

The changing prevalence of respiratory symptoms in atopic children in response to air pollution

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Summary

Following the promotion of anti-air pollution measures in steam power stations using crude oil, atmospheric concentrations of sulphur dioxide, nitrogen dioxide and suspended particulates have declined. These changes in atmospheric concentrations were accompanied by a decline in the prevalence of respiratory symptoms among schoolchildren living near the power stations. In analysing the correlation between air pollutant concentrations and the prevalence of respiratory symptoms, those with positive skin reactions to house dust extract (the positive group) showed a more significant correlation coefficient compared to those who had never had a positive skin reaction (the negative group). In addition, schoolchildren more heavily exposed to air pollutants showed the higher prevalence of respiratory symptoms than the others. With regard to the kind of air pollutants, both sulphur dioxide and nitrogen dioxide were more closely associated with the prevalence of respiratory symptoms than suspended particulates. This study has therefore demonstrated that the positive group is a useful population for monitoring the health effects associated with low-degree air pollution of gaseous agents.

Introduction

In general, air pollution predisposes atopic subjects to develop respiratory symptoms [1–3]. Specifically it has been demonstrated that inhaled sulphur dioxide and nitrogen dioxide have the potential to enhance allergic reactions in the lung [4,5]. Since house dust is the most common allergen for Japanese children [6], the positive group has been

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followed in order to observe how they would respond to air pollution associated with steam power stations using crude oil. The present study was aimed at investigating the possibility that the positive group represented a sensitive population for monitoring health effects of air pollution associated with steam power stations.

Materials and methods

Mass medical examination for schoolchildren aged 6–14 years living in the town of Awara-machi, a rural district of Japan, has been carried out in order to monitor health effects of the steam power station since 1972. The geographical detail of this town and its surroundings have been given in a previous report [1]. Most of the area is composed of flat paddy fields, and there are no major sources of air pollution, except for two steam power stations located in the neighbourhood. The first one (350,000 KWH) was commissioned in September, 1973, and the second one (250,000 KWH) in September, 1978. With regard to the concentrations of air pollutants at the centre of this town, the data on sulphur dioxide concentration (Conductometric analysis) and suspended particulates (Light scattering method) are available since 1971, and the data on nitrogen dioxide (Saltzman method) since 1974 [7]. The changes in the concentrations of these air pollutants are shown in Fig. 1. This town geographically consists of three parts; Aware (District I), Honjyo (District II) and Kitakata (District III). Districts I and II are located nearer to the power stations compared to District III. In general, although the data measured at the centre station represent the status of air pollution in this town, that in Districts I and II is more intimately reflected to the data measured at the centre than that in District III. There is another air pollution measuring station at the northern part of this town (District III) [7]. The data (District III) are shown comparing those at the town centre (Districts I and II) in Table 1. With regard to

Table 1. Changes in annual mean atmospheric concentrations of air pollutants in Districts I, II and III

Air pollutants	Districts	1971	1972	1973	1974	1975	1976	1977	1978	1979
Sulphur dioxide (ppm)	I and II	0.017	0.014	0.016	0.017	0.016	0.014	0.014	0.015	0.014
	III	NA	0.008	0.010	0.006	0.008	0.007	0.007	0.006	0.005
Nitrogen dioxide (mg NO ₂ /day/100 cm ²)	I and II	NA	NA	NA	NA	NA	NA	0.029	0.060	0.057
	III	NA	NA	NA	NA	NA	NA	0.020	0.043	0.040
Suspended particulates (mg/m ³)	I and II	0.030	0.020	0.030	0.040	0.030	0.030	0.030	0.034	0.035
	III	NA	NA	0.020	0.030	0.030	0.030	0.040	0.019	0.031

NA, not available.

nitrogen dioxide, the data with triethanolamine-guaiacol-sodium metabisulphite (TGS) filter paper method are only available at the station in District III since 1977. Therefore, corresponding data in Districts I and II were also accompanied. These data demonstrated that District III is less polluted than Districts I and II. Following Japanese custom, the figure for each year in Fig. 1 runs from April in the first year to March in the next year. Due to the promotion of anti-air pollution measures such as usage of crude oil of lower sulphur concentration, reduction of factory wastes through chimneys, etc. in the steam power stations since 1974, the concentrations of all these air pollutants except for suspended particulates are decreasing from year to year before 1978, when the second power station started operating. Since the steam power stations

are the major users of crude oil in this area, they might have contributed substantially to the peak hourly maximum value (the highest 1-hr concentration in the year) of sulphur dioxide in 1973 when the first steam power station started operating, and the increase in concentrations of these three air pollutants after operation of the second power station (Fig. 1). Based on air pollution parameters such as hourly maximum,

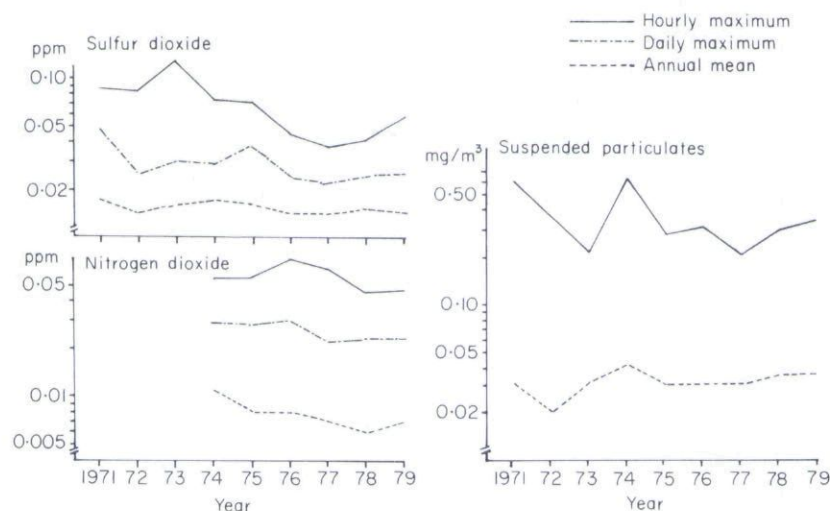


Fig. 1. Changes in atmospheric concentrations of air pollutants measured at the centre station in Awara-machi (The daily maximum suspended particulates concentration was not available).

daily maximum (the highest average 24-hr concentration in the year) and annual mean (average 1-hr concentration in the year) however, the area of the present study is still the least polluted in Japan [8,9]. According to the field survey on trees and plants spreading pollens which could cause allergic disorders, Japanese cedar and pine were widespread but *Ambrosia elatior* and *Solidago altissima* L. were not in this area, and no significant change in these habitats has developed [10]. Furthermore, there was found no significant difference in the number of airborne pollens among the Districts [11].

Mass medical examination of all schoolchildren in Awara-machi has been carried out every summer. The examination consisted of an interview questionnaire on respiratory symptoms standardized by BMRC (British Medical Research Council's Committee on Research into Chronic Bronchitis) [12], prick tests in which reactions greater than 5 mm for the weal and/or 15 mm for the erythema were recorded as positive (Research Committee for Scratch Test) [13] using house dust extract (Torii drug company) and lung function tests. Schoolchildren received an interview on respiratory symptoms and their family's smoking habit for the last year. In the case when the answer 'yes' was given to 1a (usual cough in the morning in the winter) and/or 3a (usual cough during the day or at night in the winter) of the questionnaire, the symptom was defined as subacute cough; when the answer 'yes' was to 6a (usual phlegm in the morning in the winter) and/or 8a (usual phlegm during the day or at night in the winter), it was defined as subacute phlegm; and when the answer 'yes' was to 15a (wheezing when having a cold), it was defined as wheezing. In addition to these definitions, any symptoms of respiratory disease which caused an absence from school

of over 1 week was also taken into account, and was presented in the present study as respiratory disease associated with absence. Schoolchildren who had a positive skin reaction at least once during the whole study period were classified as the positive group, and those who never had a positive skin reaction as the negative group. Seventy-two percent of schoolchildren in the positive group experienced a positive skin reaction every year. In analysing the correlation between the prevalence of respiratory symptoms and the concentration of air pollutants, Pearson's correlation coefficient was adopted. With regard to respiratory symptoms, a standardized prevalence ratio (SPR) adjusted indirectly for age and sex and based on the prevalence rate of schoolchildren in 1975 which is the middle point of years observed was used. The population examined every summer and the prevalence of respiratory symptoms in 1975 which is the basis for the calculation of SPR are shown in Tables 2 and 3.

Table 2. The number of schoolchildren interviewed every summer

Skin test group	District	Year								
		1971	1972	1973	1974	1975	1976	1977	1978	1979
The positive group	Total	451	304	360	373	648	687	701	671	625
	I and II	356	230	275	295	523	565	589	567	525
	III	95	74	85	78	125	122	112	104	100
The negative group	Total	999	809	737	737	886	884	864	932	979
	I and II	761	623	571	517	702	724	688	739	785
	III	238	186	166	220	184	160	176	193	194

Table 3. The prevalence of respiratory symptoms among schoolchildren in 1975

%	Male children age (years)			Female children age (years)		
	6-8	9-11	12-14	6-8	9-11	12-14
Subacute cough	6.0	2.2	0.0	7.2	4.3	1.2
Subacute phlegm	2.4	2.5	1.7	3.6	2.7	1.6
Wheezing	18.9	8.2	8.0	21.0	13.7	12.3
Respiratory diseases associated with absence	3.2	1.5	0.0	1.6	1.2	0.0

Results

The changes in SPRs for each respiratory symptom are shown in Fig. 2. All SPRs of the positive group were higher than those of the negative group except for subacute phlegm in 1971. SPRs for subacute cough and subacute phlegm for the positive group increased after 1973 when the first steam power station was commissioned, and besides the SPR of respiratory diseases associated with absence for the positive group showed a peak in this year. In addition, all respiratory symptoms of the present study increased their SPRs for the positive group after the second steam power station started operating, but it was not case for the negative group.

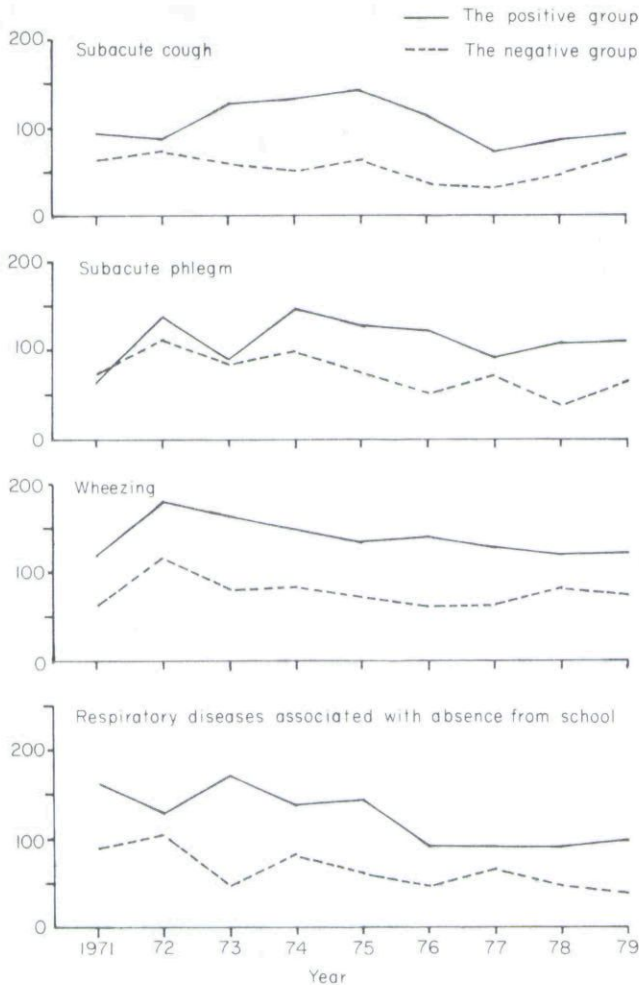


Fig. 2. Changes in SPR of respiratory symptoms for the positive and negative groups.

The correlation between SPR for each respiratory symptom and the concentration of air pollutant measured at the centre station has been investigated for both the positive and the negative group for the whole period of the present study. In this occasion, the correlation with the concentration of nitrogen dioxide was not investigated because its data were not available for the whole period. Although lag correlation coefficients for each lag order (K) were also calculated, only the case of $K=0$ showed some significant coefficients. Therefore, the correlation between the prevalence of respiratory symptoms and the concentration of air pollutant in the same year only was investigated. As shown in Table 4 and Fig. 3, SPRs for respiratory disease associated with absence of the positive group showed the most correlations of significance with sulphur dioxide concentration (Fig. 3a). With regard to the SPR for subacute cough, the positive group showed a significant correlation coefficient with the annual mean value of dioxide concentration, and the negative group with the hourly maximum sulphur dioxide concentration (Fig. 3b). With regard to the SPR for

Table 4. The matrix of correlation coefficients between the SPR for each respiratory symptom and concentration of air pollutant for the positive and negative group over the whole period and the period of air pollution control

		Air pollutants								
		Sulphur dioxide			Suspended particulate		Nitrogen dioxide			
		Hourly max.	Daily max.	Annual mean	Hourly max.	Annual mean	Hourly max.	Daily max.	Annual mean	
Respiratory symptoms										
Subacute cough										
The positive group	1971-79	0.37	0.25	0.67*	0.11	0.36	—	—	—	
	1974-79	0.84*	0.70	0.82*	0.53	0.19	0.20	0.87*	0.67	
The negative group	1971-79	0.72*	0.44	0.23	0.27	-0.31	—	—	—	
	1974-79	0.69	0.62	0.34	0.23	0.34	-0.66	0.02	0.08	
Subacute phlegm										
The positive group	1971-79	-0.11	-0.49	-0.17	0.03	0.07	—	—	—	
	1974-79	0.60	0.55	0.82*	0.84*	0.57	0.07	0.84*	0.86*	
The negative group	1971-79	0.68*	0.11	0.24	0.33	-0.32	—	—	—	
	1974-79	0.65	0.42	0.67	0.67	0.49	0.10	0.35	0.85*	
Wheezing										
The positive group	1971-79	0.56	-0.25	-0.07	-0.08	-0.50	—	—	—	
	1974-79	0.56	0.32	0.60	0.70	0.30	0.57	0.88*	0.93**	
The negative group	1971-79	0.42	-0.25	-0.16	0.01	-0.50	—	—	—	
	1974-79	0.48	0.25	0.66	0.56	0.67	-0.19	-0.14	0.20	
Respiratory disease associated with absence										
The positive group	1971-79	0.94**	0.74*	0.77*	0.38	-0.12	—	—	—	
	1974-79	0.94**	0.89*	0.87*	0.53	0.31	-0.10	0.55	0.69	
The negative group	1971-79	0.41	0.34	0.28	0.58	-0.45	—	—	—	
	1974-79	0.43	0.26	0.66	0.56	0.35	0.26	0.36	0.65	

(*: Significance at $P < 0.05$, **: at $P < 0.01$, —: Data on the concentration of nitrogen dioxide are not available from 1971 to 1973.)

subacute phlegm, the negative group only showed a significant correlation coefficient with the hourly maximum sulphur dioxide concentration (Fig. 3c). The SPR for wheezing of the both groups showed no significant correlation with sulphur dioxide concentration. No SPRs for respiratory symptoms of both groups showed a significant correlation coefficient with the concentration of suspended particulates.

During the period of air pollution control after 1974 in which three kinds of atmospheric pollutant concentrations are available at the centre station, the correlation between SPR for each respiratory symptom and the concentration of air pollutant has been also summarized for the both groups in Table 4. With regard to the SPR for subacute cough, the positive group only showed a significant correlation coefficient with the hourly maximum, and the annual mean sulphur dioxide concentration. For suspended particulates, neither the positive nor the negative group showed any significant correlation coefficient. For nitrogen dioxide, the positive group only showed significant correlation coefficients with the daily maximum concentration. With regard to the SPR for subacute phlegm, the positive group only showed significant correlation coefficient with the annual mean sulfur dioxide concentration.

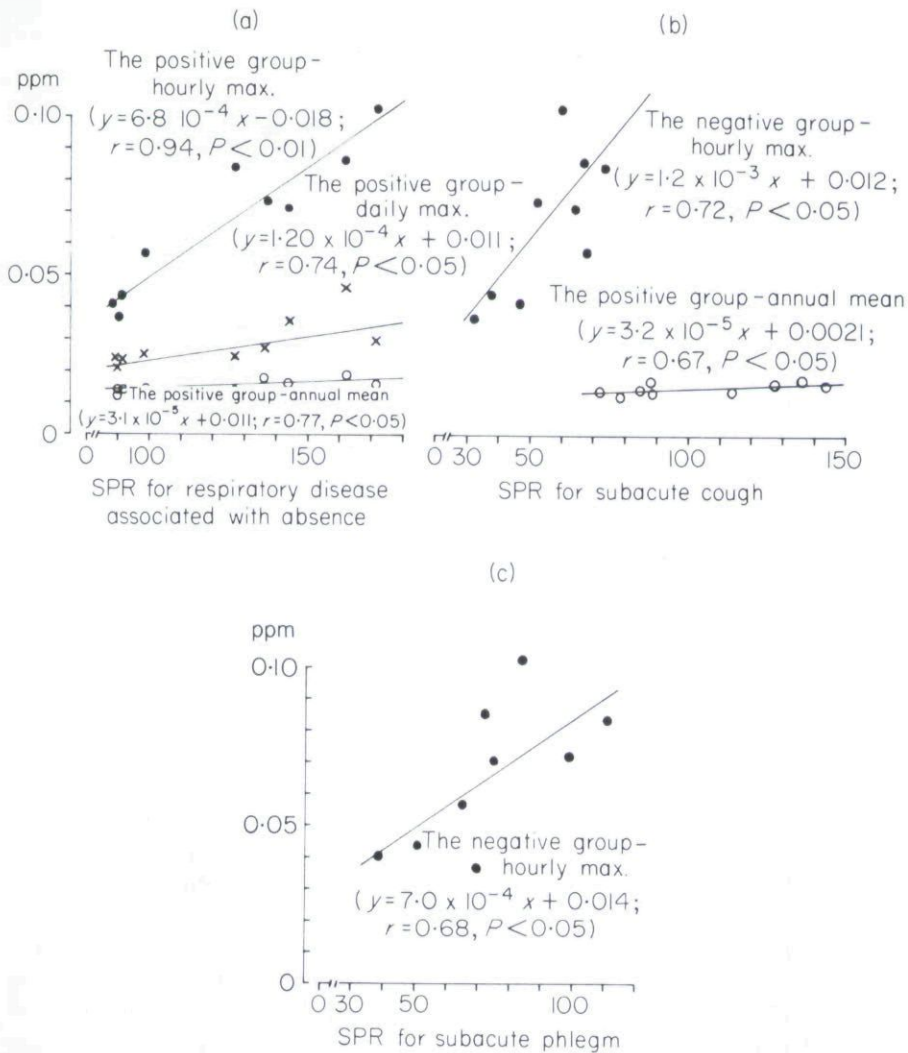


Fig. 3. The scattered diagram of correlation between sulphur dioxide concentration and SPR for respiratory symptoms 1971-79. (a) Respiratory disease associated with absence, (b) Subacute cough, (c) Subacute phlegm.

For suspended particulates, the positive groups only showed a significant correlation coefficient with the hourly maximum concentration. For nitrogen dioxide, the positive group showed significant correlation coefficients with the daily maximum and the annual mean concentration. On the other hand, the negative group only showed a significant correlation coefficient with the annual mean concentration. With regard to wheezing, the positive group only showed significant correlation coefficients with the daily maximum and the annual mean nitrogen dioxide concentration. With regard to respiratory diseases associated with absence, the positive group only showed significant correlation coefficients with the hourly maximum, the daily maximum and the annual mean sulphur dioxide concentration. The SPRs of respiratory symptoms by

Table 5. Mean SPRs and the 95% confidence limits of each respiratory symptom for the positive and the negative group in Districts I, II and III, 1971–1979

SPRs of respiratory symptoms	Skin test group	Districts	Mean (95% confidence limits)
SPR of subacute cough	The positive group	I and II	123 (112–135)
		III	88 (67–109)
	The negative group	I and II	60 (51–69)
		III	50 (37–63)
SPR of subacute phlegm	The positive group	I and II	116 (88–144)
		III	100 (76–124)
	The negative group	I and II	73 (58–88)
		III	77 (49–105)
SPR of wheezing	The positive group	I and II	159 (144–174)
		III	107 (97–117)
	The negative group	I and II	86 (78–94)
		III	59 (56–62)
SPR of respiratory disease associated with absence	The positive group	I and II	128 (89–167)
		III	58 (38–78)
	The negative group	I and II	68 (61–75)
		III	43 (29–57)

the skin test group were compared between schoolchildren in Districts I and II and those in District III. In general, as shown in Table 5, schoolchildren in Districts I and II more heavily exposed to air pollutants showed higher SPRs compared those in District III. In particular, the SPR of respiratory disease associated with absence showed great differences between Districts I and II and District III.

Changes in frequency of schoolchildren who reported at least one family member currently smoking were not significant between the positive ($79.8\% \pm 5.2$) and the negative group ($79.3\% \pm 3.5$) and between Districts I and II ($77.9\% \pm 2.5$) and District III ($80.2\% \pm 4.3$) during the period surveyed. Therefore, health effects of passive smoking to schoolchildren were not different between the two groups.

Discussion

It has already been demonstrated that positive skin reactors to common inhaled antigens have a predisposition to respiratory disorders associated with obstructive lung diseases such as persistent cough and phlegm, wheezing, dyspnea attack and etc. [14,15].

We have also reported that schoolchildren with positive skin reactions in the area of the present study continue to have a higher prevalence of subacute cough, subacute phlegm and wheezing [1]. Furthermore, the prevalences of their respiratory symptoms which have been observed for several years show a significant correlation with the degree of air pollution estimated by Japanese cedar (*Cryptomeria japonica*, D. Don) as a plant indicator sensitive to atmospheric sulphur dioxide [1]. Although, as mentioned in materials and methods, the area of the present study belongs to one of the least polluted areas from sulphur dioxide, suspended particulates and nitrogen dioxide

in Japan, the degree of injury to Japanese cedar was also demonstrated to reflect significantly the atmospheric concentration of sulphur oxides [1,16]. Therefore we have been interested in health effects of the atmospheric concentration of sulphur dioxide in this area.

Since the prevalences for subacute cough and subacute phlegm were significantly associated with changes in the concentration of sulphur dioxide when their correlation was analysed over the whole period and the period of air pollution control, present results confirm our previous findings [1]. With regard to subacute phlegm, although the prevalence for the positive group decreased responding significantly to the improvement of air pollution, it could not be concluded from the analysis of the whole period that the positive group show more intimate with the concentration of sulphur dioxide compared to the negative group. The discrepancy of these results between subacute cough and subacute phlegm indicate that the sensitive indicator of bronchial response to low concentration gaseous air pollutants is a subacute cough rather than a subacute phlegm among schoolchildren. The prevalence of more definite respiratory symptom (respiratory diseases associated with absence) which was higher during the early years of the study showed the most significant correlations with parameters of sulphur dioxide concentration only for the positive group. Therefore, these results indicate that symptomatic schoolchildren with the positive skin reaction increased the response to the air pollution, especially during the early years.

According to the observations made during the period of air pollution control, the prevalence of respiratory symptoms for the positive group decreased showing more significant correlations with the concentration of sulphur dioxide compared to the negative group. A similar finding was also obtained for the concentration of nitrogen dioxide. In addition, although a tendency to more smoking in the families living in the less polluted district would mitigate against finding differences, schoolchildren in the district more heavily exposed to air pollutants still showed higher prevalence of respiratory symptoms. Therefore, these correlations were demonstrated to include certain cause-effect relationships. In contrast with these two gaseous air pollutants, less significant correlation coefficients were observed between respiratory symptoms and the hourly maximum concentration of suspended particulates which also decreased during the period of air pollution control. According to observations made over both the whole period and the period of air pollution control, the concentration of suspended particulates has been demonstrated to contribute less to the development of respiratory symptoms than sulphur dioxide and nitrogen dioxide. However, we have reported that schoolchildren living in a factory district showed an improvement of respiratory symptoms and functions after dust collectors had been set up [17,18]. Further observation is required for the concentration of suspended particulates, especially for the annual mean concentration which did not clearly decrease after the promotion of anti-air pollution measures. Although many studies have shown a relatively poor association between respiratory symptoms and skin-prick reaction to common agents [19,20], we would recommend the use of the prick test with house dust extract for the longitudinal population-based survey on health effects of low-degree air pollution considering associated factors such as air-borne pollens, passive smoking etc.

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