	73,14	0,244

Results of $RAPI_h$ at 116 monitoring sites in industrial zones/clusters (110 sites S1 – S10) and trade villages (06 sites LN1 – LN6) in Hanoi in Oct – Nov 2020 were illustrated in Figure 1 – 3.

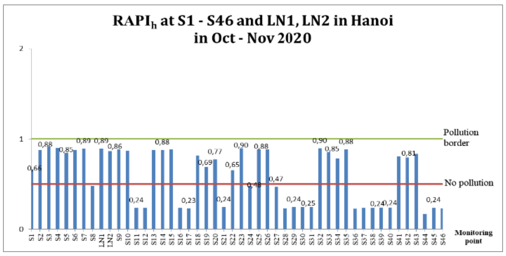

Figure 1. Chart of aggregate assessment of ambient air pollution by $RAPI_h$ at sites in industrial zones/clusters S1 - S46 and trade village LN1, LN2 in Hanoi (Oct - Nov 2020)

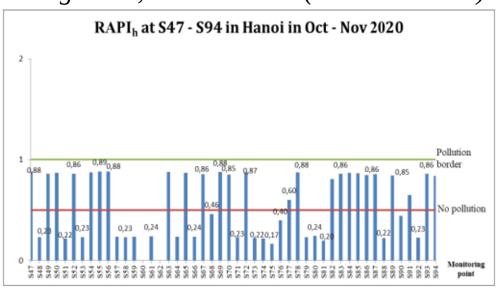

Figure 2. Chart of aggregate assessment of ambient air pollution by $RAPI_h$ at sites in industrial zones/clusters S47 - S94 in Hanoi (Oct - Nov 2020)

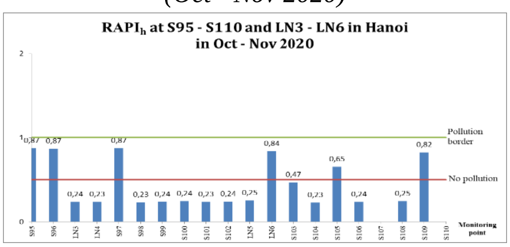

Figure 3. Chart of aggregate assessment of ambient air pollution by $RAPI_h$ at sites in industrial zones/clusters S95 - S110 and trade villages LN3 – LN6 in Hanoi (Oct - Nov 2020)

3.2. Discussion

Three figures clearly illustrate the values of $RAPI_h$ at each monitoring sites and the level of pollution drawn from those values of each sites. There is a relatively equal number of sites having no pollution and sites at pollution border, accounting for 49.14% and 50.86% respectively. The highest value of $RAPI_h$ calculated is 0.90 at site S34 while the lowest one is 0.17 at two sites S46 and S77. There are four sites (S60, S62, S107 and S110) that had insufficient data (no data or data does not ensure statistical stability), leading to failure to calculate $RAPI_h$ value.

4. CONCLUSION

A case study was undertaken in Hanoi for ambient air pollution/quality aggregate assessment. Selected monitoring sites were located in industrial parks and industrial clusters where production and discharge of fumes into the surrounding air take place regularly.

Calculations include: Final weighing factor W_i of 4 parameters (SO_2, CO, NO_2 and TSP); individual index q_i; daily relative air pollution index $RAPI_h$ which was integrated from the q_i index of each parameter; hierarchical rating scale with n = 4 parameters and 5 levels (no pollution (level I), light pollution (level II), heavy pollution (level III), very heavy pollution (level IV) and serious pollution (level V)), corresponding to good/ moderate air quality, fair quality, poor quality, very poor quality and dangerous. In case all parameters at one monitoring site have individual index $q_i < 1$, the hierarchical rating scale has only 2 levels: no pollution (good quality) and pollution border (moderate quality).

When taking 4 parameters into account, values of $RAPI_h$ ranged from 0.17 to 0.9. Calculation results have shown that the ambient air at most of selected monitoring sites in industrial zones and clusters in Hanoi in Oct – Nov 2020 was at pollution border with a proportion of 68/116, accounting for 58.62% while there was no pollution detected at the remaining 48 monitoring sites. Values of RAPI ranged from 0.17 to 0.9.

In addition, it should be emphasized that in the calculation of $RAPI_h$, weighing factors are calculated for all survey parameters following the country's environmental standards. Also, the evaluation threshold and the hierarchical rating scale are scientifically based as they are developed based on mathematical conditions having physical meaning. The $RAPI_h$ index is integrated from separate subgroups of individual indices (P_m and P_k). Therefore, when being considered together with individual indices, it will indicate which parameters exceed the permissible standards excessively and need to take appropriate technological measures for mitigation.

RECOMMENDATION

Additional monitoring of two parameters PM_{10} and $PM_{2.5}$ should be conducted to obtain data for RAPI index calculation of the study area.

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