Pulmonary Function Impairment Produced by Atmospheric Pollution*

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The inspired air may be polluted by a variety of factors ranging from personal air pollution, as cigarette smoking, to contamination of all the air in a locality as occurs in Los Angeles or the Tokyo-Yokohama area of Japan. The rapid expansion of industry, the use of synthetic chemicals and the increased use of the automobile have created many air pollution problems, so that the clean air supply in some areas may be more of a limiting factor for future growth than the water supply. This paper will be limited to a discussion of our studies on three types of air pollution and the effects of breathing such air on pulmonary function measurements. The types are: the Los Angeles smog, allergic types related to air pollution such as seen in Tokyo-Yokohama, and industrial exposures and cigarette smoking.

The effect of breathing Los Angeles smoggy air was studied extensively over a three-year period (1955-58) on both normal subjects and patients with chronic pulmonary disease. These studies consisted of spirometric, residual air and evaluation of intrapulmonary mixing with a nitrogen meter while breathing Los Angeles smoggy air, after which the subjects were kept in rooms where all the air was filtered over activated carbon to remove the smog. The function measurements were repeated after time intervals varying from two to four hours to as long as three days or more, breathing the filtered air. The residual air measurement was found to be the most sensitive test, and the second best test was the nitrogen washout with continuous recordings of each breath on oxygen breathing with the nitrogen meter. Changes observed for spirometric measurements of vital capacity, timed vital capacity and maximal breathing capacity were of smaller magnitude. In order to obtain the maximal benefits from breathing the filtered air, patients with significant pulmonary emphysema had to be kept in the filtered rooms for 40 hours or more. A decrease in the residual air and improvement in the intrapulmonary mixing was observed. No changes were observed in the function measurements after breathing the filtered air two to four hours, and even after 20 hours the improvement was minimal. In normal subjects, breathing smog produced no significant changes which were demonstrated by the function tests. In a few cases, the function studies were obtained on emphysema subjects first during non-smoggy periods (at least three days or more with no smog reported by the Los Angeles Air Pollution Control District), and follow-up studies were performed later during smoggy periods of at least two days duration. These studies also revealed significant changes, a further increase in the absolute volume of the residual air and a more marked prolongation of the nitrogen washout test with the nitrogen meter being noted when breathing smoggy air.

The studies indicated that breathing Los Angeles smoggy air aggravated the severity of the emphysema, and the response could be reversed by removing the smog from the air breathed, but with a delay in the disappearance of the adverse effects. The studies indicated a lag of two days or more in the onset of the maximal smog effect. The concentrations of the pollutants during...
the smoggy periods were below the first stage alert level of the Los Angeles Air Pollution Control District during most of the studies. However, low levels of air pollutants are important factors in the evaluation of smog effects on a long range basis, where the cumulative responses are unknown at present. Delayed responses have been observed clinically during acute episodes of air pollution, such as occurred in the Meuse Valley, in Donora and in London. The only treatment provided the subjects in the Los Angeles study was filtering the air with activated carbon to remove the smog, a procedure which effectively removes most of the pollutants except carbon monoxide. Ozone was the only pollutant to exceed the concentration for the first stage alert as set by the Los Angeles Air Pollution Control District. These physiologic studies do not enable one to state which substance or substances are most detrimental either singly or in combination.

The type of subjects that we have studied, for the most part, were the most sensitive segment of the population. Although we were not able to demonstrate significant changes from the breathing of smoggy air in normal individuals, this does not necessarily mean that damage may not be occurring. It is extremely difficult at the present time to know what the safe levels of air pollution are for any given substance, hence standards must be based on opinion, for proof is difficult. The fact that the evidence is not available cannot be interpreted to mean that no relationship exists, and that chronic pulmonary disease may not be further extended by the low concentration of pollutants which now exist much of the time in the Los Angeles area. For example, I don't think we have really good data on which to evaluate the effects of sulfur dioxide present in the Los Angeles area, although by present methods of measurements this pollutant exists at a lower level than is usually regarded hazardous, based on levels permitted in manufacturing plants. However, this may not be valid in evaluating the presence of a substance on a 24 hour basis that is breathed for seven days a week throughout the year. Reaction with other pollutants may obscure the total amount of sulfur dioxide, so that the usual measurement obtained reflects only in part the true level of air contamination by this substance.

In my opinion, smog that presently occurs in the Los Angeles basin is a serious health menace, and every effort should be made to diminish the amount of smog. It is very difficult to prove statistically one way or the other how many deaths may be attributed to smog or how much cumulative damage may be occurring at the present time, even in supposedly healthy normal individuals. The studies that have been done on Los Angeles smog indicate that serious problems could occur for the chronic pulmonary cripple during prolonged periods of adverse weather conditions with increased concentrations of pollutants.

Tokyo-Yokohama Asthma

An asthmatic type of bronchitis commonly called Tokyo-Yokohama asthma* and related to air pollution, has been reported as a major cause of sickness among the U. S. Armed Forces personnel in the Tokyo-Yokohama area of Japan since 1946. At the present time, it is estimated that approximately 4 to 6 per cent of all the military personnel in Japan from the United States become adversely affected by breathing the polluted air in the Kanto Plains, which includes the area in and around Tokyo and Yokohama, both highly industrialized regions adjoining a bay and surrounded by hills and mountains. The smog is most intense during the fall and winter months and during periods of no rain or wind. This smog tends to lie close to the ground and rarely rises above 1000 feet altitude. The industrial pollution in this area represents a completely uncontrolled situation as far as the stationary sources of air pollution are concerned. Even on a fairly clear day during a helicopter flight over the area in June, 1961, the extent of the air pollution was appalling. Studies on
molds, dust and plant extracts as desensitizing materials have been completely unsuccessful. Chemical studies of the atmosphere in this area have been limited. There are many automobiles in the area and the expansion of industry has been very rapid.

The most prominent symptoms in individuals affected are nocturnal cough, wheezing and shortness of breath. For the most part, there is a complete absence of a history of previous allergy. The most characteristic feature of the condition is the subsidence of symptoms when the patient leaves the area. Most of the Japanese living in the regions affected do not leave the area, so they do not have the type of control study seen in the American evacuated back to the United States. The condition is probably regarded as bronchitis in most cases. The pulmonary function studies performed by the Army at Camp Zama indicate persistent airway obstruction, elevated residual air and significant hypoxia. In the Tokyo-Yokohama type, there appears to be a definite allergic aspect for in numerous cases on returning to the area, there was a prompt recurrence of the previous symptoms, typically an allergic type of bronchitis. The symptoms usually disappear rapidly upon leaving the Kanto Plains area. The use of activated carbon air filters has been effective in the treatment of the Tokyo-Yokohama asthma in Army personnel during the past year (1962-63). Sensitization usually occurs in the first year in susceptible individuals. Bronchodilators are helpful, but the response is poor, on the whole, as compared to the typical asthmatic. Steroids give relief in the more severe cases, but such cases are usually evacuated back to the United States when this is necessary. One question to be answered is the potentiality of this condition producing significant emphysema if the individuals stay in the area too long. This aspect is being studied at the present time on individuals evacuated back to the United States after being incapacitated in the Kanto Plains area of Japan. Most of the individuals in the military affected by this allergic type of bronchitis were young people and previously healthy, except for cigarette smoking. Meteorologic studies revealed an increased turbulence of the air in 1962-63 as measured in a vertical manner, and the presence of less stable air as compared to previous years. The meteorologic conditions may account for differences in distribution of atmospheric pollutants from the heavy industrial areas to other regions. Stable air enhances the smog effect. The presence of less stable air the past season may have accounted for the lower incidence of Tokyo-Yokohama asthma observed in 1962-63.

Follow-up studies in 1962 on 244 cases who were returned to the United States revealed that 64 per cent still had abnormal air flow patterns, and in some, significant emphysema was present. The evidence seems to be increasing that emphysema may occur in susceptible individuals if they stay too long in the Kanto Plains area.

A recent survey was made of 40 subjects who had been back in the United States for two years or more. This group consisted of 31 men and nine women with an average age of 37. There was a history of cigarette smoking in all except one, with an average pack years of 16.2 (average one pack of cigarettes smoked daily for 16.2 years). The follow-up study revealed that after two years, nine of the patients felt completely well, one had died and the other 30 felt they were improved, but cough, wheezing and shortness of breath were still present. The average vital capacity of the group did not change significantly after two years away from Japan, Fig. 1A (average 3633 ml. in Japan and 3655 ml. after two years in the United States) although there was considerable variation for individual cases. The timed vital capacity for one second was still significantly decreased in most cases after two years, Fig. 1B. The average volume of the one second timed vital capacity was 65.9 per cent of the observed total vital capacity in Japan and 70.2 per cent after two years away (normal 80 to 85 per cent). There was no
Further decrease in the timed vital capacity after two years in the nine cases feeling completely well. The maximum mid-expiratory flow rate showed changes similar to those observed for the one second timed vital capacity, Fig. 1C.

The maximal breathing capacity (MBC) in liters per minute revealed the best overall improvement of the spirometric studies after two years in the United States, with an average value of 67.7 per cent of predicted in Japan and 80.9 per cent after being away two years, Fig. 1D. There was no further decrease in the MBC in the nine cases feeling completely well. The spirometric data indicate that significant abnormalities are still present two years after leaving Japan. Residual volume measurements of this group were not available before and after leaving Japan except in...
four cases. In three of this group, there was an increase and in one a decrease after leaving. More observations are needed on this aspect of the problem.

A somewhat similar type of allergic bronchitis was studied in 37 workers in a rubber industry in Los Angeles, where the introduction of two new substances (resorcinol and a complex synthetic chemical) in the manufacturing process was followed almost immediately by a marked increase in employee absenteeism due to incapacitating respiratory illnesses in long-term workers. The workers (27 men and ten women, average age 49 years, range 35-62) had a past history of very little loss of time. All workers in the industry were not affected, but there was a history of cigarette smoking in all except six cases, with an average pack year of 16. The affected workers apparently developed a sensitivity to the new chemicals employed, for on their return to work, the second attack was often worse than the first and frequently occurred in less than a week, necessitating further absenteeism. Some employees had to quit this work permanently. The symptoms consisted of cough, wheezing, dyspnea, thick tenacious secretions and often hoarseness. They responded slowly to treatment, but bronchodilators helped some. Antibiotics and steroids were given to some by different family doctors. Convalescence at home was slow, but eventually they felt well enough to return to work (for some after two to three months), but after a few days, recurrence of the above symptoms was common. Since elimination of the two substances in the manufacturing process, the problem has practically disappeared, except for a few of the most sensitive individuals (at present retired); these people still experience symptoms on visiting the plant even for a few hours.

The pulmonary function studies on the above group revealed significant airway obstruction in 27, even in some of the asymptomatic cases now working. The total vital capacity was normal in all except two (average 101.2 per cent of predicted)

The average timed vital capacity for three seconds was 90.0 per cent of the observed total vital capacity, with a significant prolongation in all cases except three. The timed vital capacity for 0.5 sec. was 47.5 per cent of the total observed vital capacity standing, and for 1.0 sec. 68.1 per cent (normal values 50 to 55 per cent for 0.5 sec. and 80 to 85 per cent for 0.1 sec.). The Wright peak flow measurement was abnormal in ten cases (average of the ten cases 270 liters per minute, normal values 450 liters or more per minute). The maximal breathing capacity was significantly decreased in 11 cases (average of the 11 cases 55.2 per cent of predicted) and after one bronchodilator treatment increased to 62.8 per cent of the predicted normal. Emphysema was not a factor (only one case had significant emphysema). Hypoxia of a moderate to severe degree was a consistent finding, and only two cases had normal arterial blood oxygen saturations both at rest and with exercise. The average saturation at rest was 91.3 per cent and 92.6 per cent with exercise. In 18 cases, the saturation was improved 2 to 4 per cent with exercise, decreased in two and in the others there was no significant change. The carbon monoxide diffusing capacity (steady state method at rest) was decreased in a significant manner in 16 of the cases (average 5.13, range 3.73-6.90, CO uptake, ml. per minute per mm. Hg alveolar pCO).

Cigarette smoking decreases compliance and increases the work of breathing in patients with severe emphysema. Even in essentially normal individuals, the smoking of one cigarette produces measurable changes in pressure volume relationships by compliance studies. (3) Studies on 19 cases of severe emphysema revealed a significant decrease in the arterial blood oxygen saturation after smoking one cigarette with a smoking device, which was used to insure the smoke getting into the lungs, Table 1. The arterial pO2 was decreased and the pCO2 increased by direct tension measurements, Table 1. In our experience from
studying many cases of severe obstructive pulmonary emphysema, when there was no past history of tuberculosis, asthma, hay fever or pneumoconiosis, a past history of heavy cigarette smoking was almost invariably obtained (over 99.5 per cent). Most of the servicemen that developed the Tokyo-Yokohama asthma were cigarette smokers, and very few cases have been observed in non-smokers. Cigarette smoking appears to be a factor in making some sensitive individuals more susceptible to air pollution. Phelps et al. feel that cigarette smoking sustains a persistent bronchial irritation along with the polluted atmosphere. Furthermore, cigarette smoking in itself is a factor by the damage produced on the respiratory epithelium. The persistent bronchial irritation with a damaged respiratory epithelium predisposes to chronic asthmatic bronchitis and eventually to emphysema.

**DISCUSSION**

The Los Angeles smog is a photochemical type as described by Haagen-Smit involving reaction of sunlight with nitrogen dioxide, sulfur dioxide, hydrocarbons and aldehydes which result in ozone formation, and set the stage for a complex series of chemical reactions. Ozone in a concentration of two parts per million was breathed by an essentially normal volunteer for two hours in a chamber. Spirometric measurements revealed a significant decrease in both the timed vital capacity and maximal breathing capacity. These measurements were still diminished after 22 hours, and accompanied by constrictive substernal chest pains, lack of coordinating ability and difficulty in expression and articulation. There was no eye irritation in the chamber from the ozone.

The investigations of the Los Angeles Air Pollution Control District indicate that at the present time, 75 to 80 per cent of the air pollution is from the automobile and 20 to 25 per cent from stationary sources. No coal is burned in the Los Angeles area, hence there is a big difference in the air pollution here, as compared to the Tokyo-Yokohama type or that in most other areas where soft coal is burned. This is particularly evident with respect to sulfur dioxide, soot and particulate matter. In Los Angeles, the stationary sources of air pollution are rigidly controlled, and the use is prohibited of all backyard incinerators and all open fire burning. In the Tokyo-Yokohama area, no such control exists. At the present time, in Los Angeles County, only natural gas is used by industry for seven months of the year and fuel oil for the five winter months, except when air pollution is bad and the Air Pollution Control District requests a fuel switch. Soot and particulates are high in the Tokyo-Yokohama area as compared to Los Angeles. Toyama, in a study of school children from two schools in Japan, one in a polluted area with heavy dustfall, revealed mean peak flow rates varying according to the level of the monthly air pollution, while in the other with a low dust fall, no such difference was found. The air pollution in the Tokyo-Yokohama area as it affects the military personnel appears to be an allergic type of bronchitis, and this is probably no different from air pollution in many other parts of the world. The management of affected cases by the military with the evacuation back to the United States provides an unique type of control not usually available in studies on air pollution.

An outbreak of asthma from air pollution has been reported from New Orleans. This was associated with the burning of dumps and of wind of low speed from the south and southwest, related to a poor combustion particle associated with silica. Chemicals used in the rubber industry have been demonstrated to produce an allergic

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<th>Table 1—Effect of Smoking One Cigarette on the Blood Gas Exchange in 19 Cases of Severe Emphysema</th>
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<td>Arterial Blood Oxygen Saturation %</td>
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*PULMONARY FUNCTION IMPAIRMENT*
type of bronchitis, similar in a number of respects to the Tokyo-Yokohama asthma, except that the amount of secretions was larger.

The Los Angeles smog aggravates the severity of emphysema as demonstrated by the increase in residual air and a more marked impairment in intrapulmonary mixing as shown with the nitrogen washout with a nitrogen meter. The changes were reversed by letting the subjects breathe air filtered over activated carbon for 40 hours or more. The use of treatment rooms with activated carbon filtered air has also been effective in the treatment of Tokyo-Yokohama asthma during the past year (1962-63). Two cases were studied in Los Angeles with a clinical history similar to the Tokyo-Yokohama cases, and pulmonary function studies revealed airway obstruction without significant emphysema. Since there is no control over the population in the Los Angeles area comparable to that of the military personnel in Japan, the incidence of an allergic type may be more of a problem than is at present realized.

Spirometric studies on 40 cases two years after leaving Japan revealed that significant abnormalities were still present. Spirometric and residual air measurements are not available for the most part on the Tokyo-Yokohama asthma cases before going to Japan; therefore the previous status of their pulmonary function is unknown. However, the reversibility of the Tokyo-Yokohama asthma appears less complete than was believed at first. More residual air studies are needed, but the evidence keeps accumulating that air pollution including personal air pollution from cigarette smoking plays a significant role in the development of emphysema. These studies on air pollution indicate the serious medical problem produced by air pollution at the present time, and the prospects of still further increase to come unless all possible measures are taken to decrease contamination of the atmosphere. The air supply is limited in many areas of the world.

Summary

1. The Los Angeles smog was found to aggravate the severity of emphysema by increasing the residual air and impairing still further air distribution in the lungs.

2. The Tokyo-Yokohama asthma type probably should be referred to as an allergic bronchitis, and this condition probably exists in many parts of the world. The control of the military personnel in Japan by the armed forces is unique, and this method of studying the effects of air pollution is not available in most other areas. Airway obstruction was a consistent finding, often associated with increased residual air and hypoxia. The present outlook is less favorable than at first thought regarding complete reversibility when the subjects stay too long in the Tokyo-Yokohama area after the condition has become manifest.

3. The use of treatment rooms with air filtered over activated carbon has been demonstrated to protect patients against air pollution in Los Angeles and in the Tokyo-Yokohama areas.

4. An allergic type of bronchitis was demonstrated in an industry from the introduction of two chemicals in the manufacturing process, and the clinical and physiologic findings in the sensitive patients were similar to the Tokyo-Yokohama asthma type.

5. Cigarette smoking (personal air pollution) irritates the bronchial epithelium and appears to be an important factor in rendering individuals more susceptible to allergic factors in air pollution. Cigarette smoking impairs the transfer of oxygen to the blood from the lungs in severe emphysema.

6. Air pollution has become a serious medical problem in many of the larger cities of the United States, and all possible measures should be taken to reduce the pollution from all sources and to prevent further increases.

Resumen

1. El "smog" de Los Angeles se ha encontrado que agrava el enfisema aumentando el aire resi-
dual y dañando más aún la distribución del aire en los pulmones.

2. El asma del tipo Tokio-Yokohama probablemente debe atribuirse a una bronquitis alérgica y esta afección probablemente existe en muchas partes del globo. El control del personal militar en Japón por las Fuerzas Armadas es único y este método de estudio de los efectos de la polución del aire no puede obtenerse en la mayoría de otras partes. La obstrucción de las vías aéreas fue un hallazgo constante, a menudo asociada con aumento del aire residual y de la hipoxia.

El presente estudio es menos favorable de los que primariamente se pensó respecto de la reversibilidad completa cuando las personas permanecen demasiado tiempo en el área de Tokio-Yokohama después de que se ha revelado la afección.

3. El uso de cuarto de tratamiento con aire filtrado a través de carbón activado ha demostrado que proteje a los enfermos contra la polución tanto en Los Ángeles como en Tokio-Yokohama.

4. Se demostró en la industria un tipo alérgico de bronquitis desde que se introdujeron dos materiales químicos en la manufactura y los hallazgos clínicos y fisiológicos en los enfermos sensibles fueron similares a los encontrados a los del asma de tipo Tokio-Yokohama.

5. El fumar cigarillos (polución personal del aire), irrita el epitelio bronquial y parece ser un factor importante que hace a los individuos más susceptibles a los factores alérgicos existentes en el aire. El fumar cigarillos dificulta el tránsito del oxígeno hacia la sangre de los pulmones en el enfisema avanzado.

6. La polución aérea se ha hecho un problema serio en muchas de las ciudades grandes de los Estados Unidos y todas las medidas posibles deben ponerse en práctica para reducir esa contaminación de todos orígenes y evitar que aumente.

**Resumen**

1. El autor a trouvé que la polución de l'air de Los Angeles augmentait la gravité de l'empyseème en accroissant l'air résiduel et en perturbant alors la distribution ultérieure de l'air dans les poumons.

2. L'asthme tel qu'on le trouve à Tokyo-Yokohama devrait être probablement rapporté à une bronchite allergique, et cet état existe probablement dans toutes les parties du monde. Le contrôle du personnel militaire au Japon par les Forces Armées est groupé en un centre unique, et cette méthode pour étudier les effets de la polution atmosphérique n'est pas utilisable dans la plupart des autres zones. L'obstruction des voies aériennes fut une constatation permanente, souvent associée à l'augmentation de l'air résiduel et à l'hypoxie. La perspective actuelle est moins favorable qu'au premier abord, en ce qui concerne l'entiére réversabilidad lorsque les individus séjourner longtemps dans la zone de Tokyo-Yokohama après que leur condition soit devenue manifeste.

3. L'emploi de salles de traitement avec air filtré sur du carbone activé s'est révélé protéger les malades contre la polution atmosphérique dans les zones de Los Angeles et de Tokyo-Yokohama.

4. On a mis en évidence une bronchite de type allergique dans une industrie depuis l'introduction de deux produits chimiques dans le processus de manufacture et les constatations cliniques dans et physiologiques chez les malades sensibles furent semblables à celles de l'asthme rencontré à Tokyo-Yokohama.

5. La fumée de cigarette (pollution aérienne personnelle) irrita l'épithélium bronchique et semble être un facteur important rendant les individus plus sensibles aux facteurs allergiques dans la polution atmosphérique. La fumée de cigarette perturbe le transfert de l'oxygène au sang pour les poumons atteints d'empyseème grave.

6. La polución de l'air est devenue un problème médical grave dans beaucoup de villes les plus importantes des Etats-Unis et toutes les mesures possibles devraient être prises pour réduire la polution à partir de toutes ses sources, et pour éviter ses augmentations ultérieures.

**Zusammenfassung**

1. Von dem Nebel in Los Angeles wurde nachgewiesen, daß er die Schwere eines Emphysems verstärkt durch Erhöhung der Residualluft und VerSchlechterung weiterer Luftverteilung in den Lungen.


3. Der Gebrauch von Behandlungsräumen mit gefilterter Luft über aktiver Kohle hat sich als Schutz erwiesen für die Patienten gegen Luftve-
runreinigungen in Los Angeles und dem Bereich von Tokyo-Yokohama.


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ASPHYXIA DUE TO HEMANGIOMA

Clinical features and necropsy findings are presented in an infant with asphyxia due to obstructing intratracheal infantile hemangiomas. This uncommon but basically curable lesion presents clinically as episodic respiratory obstruction with stridor, wheezing and retractions, and is frequently associated with hemangiomas elsewhere. Female infants are affected twice as frequently as boys and the patient is usually several weeks to several months of age.

Diagnosis is established by endoscopy which reveals the characteristic sessile, reddish-blue, soft, compressible lesion beneath the mucosa in subglottic or tracheal regions. Biopsy is generally contraindicated. The preferred therapy is small doses of x-radiation to hasten spontaneous regression, together with tracheostomy if necessary.