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Kinetics of low level chemiluminescence from plant leaf smoked by air pollutants

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Abstract—The kinetics of low level chemiluminescence from Chinese white polpar leaf smoked by CO and two gaseous mixture of SO_2 and CO or SO_2, NO_x and CO, and their luminescence intensity formula were described. The comparison of the results indicated that three kinds of the gaseous compounds could cause no changes of the substantial nature of foliar biophoton emission. However, they made the luminescence intensity, including $Io^{(1)}$ and $Io^{(2)}$, altered in a certain degree, and the changes caused by the fumigation of CO and the mixed gas of SO_2 and CO were different from that made by the gaseous mixture of SO_2, NO_x and CO in τ' and τ'' of the photo-induced luminescence from plant leaf.

Keywords: kinetics; low level chemiluminescence; plant leaf; air pollutants.

1 Introduction

In our previous paper, the changes of low level chemiluminescence spectra from plant leaf smoked by air pollutants have been described (Wang, 1993a; 1993b). The kinetic process of low level chemiluminescence and its alteration due to the induced plant leaf by air pollutants, this work being further study, will be observed in the same experimental conditions as reported from the reference cited above. The results of this observation might be considered to be valuable for understanding the nature of low level photon emission from plant leaf, the dependence with the time in the course of air pollutant action and, correspondingly, the changes of various parameters from folair chemiluminescence. In addition, it would have benefit for establishing a rapid, simple and sensitive biochemiluminescence technique for the air pollution monitor.

2 Materials and methods

Leaf of Chinese White Polpar (*Polulus tomentosa* C) was chosen as a bio-indicator (Wang, 1991). The period of this observation was May-August, 1993, and the situation was at Western suburb in Beijing. All measurements were conducted with model intelligence low level luminescence measurement system (Made in China). Graphic calculation of the experimental data was given (Wang, 1990; 1991).

3 Results and discussion

Fig 1 shows the kinetic curves of low level chemiluminescence from the leaves of white polpar

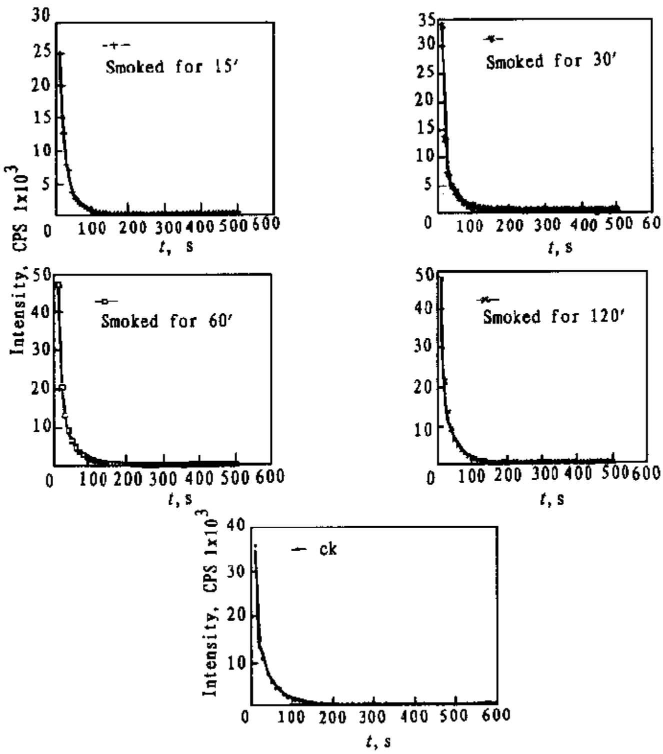

Fig. 1 Kinetic curves of chemiluminescence from leaf smoked by CO

CK: unsmoked, control group

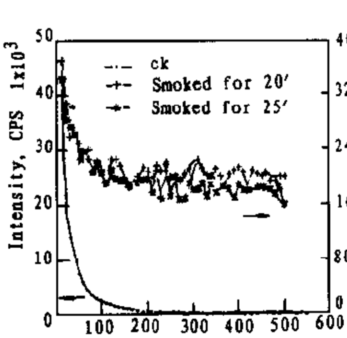

Fig. 2 Kinetic curves of chemiluminescence from leaf smoked by SO_2 and CO

CK: unsmoked, control group

exposed by CO, one of the common air pollutants, in five smoked times of 0, 15, 30, 50 and 130 min, respectively. Fig. 2 shows the kinetic curves of low level luminescence from the leaves smoked by the mixed gases of SO_2 and CO in the smoked times of 0, 20 and 25 min. The kinetic curves in Fig. 3 represent the luminescence-time curves process from the leaves exposed by the gaseous mixture of SO_2, NO_x and CO, three common air pollutants, in fourteen smoked times of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120 and 130 min, respectively. From the analysis of three curves, they are similar in the line-shaped each other showing a fast decrease component and a slow decrease component. Thus, it is evident that neither the single gas of CO nor the gaseous mixture of

SO_2 and CO or SO_2, NO_x and CO, as comparison to the unsmoked, control group, exert the appreciable effect on the nature of low level photon emission, and also there exists no dependence of the fumigation time, in the luminescence intensity, however, there are a various differences between the groups of the leaves smoked and unsmoked. For instance, the fumigation of CO in 15, 30 min, and SO_2 120 min cause little changes of intensity compared with the control, showing the curves of four smoked leaves and the control basically replicate each other. When smoking with the gas mixture, the kinetic curves of the leaves smoked by SO_2 and CO or SO_2, NO_x and CO are very higher than that of the control, except that the curve for 10 min fumigation is to approximate to the control and one for 30 min is lower than that of the unsmoked.

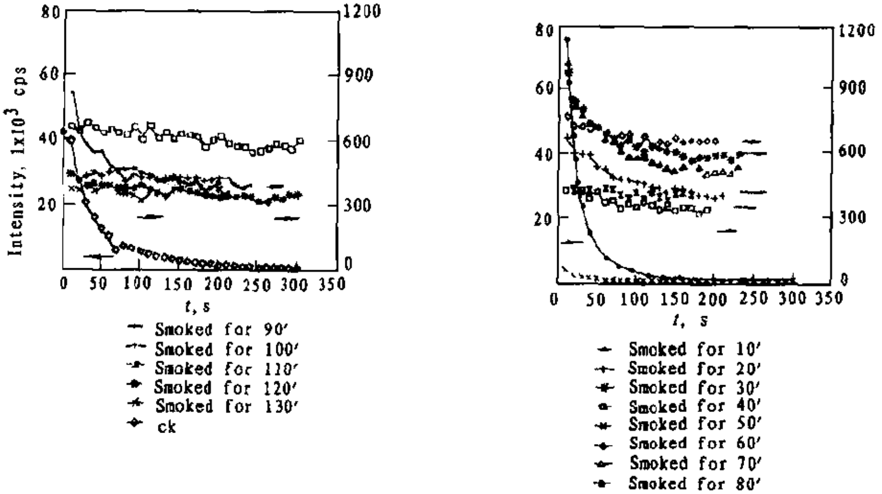

Fig. 3 Kinetic curves of chemiluminescence from leaf smoked by SO_2, NOx and CO

CK: unsmoked, control group; ←: ordinate on the left; →: ordinate on the right

To demonstrate the effect of air pollutants on the dynamic process of low level chemiluminescence intensity is further analyzed. As is well known, the luminescence intensity formula can be derived

$$I = Io^{(1)}(k_1 e^{-t/\tau'} + k_2 e^{-t/\tau''}) + Io^{(2)},$$

where, I is the low level luminescence intensity; $Io^{(1)}$ is the primary intensity of the foliar photon emission, the formula of photo-induced luminescence; $Io^{(2)}$ is the luminescence intensity caused with the biochemical metabolism; τ is the life(s) of the photo-induced luminescence; τ', τ'' are the two exponential attenuation components of the fast phase and the slow phase in the life, respectively; k_1, k_2 are the attenuation rate constants of two components; e is the base of natural logarithm.

Formula in Table 1 are obtained from the kinetic curves in white polpar leaves smoked and unsmoked (the control) by CO, SO_2 and CO or SO_2, NO_x and CO in a manner that applies the graphic calculation (Wang, 1990; 1991). In comparison to the control, I, including $Io^{(1)}$ and $Io^{(2)}$, caused by CO go on increasing of the smoked time and that this effect is enhanced when SO_2

participating in the fumigation. It is much the same to the change of I from the leaves smoked by SO_2, NO_x and CO. Io of two I parts in the formula seen to exhibit on ecotoxicological sense for the effect of air pollutants on biophoton emission. This is because there is the close relationship of Io with the biochemical process, for example, photosynthesis, oxidation, detoxification and so on (Slawinska, 1985a; 1985b). And so it is indicative of a certain interfere of air pollutants on the foliar metabolism, although it does not change the substantial mechanism of low level chemiluminescence from leaf.

Table 1 Analysis of the kinetics of low level luminescence from the plant leaf exposed by various air pollutants in the different smoked times

Type of gas	Time, min	Formula of low level luminescence intensity	τ	τ'	τ''
Control	0	$I = 42500\ (0.988e^{-t/31} + 0.081e^{-t/720}) + 500(\text{cps})$	720	31	23
CO	15	$I = 25000\ (0.980e^{-t/20} + 0.010e^{-t/2600}) + 250(\text{cps})$	2600	20	30
	30	$I = 11200\ (0.972e^{-t/50} + 0.028e^{-t/1820}) + 320(\text{cps})$	1820	50	36
	60	$I = 18000\ (90.986e^{-t/39} + 0.014e^{-t/2570}) + 350(\text{cps})$	2570	39	91
	120	$I = 16800\ (0.985e^{-t/39} + 0.015e^{-t/2570}) + 260(\text{cps})$	2570	39	
SO_2 + CO	20	$I = 420\ (0.656e^{-t/65} + 0.334e^{-t/1980}) + 220(\text{cps})$	1980	65	30
	25	$I = 410\ (0.564e^{-t/60} + 0.357e^{-t/1920}) + 228(\text{cps})$	1920	60	32
$SO_2 + NO_x$ + CO	10	$I = 105000\ (0.999e^{-t/15} + 0.010e^{-t/400}) + 1000(\text{cps})$	400	15	26
	20	$I = 680\ (0.584e^{-t/200} + 0.416e^{-t/895}) + 484(\text{cps})$	895	200	4
	30	$I = 10020\ (0.596e^{-t/85} + 0.404e^{-t/1752}) + 690(\text{cps})$	1725	85	20
	40	$I = 425\ (0.640e^{-t/275} + 0.481e^{-t/1100}) + 394(\text{cps})$	1100	275	4
	50	$I = 6800\ (0.507e^{-t/20} + 0.045e^{-t/420}) + 610(\text{cps})$	420	20	21
	60	$I = 790\ (0.530e^{-t/410} + 0.470e^{-t/1735}) + 700(\text{cps})$	1735	410	4
	70	$I = 1300\ (0.91e^{-t/40} + 0.380e^{-t/1735}) + 580(\text{cps})$	1735	40	43
	80	$I = 430\ (0.506e^{-t/470} + 0.494e^{-t/1485}) + 420(\text{cps})$	1485	470	3
	90	$I = 900\ (0.662e^{-t/30} + 0.338e^{-t/500}) + 460(\text{cps})$	500	30	16
	100	$I = 440\ (0.512e^{-t/1875} + 0.488e^{-t/2250}) + 420(\text{cps})$	2250	1175	1
	110	$I = 430\ (0.540e^{-t/360} + 0.460e^{-t/1640}) + 351(\text{cps})$	1640	360	4
	120	$I = 660\ (0.532e^{-t/1250} + 0.468e^{-t/3600}) + 580(\text{cps})$	3600	1250	3
	130	$I = 334\ (0.506e^{-t/2150} + 0.49e^{-t/4850}) + 326(\text{cps})$	4850	2150	2

From the luminescence-time curve, I, a life of the photo-induced luminescence contains two attenuatin components of τ' and τ''. τ', a component in rapid luminescence decay, is related to a photo-induced delayed luminescence and, τ'', a component in slow decay, is involved with both fluorescence and delayed photon emission, which are already available for rapid assay the environmental pollution, for instance, herbicide and their toxic intermediate (Slawinska, 1985a, 1985b). Table 2 lists the ratio of τ' or τ'' respectively to τ. The analysis of the unsmoked, control data shows that the photoemission in the fast phase decrease rapidly and almost linearly, containing no more than about 4.1% in the total life of the photo-induced luminescence. In contrast with this, the biological chemiluminescence in the leaves smoked by CO and the mixed gaseous of SO_2 and CO shows a tendency to minify τ' with the increasing smoked time, on contrary, to maximize τ''. Instead, the mixture of three air pollutants of SO_2, NO_x and CO makes τ' maximized with the increasing smoked time, on contrary, τ'' minified. A comparison with the results of SO_2 and CO mixture reveals that NO_x might be a main cause of the contrary effect above. Namely, the apparent inconsistency here may lie in the influence of both gaseous mixture on light induced luminescence process.

Table 2 Rate (%) between I' or I'' and I

Type of gas	Control	CO				SO_2 + CO	
Time, min	0	15	30	60	120	20	25
$\tau(\tau'+\tau'')$	751	2620	1870	2609	2609	2045	1980
τ'/τ, %	4.1	0.8	2.7	1.5	1.5	3.2	3.0
τ''/τ, %	95.6	99.2	97.4	98.5	98.5	96.8	97.0

SO_2 + NO_x + CO												
10	20	30	40	50	60	70	80	90	100	110	120	130
415	1195	1810	1375	440	2145	1775	1955	530	4125	2000	4850	7000
3.1	16.7	4.7	20.0	4.5	19.1	26.5	24.0	5.7	45.4	18.0	25.8	30.7
96.4	74.9	95.0	80.0	95.4	80.9	83.7	75.0	94.3	54.5	82.0	74.2	69.2

4 Conclusion

The kinetics of low level chemiluminescence-time curve in plant leaf to couple with their spectra as described in our previous paper (Wang, 1990; 1991; 1993) will be helpful of making a more accurate identification of air pollutants from the gaseous mixture in monitoring air pollution. Further to combine the foliar chemiluminescence intensity, as seen, the comprehensive assessment of air pollution will be possible to be conducted. Although the fact that there exist several problems for analytical application has yet to study, the biological chemiluminescence assay still is a new, developing technique with a potential prospects in the environmental protection, being possessed of rapidness, simplicity and sensitiveness as well as identification of the different compounds among the multiple hazardous gaseous chemicals.

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