Pulmonary Effects of Ozone -generating Air Purifiers

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Air purifiers are marketed to asthmatics and others to improve breathing. However, some air purifiers emit harmful ozone-a key component of smog. This study examines the hypothesis that ozone-generating air purifiers and other household devices that generate ozone may have a negative effect on pulmonary function. According to a recent study by the California Air Resources Board, 10% of California households own an air purifier that may produce ozone. No published studies on the direct pulmonary effects of these air purifiers have been found on Medline. The investigator used an ozone sensor to measure the amount of ozone generated from several types of air purifiers, food purifiers, and assorted ionizing household devices in a home environment. A room air purifier, personal air purifier, and food purifier, respectively, produced concentrations of ozone near the device of approximately 15 times, 9 times, and 3 times higher than a Stage 3 Smog Alert (range of error ?20%). A microspirometer was used to measure pulmonary function before and after exposure to each household device (range of error ?3%). A two-hour exposure to a room air purifier caused a statistically significant drop in an important measure of pulmonary function (FEV[sub] 1 /FVC) among asthmatic subjects, but not among the whole study sample (P< 0.05) (n=24). There was a mean decrease' of 11% in the FEV[sub] 1 /FVC ratio among the asthmatics. A three-hour exposure to a personal air purifier resulted in a statistically significant reduction in pulmonary function among the whole study sample, as well as in the asthmatic subset (P< 0.05) (n=10). The mean reduction in FEV[sub] 1 /FVC ratio among the whole study sample was 9.6%, while it was 22.8% among the asthmatics. One asthmatic individual experienced a 29% drop accompanied by a severe asthma attack. A food purifier resulted in a reduction in the FEV[sub] 1 /FVC ratio of 4.2 and 9.6% among the whole study sample and the asthmatic subset, respectively (P< 0.05) (n=32). Ozone-generating air purifiers and food purifiers that use ozone may impair pulmonary function.

Introduction

Although air purifiers are advertised to improve breathing, certain types of air purifiers emit harmful ozone. Some reports state that certain air purifiers produce ozone in amounts about two times higher than the California state outdoor health standard for ozone.[sup] [1] This would be equivalent to having a first Stage Smog Alert inside a home, 24 hours, seven days a week. Though there have been reports on how much ozone ionic air purifiers produce, Medline searches did not show any published studies on the direct effect of ozone-generating air purifiers or other ozone-generating household devices on pulmonary function. The purpose of this research is to clarify the pulmonary effects of ozone-generating air purifiers and other ozone-generating household devices.

Although indoor air pollution receives relatively little attention, the California Air Resources Board estimates that the overall indoor levels of air pollutants are often 25-62% greater than outdoor levels.[sup] [2] Ozone is one of the principle components of smog. It is a strong oxidant that oxidizes respiratory tissue causing inflammation similar to sunburn. Asthma is a disease of inflammation, so ozone is especially serious for the over 16 million asthmatics in the United States.[sup] [3] Many air purifiers are specifically marketed to individuals with asthma and allergies; the very people who are most sensitive to the harmful effects of ozone. In fact, Americans spend more than $350 million each year on air purifiers.[sup] [4]

There are three basic methods of air purification: (1) filtration through filters, e.g. HEPA filtration, (2) ionization of the air and electrostatic precipitation of the charged particles onto metal electrodes, and (3) ozonolysis of air impurities. Many ionizing and ozonolysis type air purifiers produce ozone either intentionally or unintentionally as a byproduct of air ionization. [sup] [5] A recent study conducted by the California Air Resources Board showed that 10% of California households own an air cleaner that may produce ozone, placing approximately 828,000 Californians at risk.[sup] [6] Many other ionizing household devices may also create ozone unintentionally.

United States federal government regulations do not require air purifiers to meet ozone limits. Neither the United States Food and Drug Administration, which regulates only what it considers medical devices, nor the federal Environmental Protection Agency, which regulates only outdoor air, have regulatory standards for indoor air purifiers. To remedy this regulatory gap, the California legislature passed the legislation in September, 2006, that gave the California Air Resources Board (CARB) the authority to adopt a regulation.[sup] [7] The data generated from this study were shared with CARB as they wrote a proposal for a regulation to limit ozone emissions from air purifiers to less than 0.050 parts per million (ppm). The investigator presented the data at the public hearing of the CARB on September 27, 2007. At the hearing, CARB adopted the first regulation in the nation to regulate ozone emissions from air purifiers.

Ozone irritates the respiratory system, and can cause coughing, shortness of breath, and chest pain. It also reduces lung function, causes bronchospasm, and aggravates asthma. Ozone causes inflammation and makes the respiratory epithelium more permeable, so an asthmatic might react to a lower dose exposure of an allergen. In addition, ozone aggravates chronic lung disease.[sup] [8] Recent studies have shown worrisome evidence that even small increases in outdoor ozone exposure are associated with increased risk of premature mortality, even when the levels are still within the current US Environmental Protection Agency's standards.[sup] [9]

In light of the plethora of negative effects that ozone has on the respiratory system, the investigator hypothesized that ozone-generating air purifiers would have a negative effect on pulmonary function, especially in people with asthma and allergies. Additionally, she also

hypothesized that other ionizing household devices that produce ozone would have a similar effect.

To test pulmonary function, the following common, quantifiable, and objective measures were tested before and after exposure: (1) forced expiratory volume in one second (FEV[sub] 1)-a measure of how fast a person can blow out, (2) forced vital capacity (FVC)-a measure of the largest volume a person can blow out, and (3) the percent oxygen saturation (O[sub] 2 sat.) of the blood. The FEV[sub] 1 /FVC ratio was selected as the primary focus of this study, because the American Thoracic Society states that it is "the most important parameter for identifying an obstructive impairment in patients."[sup] [10]

Materials and Methods

The investigator designed and executed eight experiments over a period of two years to test her hypothesis that the ozone-generating devices tested would have a negative impact on pulmonary function. (See [Table 1].) In experiment A, the concentration of ozone produced by several ozone-generating air purifiers was measured at various distances. The amount of ozone produced by each device was measured with an ozone sensor made by Eco Sensors, Inc., Model A-21ZX, which detects ozone from zero to 10 ppm and has a range of error of[+ or -]20%. This particular device was calibrated by Eco Sensors, Inc. immediately prior to the beginning of the experiment.

The amount of ozone produced by each ozone-generating air purifier was measured close to the source, six inches from the source, and one foot from the source. In addition, the Brand #1 room air purifier was tested at two, three, four, and five feet away from the source. The measurements were done consecutively each hour, starting from the closest distance. Each machine was tested with the ionizer set on the highest level for use with people present. Brand #2 was also tested at a higher level called the "away setting," which is intended for use when people are not at home. The testing was done under typical conditions, in a carpeted living room rather than in a Plexiglas testing chamber, in order to simulate real-life conditions.

In experiment B, the concentration of ozone produced by the following devices was measured: Brand #1 Ionizing Bathroom Air Purifier with night light, Brand #2 Ionizing Bathroom Air Purifier, Ionizing Car Air Purifier, Brand #1 Food Purifier, Brand #2 Food Purifier , Ionizing Blow Dryer, Ionizing Ceramic Hair Straightener, Ionizing Smokeless Ashtray, and Ionic Pet Hairbrush. Since the ASTM testing standard for measuring ozone produced by air purifiers is at a distance of two inches, these measurements were taken at two inches from the face of the device. For each test, the length of time and the testing location varied depending upon the device, in order to simulate average "real life" conditions. For instance, the hair appliances were tested in a bathroom after 10 minutes. The food purifiers were tested in a kitchen after completion of the heavy-duty cycle of approximately

23 minutes. The HEPA filter air purifier was tested in a carpeted living room after two hours. The ionizing smokeless ash tray was tested in a bathroom after two hours, and the car air purifier was tested after one hour in a car.

In all experiments involving human subjects, informed consent was obtained, and the study subjects filled out a health questionnaire. The study subjects recruited were fellow students, friends, and relatives of the investigator. The ages of the study subjects ranged from 12 to 77 years of age. This research involving human subjects was conducted under the supervision of an experienced researcher, Karen Jakpor, MD, MPH, and followed state and federal regulatory guidance applicable to the humane and ethical conduct of such research. A school reviewed and approved the research proposal according to the procedures of the RIMS Inland Science and Engineering Fair.

Experiment C tested the effect of an ozone-generating room air purifier (Brand #1) at its highest setting on the FEV[sub] 1 /FVC ratios and oxygen saturations of 24 test subjects. Among the 24 test subjects were three subjects with asthma and one subject with chronic obstructive pulmonary disease (COPD). For simplicity, the subset of patients with obstructive lung disease (either asthma or COPD) will be referred to as the "asthmatic subset" (although it included one subject with COPD). To simulate real life conditions, test subjects were permitted to walk around freely for approximately two hours in the carpeted living room of a house while the air purifier was running. Each subject's FEV[sub] 1 /FVC ratio was measured before and after exposure to the room air purifier by using a Micro Direct "Micro" spirometer made by Micro Medical Ltd. This instrument has a range of error of[+ or -]3%. Spirometry was performed in the standard fashion. Each subject's oxygen saturation was measured using a Nonin Onyx 9500 Pulse Oximeter, which has a range of error of[+ or -]2%.

Experiment D tested the effect of a personal air purifier that hangs around the neck on the FEV[sub] 1 /FVC ratios and oxygen saturations of 10 test subjects, before and after wearing a personal air purifier for three hours. This study group included three asthmatics and one subject with COPD. One subject with severe asthma was tested every 15 minutes as a pilot test before any of the other subjects were tested.

Experiments E, F, G, and H tested the pulmonary effects of (1) a HEPA room air purifier that does not produce ozone, (2) the Brand #1 food purifier, (3) an ionic hair blow dryer, and (4) a regular non-ionic blow dryer. The numbers of study subjects in experiments E, F, G and H were 28, 32, 23, and 16, respectively. The numbers of these study subjects with obstructive lung disease (either asthma or COPD) in experiments E, F, G and H were 5, 11, 6, and 3, respectively. In experiments C through H, each subject served as his or her own control as pre-exposure and post-exposure measurements for each subject were compared. Experiments E and H were also additional group control studies, performed to make sure that the non-ionic equivalents of the ionic devices tested had no adverse pulmonary effects, and that possible psychological effects of being tested were taken into consideration.

Statistical analysis with a Student's Paired T-Test was performed in all the experiments measuring changes in pulmonary function. First, the change in each subject's FEV[sub] 1 /FVC ratio was calculated. Then the mean change in FEV[sub] 1 /FVC ratio was calculated. Next, the standard deviation, standard error of the mean, two times the standard error of the mean, and 95% confidence intervals were determined. Standard deviation and standard error of the mean are both statistical terms which indicate how variable or spread out the data are from the mean. Standard error of the mean is the most appropriate measure when dealing with a study sample rather than the entire true population. The 95% confidence intervals indicate a range of plausible values, and means that there is only a five per cent chance that the true mean (as opposed to the mean of the test sample alone) falls outside of the confidence interval, and the sample results are a fluke. A statistical calculator found online at www.mathisfun.com was used to determine the standard deviation and mean, but the standard error of the mean and the 95% confidence intervals were manually calculated. The mean change in the ratio and the 95% confidence intervals are included on the graphs. The statistical analysis of the oxygen saturation readings was performed in the same fashion.

The mean of the group's FEV[sub] 1 /FVC ratio before exposure and the mean of the group's FEV[sub] 1 /FVC ratio after exposure were also calculated, in order to determine the overall percentage drop in FEV[sub] 1 /FVC ratio. However, the statistical analysis to calculate standard error of the mean was performed by pairing each individual's pre-test and post-test data, since that is a stronger statistical test, making it more likely that the hypothesis would be rejected if it were incorrect.

Results and Discussion

In experiment A, the amount of ozone produced by Brand #1 Air Purifier was measured at distances up to five feet. (See [Table 2].)

Next to the grill of the air purifier, the ozone concentration was highest-7770 parts per billion (ppb), which is approximately 86 times higher than the outdoor California ambient air quality standard for an exposure time of one hour (90 ppb). For perspective, Stage 1 Smog Alert is issued when the outdoor ozone level is at or above 200 ppb, stage 2 at 350 ppb, and stage 3 at 500 ppb.[sup] [11] The ozone concentration of Brand #1 near the source was approximately 15 times higher than the level of even Stage 3 Smog Alert. This unexpectedly high result was not a measurement error, and was verified a second and third time.

Though the concentration of ozone near the grill of the air purifier was very high, the level quickly dropped off with distance. As seen in [Table 2], a distance of five feet the amount of ozone was undetectable. This can probably be explained by the fact that ozone is a highly reactive molecule that reacts with other substances in the room, such as the carpet.

This experiment was not performed in a small sealed plastic room such as those used in some industry tests for voluntary standards; sealed plastic rooms do not simulate real life conditions. To simulate typical conditions, this experiment was conducted in an ordinary carpeted living room with people talking and moving about. Perhaps air currents might have caused fluctuations in the measurements. These values should be viewed only as a general indication of the amount of ozone generated, since the test conditions were not ideal and the ozone sensor itself had a range of error of[+ or -]20%. It is possible that in a smaller room without carpet and a longer testing time, the accumulation of ozone in the room might be greater.

It is important to keep in mind that exposure to ozone can be extremely varied in real life situations. There are, for example, some people who make a point of keeping their ozone-generating air purifiers on their bedside Tables, less then two feet away from their faces while they sleep for eight hours; or on their computer desks next to them as they work throughout the day. Some photographs in advertisements for such air purifiers suggest this dangerous manner of placement for their products.

In addition to distance, factors such as various fabrics in the room may play a part. For instance, ozone reacts with carpet and other substances to create a multitude of other potentially hazardous known and unknown chemical reaction products.[sup] [12] Although the ozone levels dropped off very quickly, the ozone reaction products were probably increasing, and these have unknown effects.

The concentration of ozone dropped off similarly in the tests of other ozone-generating air purifiers [Table 3].

It should be noted that the personal air purifier also generated an extremely high level of ozone at its mouth: 4740 ppb, which is approximately 53 times higher than the outdoor California ambient air quality standard for an exposure time of one hour. This level is more than nine times higher than the level of a Stage 3 Smog Alert. Under typical conditions, this personal air purifier is actually run at about six inches from the face, so it is of particular concern that the amount of ozone generated at six inches is 70 ppb. To put that in perspective, 70 ppb is the California ambient air quality standard for an exposure time of eight hours.

The concentration of ozone produced by the devices measured in experiment B was significantly lower than the concentration of ozone produced by the ozone-generating air purifiers tested in experiment A, with the exception of the open food purifier [Table 4].

Please keep in mind that the ozone sensor may not be accurate at measuring very low levels of ozone, such as levels below 20 ppb.

The Brand #1 food purifier contained the ozone fairly well during the washing of the potatoes on the heavy disinfection cycle. However, when the lid was opened in order to remove the potatoes at the completion of the wash, very high levels of ozone were released [Table 5]. These high levels declined over time but still stood at 30 ppb after five minutes.

Experiment C tested the respiratory effects of a two-hour exposure to Brand #1 Room Air Purifier on 24 subjects. The effect of the room air purifier on the FEV[sub] 1 /FVC ratio is shown in [Figure 1].

The room air purifier had no statistically significant effect on the whole study sample of 24 subjects. This is not surprising, considering that many of the subjects were at times moving beyond five feet from the room air purifier. As mentioned earlier, experiment A showed that the concentration of ozone produced by Brand #1 was undetectable at distances at or beyond five feet.

Because individuals with obstructive lung disease (such as asthma and chronic obstructive pulmonary disease) are sensitive to ozone at lower levels than other individuals, a subset analysis was performed on the subjects who had obstructive lung disease. Even with a small sample size, there was a statistically significant drop in the FEV[sub] 1 /FVC ratio among the asthmatic subset (P< 0.05). The mean of the changes in each subject's FEV[sub] 1 /FVC ratio was reduced by -0.070[+ or -] 0.023 among the asthmatics. Another way to look at this is to compare the mean FEV[sub] 1 /FVC ratio before and after exposure. As seen in [Table 6], the mean FEV[sub] 1 /FVC ratio among the asthmatics dropped by 11%.

Experiment D tested the respiratory effects of a three-hour exposure to a personal air purifier on 10 subjects. [Figure 2] shows the effect on the mean of the subjects' delta FEV[sub] 1 /FVC ratio in this experiment.

The mean change in the FEV[sub] 1 /FVC ratio in the whole study sample after exposure to a personal air purifier was -0.076[+ or -] 0.066. This reached statistical significance (P < 0.05). An FEV[sub] 1 /FVC ratio of less than 0.70 is a marker that physicians use to help identify patients with obstructive lung disease (asthma or chronic obstructive pulmonary disease). A fall of 0.076 was enough to drop some subjects' FEV[sub] 1 /FVC ratios into this range. This is an important finding.

It is interesting to note that the drop in the FEV[sub] 1 /FVC ratio with the personal air purifier was significant in the whole study sample, despite the fact that it was not significant with the room air purifier. This is likely because in the case of the personal air purifier, the generator of ozone was consistently about six inches from the face for an extended period of time, so the subjects were exposed to a higher concentration of ozone.

The mean change in the FEV[sub] 1 /FVC ratio in the asthmatic subset in experiment D was -0.178[+ or -] 0.084. (See [Figure 2] above.) This was also statistically significant (P< 0.05). The change was greater among the asthmatics than the general study sample. This was an

expected finding, since asthmatics are known to be more sensitive to the respiratory effects of ozone. Asthma is a disease of inflammation, and ozone causes inflammation of the respiratory tract. This test shows the effects within just 3 hours. Inflammation, however, might take a day or two to show its full effects on pulmonary function, as has been shown in studies of how asthmatics respond to outdoor smog. Delayed testing could be a topic for future research.

In [Table 7], the effects of the personal air purifier are shown in an alternative way, comparing the group's mean FEV[sub] 1 /FVC ratio before and after exposure.

The FEV[sub] 1 /FVC ratio in the whole study sample fell by 9.6%. The ratio of the asthmatic subset fell by 22.8%. This is especially worrisome because the people in the asthmatic subset had lower than average FEV[sub] 1 /FVC ratios to begin with. A fall of almost 23% in the FEV[sub] 1 /FVC ratio is definitely noteworthy. To put this fall in perspective, when physicians perform a specific inhalation challenge test to diagnose occupational asthma, they consider a fall of 15% in FEV[sub] 1 to be significant.[sup] [13]

[Figure 3] shows, in detail, the drop in the FEV[sub] 1 /FVC ratio of one subject with severe asthma while wearing the personal air purifier. This subject began with an FEV[sub] 1 /FVC ratio of 0.89 and was tested every 15 minutes over a period of three hours. The ratio began to drop after one hour of exposure, decreasing more rapidly as time went on. This was a pilot test and had originally been planned to go on for eight hours. However, the test had to be terminated at three hours, because a full-blown asthma attack occurred. By the next day the FEV[sub] 1 /FVC ratio had returned to baseline after multiple nebulized breathing treatments. At the point when the experiment was terminated, the FEV[sub] 1 /FVC ratio had fallen to 0.63, which represents a 29% fall from the starting point.

In light of the findings with this subject with severe asthma, the decision was made not to test any other subjects with severe asthma and to limit the exposure time to the personal air purifier to three hours. In fact, only one other subject with previously diagnosed asthma was knowingly tested, but his case was very mild. During the spirometric testing of this experiment, however, the investigator unexpectedly discovered two additional subjects, in year 1, with asthma who had previously been undiagnosed. Their physicians subsequently confirmed the diagnosis of asthma and placed them on medication. In year 2, two more previously undiagnosed subjects were found to have probable asthma/obstructive lung disease. Neither the investigator nor the supervising research scientist anticipated such a large effect on FEV[sub] 1 /FVC ratio, especially on the asthmatics of this study. The personal air purifier had been purchased through an allergy and asthma catalog. Also, one of the room air purifiers bore the "Seal of Truth" from the Asthma and Allergy Foundation of America. When the preliminary analysis showed evidence of a substantial negative effect on pulmonary function, the decision was made not to expand the number of subjects tested with exposure to ozone-generating air purifiers.

Both asthmatics and non-asthmatics experienced some symptoms during exposure to the personal air purifier, such as chest tightness, coughing, and eye, throat, and nose irritation.

See [Figure 4] to compare the changes in the FEV[sub] 1 /FVC ratios caused by each air purifier tested in both the whole study sample and the asthmatic subset.

The largest drop, by far, occurred in the asthmatic subset with the personal air purifier. The asthmatic subset exposed to the ozone-generating room air purifier experienced the next largest drop in FEV[sub] 1 /FVC ratio. There was a very slight drop in the asthmatic subset in the HEPA filter group. Though this change was statistically significant, it was probably too small to have clinical significance. A larger sample size of asthmatics would be required to ascertain if there is a true effect. It is conceivable that because asthmatics often have reactive airways, the process of blowing hard repeatedly into a spirometer to complete multiple pulmonary function tests might have had a small effect in of itself.

Experiment F studied the pulmonary effects of the Brand #1 ozone-generating food purifier. [Figure 5] shows a statistically significant reduction in FEV[sub] 1 /FVC ratio after a 23-minute exposure for both the whole study sample and the asthmatic subset.

[Table 8] shows the reduction in mean FEV[sub] 1 /FVC ratio at 4.17% among the whole study sample and 9.55% among the asthmatic subset. This food purifier generated high amounts of ozone that were released when the potatoes were removed at the end of the cleaning cycle.

In experiments G and H, neither the ionic or non-ionic blow driers caused any significant change in FEV[sub] 1 /FVC ratio among the whole study sample. (See [Figure 6].)

In experiments C-H there were no statistically significant changes in oxygen saturation among the whole study samples. (See [Figure 7].) Presumably a significant amount of bronchospasm, reflecting a larger decrease in FEV[sub] 1 /FVC ratio, would be required to affect oxygen saturation.

Conclusion

Although ionizing air purifiers are advertised to improve air quality and promote healthy breathing, some purifiers generate ozone in concentrations far higher than current State of California outdoor air quality standards. The ozone concentration dropped off quickly with distance--possibly because of the ozone reacting with carpet and other materials, perhaps creating byproducts of unknown safety.

The ozone-generating room air purifiers tested clearly showed no beneficial effects on the respiratory parameters that were measured. For asthmatics there was a clinically important negative effect on lung function, in contrast to the control tests with a non-ionizing HEPA filter.

The ozone-generating personal air purifier had an even greater negative effect, probably because there was a higher exposure to ozone in the immediate breathing zone. The personal air purifier caused an almost 10 % average reduction in the FEV[sub] 1 /FVC ratio for all tested subjects and an almost 23% reduction for the asthmatics in the group. In light of this evidence of a strong negative effect on lung function caused by the personal air purifier, perhaps the California Air Resources Board should consider tightening their new regulation to set a stricter ozone limit for personal air purifiers.

This study found that many ionic household devices, other than air purifiers, produced ozone. Unlike some air purifiers, most of these devices produced very low levels of ozone. A notable exception was the ozone-generating food purifier which, on opening, released an amount of ozone rivaling that of the ozone-generating air purifiers. The ozone-generating food purifier also had a negative effect on the pulmonary function of the test subjects, especially among the asthmatics. The new research on ozone-generating food purifiers further corroborates the pattern seen in my earlier findings with regard to ozone-generating air purifiers. This original research suggests that the California Air Resources Board should investigate a variety of other types of ozone-generating household devices and perhaps include them as well in their regulations. Federal regulation is also needed in the United States and in nations around the world to protect unknowing consumers from the pulmonary hazard of ozone-generating air purifiers.

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About the Author

Fifteen-year-old Otana Jakpor is a senior at Woodcrest Christian High School in Riverside, California. In April 2008, President Bush presented Otana with the President's Environmental Youth Award for EPA Region 9 at a White House ceremony in the Rose Garden. This award was given for her original medical research and public policy advocacy on the pulmonary effects of ozone-generating air purifiers. Otana presented her research findings at a California Air Resources Board public hearing on a proposed regulation for indoor air purifiers. The proposal passed and California became the first state in the United States to limit ozone emissions from air purifiers.

References

1. Indoor Ozone. Epidemiology in North Carolina. 3 Nov. 2005. North Carolina Department of Health and Human Services. Available from: http://www.epi.state.nc.us/epi/oee/ozone/indoor.html. [last cited on 2006 Nov 29].

2. Indoor and Outdoor Air Pollution. Lawrence Berkeley National Laboratory. Lawrence Berkeley National Laboratory. Available from: http://www.lbl.gov/Education/ELSI/pollution-main.html. [last cited on 2008 Jan 9].

3. Faststats Asthma. Centers for Disease Control and Prevention. Centers for Disease Control and Prevention. Available from: http://www.cdc.gov/nchs/fastats/asthma.htm. [last accessed on 2009 May 15]. [last reterived on 2006 Nov 29].

4. The Best Air Purifier Buying Advice. Find Product Reviews and Ratings from Consumer Reports. Consumer Reports, 2009. Web. Available from: http://www.consumerreports.org/cro/appliances/heating-cooling-and-air/air-purifiers/air-purifier-buying-advice/index.htm. [last cited on 2009 Aug 12].

5. Britigan N, Alshawa A, Nizkorodov SA. Quantification of Ozone Levels in Indoor Environments Generated by Ionization and Ozonolysis Air Purifiers. J Air Waste Manag Assoc 2006;56:601-10.

6. Piazza T. Survey of the Use of Ozone Generating Air Cleansers by the California Public. Air Resources Board. Jan. 2007. University of California, Berkeley. Available from: http://www.arb.ca.gov/research/abstracts/05-301.htm. [last cited on 2007 Jan 29].

7. California. Assembly Bill No. 2276. 29 Sept. 2006.

8. Ozone and Your Health. Available from: http://airnow.gov/index.cfm?action=static.brochure. [last cited on 2006 Nov 29].

9. Bell ML, Peng RD, Dominici F. The Exposure-Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations. Environ Health Perspect 2006;114:532-6.

10. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, et al. Interpretative Strategies for Lung Function Tests. Eur Respir J 2005;26:948-65.

11. Britigan N, Alshawa A, Nizkorodov SA. Quantification of Ozone Levels in Indoor Environments Generated by Ionization and Ozonolysis Air Purifiers. J Air Waste Manag Assoc 2006;56:601-10.

12. Weschler CJ. Ozone's Impact on Public Health: Contributions from Indoor Exposures to Ozone and Products of Ozone-Initiated Chemistry. Environ Health Perspect 2006;114:1489-96.

13. California. California Code of Regulations. Treatment Guideline for Occupational Asthma. Title 8, Section 72. Available from: http://www.dir.ca.gov/t8/72.html. [last cited on 2007 Jan 14].

14. Beware of Ozone-generating Indoor 'Air Purifiers.' California Air Resources Board. March 2006. California Air Resources Board. Available from: http://www.arb.ca.gov/search. [last cited on 2006 Nov 29].

15. Hazardous Ozone Generators Sold as Air Purifiers." Welcome to California. Air Resources Board. 29 Nov. 2006. Available from: http://www.arb.ca.gov/research/indoor/o3g-list.htm. [last cited on 2006 May 5].

Otana. Jakpor

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