LaserJet Printer Emissions: Do They Pose a Health Risk?

Analysis of the Controversy and Interim Guidelines for Controlling LaserJet Printer Emissions in City Workplaces

City and County of San Francisco Department of Human Resources

August 2007

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Introduction

Some of you have no doubt become aware of the controversy concerning laserjet printers. Findings from a recent study indicate that some laserjet printers emit ultrafine particles (UFPs) at potentially harmful concentrations, and one of the researchers reignited the debate about the potential for printer emissions to be toxic and perhaps carcinogenic. Such controversies are commonplace in occupational health and safety, and in fact, often occur as a byproduct of ever-improving technologies. Under its authority in the City Charter and because laserjet printers identified in the study can be found in City workplaces, the Department of Human Resources (DHR) is investigating this issue. This document summarizes the study and its results, offers a critical analysis of stakeholders' claims to allay fears and give perspective, assesses the status of the controversy, and provides policy guidance on what actions City departments should take.

What are UFPs?

UFPs come from various sources such as industrial processes, motor vehicle emissions, and smoking tobacco products. They are extremely small particles, typically hundreds of times smaller than the width of a human hair. Size distinction is important because the respiratory system uses different clearance mechanisms to prevent airborne particles from reaching the lungs and causing harm, based on their size. Particle size is measured in microns or millionths of a meter (µm). Particles that are 10 µm in diameter or larger are typically too big to be inhaled into the lungs. If they get past the nose and throat, most impact and settle on the walls of the upper respiratory tract and are eventually swallowed or spit out. For reference, the smallest grain of sand is about 60 µm in diameter. The 10-µm size does not represent a strict boundary between respirable and non-respirable particles. Particles ranging between 2.5 and 10 µm (PM_{10}) can settle in the bronchi and lungs, and many of them incur the previous fate. Particles ranging between 0.1 and 2.5 µm ($PM_{2.5}$) often reach the pulmonary region of the lungs (alveolar ducts and alveoli) where gas exchange occurs. They are removed by specialized immune cells and excreted via the lymph system or are returned to the upper respiratory tract for excretion. Some respirable particles are retained indefinitely. UFPs, at under 0.1 µm in diameter, do not appear to trigger the immune-cell response, and they can make their way into the bloodstream where they can be transported throughout the body and interact with other cells. This has significant implications for their potential health effects: respiratory tract irritation, exacerbation of cardiovascular disease, and increased lung cancer risk. UFP composition may also be a risk factor; at this point, it is not well understood.

The Study

The paper on the recent study is entitled *Particle Emissions Characteristics of Office Printers* and was published in the American Chemical Society's *Environmental Science & Technology Magazine*[1]. In summary, a team of Australian researchers used direct-reading instruments to measure particle concentration over time and determine particle size distribution outside an air-conditioned office building in downtown Brisbane, Australia, and inside the building in a 1,300 square-foot office suite with numerous operating laserjet printers. They also measured the UFP concentration nearly 20 inches above 62 printers located throughout the building. Three printers (representative of low-, medium-, and high-emitters) were individually tested in an experimental flow chamber to determine their emission rates and the concentrations and particle size distribution of the emissions. The researchers did <u>not</u> attempt to determine the chemical composition of the emissions. Key findings are listed below:

- The average indoor UFP concentration nearly quintupled during working hours and was significantly higher than that for the outdoors.
- The average outdoor UFP concentration consistently exceeded the average indoor UFP concentration during non-working hours.
- The maximum average indoor UFP concentration (38,200 particles per cubic centimeter) was 3.5 times that of the outdoors.
- Certain laserjet printers were the main sources of UFPs and the sole cause of spikes in UFP concentrations.
- Particle emissions from the representative printers enclosed in the experimental chamber rose sharply the moment that the printer started printing a page, and they were generally of the same size and shape. UFPs accounted for about 73% of submicron particle emissions from the low-level emitting printer and 98 to 99% of submicron particle emissions from the mid and high-level emitting printers. Increases in particle numbers did not correspond to measurable increases in particle mass.
- Based on their relative emissions, researchers classified the 43 printer models (62 laserjet printers in all) that were tested into four groups. Twenty-four (24) models (about 55%) were classified as non-emitters. Four (nearly 10%) were classified as low-level emitters. Two printers (about 5%) were classified as medium-level emitters, and 13 (30%) were classified as high-level emitters. Hewlett Packard (HP) printers accounted for the lion's share in each category. Four of the 17 models reported among the low-, medium-, and high-level emitters had tests for two or more units.

The Controversy

Although this is not the first study investigating printer emissions, it has jump-started a lot of controversy. Printer emissions research has been lacking, considering the pervasiveness of laserjet printers in today's office environments. The limited body of research on printer emissions has its fair share of misleading results and experimental designs that omit studying the ultrafine fraction of printer emissions or fall short of answering key questions about UFPs. For example, a 2002 German study[2] concluded that black-and-white laserjet printers ". . . released no measurable quantities of toner dust during the printing process." While the conclusion may have been valid, the problem is that the researchers did not evaluate the ultrafine fraction of the laserjet printers' emissions.

For decades, manufacturers have steadfastly held the position – supported by limited research – that laserjet printer particle emissions are virtually non-toxic and are emitted in concentrations that are just too low to pose a health risk. This position has evolved into a consensus. Government does not regulate UFP emissions from office equipment and has demonstrated little or no leadership on researching them. Printer manufacturers are, perhaps intentionally, behind the curve on informing the public about printer emissions and any potential health risks that they may pose. So, not surprisingly, the findings from this latest study fan the flames of controversy because they show that laserjet printers emitted UFPs in relatively high concentrations. Some of the comments that Dr. Morawska, one of the study's researchers and coauthor of the paper, made in follow-up interviews and press releases are controversial, and other authorities have made noteworthy counterstatements. Examples are provided below:

- "Most of the printer-generated particles detected were ultrafine," Dr. Morawska said, explaining that such contaminants are easily inhaled into the smallest passageways of the lungs where they could pose "a significant health threat."

- The health effects from inhaled ultrafine particles depend on particle composition, but the results can range from respiratory irritation to more severe illnesses, such as cardiovascular problems or cancer, Morawska said.
- "Even very small concentrations can be related to health hazards," she said. "Where the concentrations are significantly elevated means there is potentially a considerable hazard."
- “But showing that printers produce pollutants is not the same thing as knowing that it causes certain health effects.” – Mark Mendell, a Lawrence Berkeley Lab epidemiologist.
- “Fine particles alone are not enough to worry about” – Thomas McKone, a UC Berkeley Professor of Public Health, who cited other indoor sources of UFPs including home cooking, candles, and fires.
- “It's not clear that these [printer] ultrafine emissions are dangerous.” – Robert Hamers, a University of Wisconsin-Madison Chemistry Professor.

The statements above show shades of disagreement and caution among various authorities within the science community over the strength of the evidence that printers generate emissions in potentially toxic concentrations and/or that printer emissions are inherently toxic. However, recent advances have turned the corner on linking ultrafine air pollutant exposures, not ultrafine printer emissions, to adverse health effects and some of Dr. Morawska’s claims seem to be based on them. The following are examples of such advances:

- The World Health Organization recently updated its *Air Quality Guidelines* with the following statement: “There is considerable toxicological evidence of potential detrimental effects of ultrafine particles on human health.”

- A brief write-up[3] on research conducted by the National Institute for Occupational Health and Safety (NIOSH) showed that inhalation exposures to engineered nanoparticles (the same size range as ultrafine printer emissions) were associated with adverse pulmonary and cardiovascular effects in mice. A NIOSH official offered the following statement: “The latest studies of nanoparticle toxicology confirm and expand initial research findings of nanoparticle-related health hazards, but this research has not yet been correlated with human exposures and risk.”

- A 2003 study[4], which was an EPA-funded collaborative effort among leading researchers in the field, was among the first to show a direct link between inhalation exposures to the UFP fraction of air pollutants and human cell damage.

HP’s Response

Researchers classified the tested printers based on their relative emissions and HP overwhelmingly led the pack in all categories. This is probably the result of HP’s market dominance, as opposed to their printers being more likely to emit UFPs at high concentrations compared to other manufacturers’ printers. Nevertheless, some reports in the press have inferred that HP printers are more dangerous than others. HP responded to the press reports, the study’s findings and Dr. Morawska’s so-called “bold claims.” Tuan Tran, HP’s Vice President of Marketing posted a response on HP’s website[5]. In summary, he wrote that HP disagreed with the study’s and Dr. Morawska’s conclusions and pointed out that laserjet printer emissions have not been linked to “special health risks.” He assailed the credibility of contemporary analytical technologies, claiming that they cannot accurately characterize the

chemical composition of UFPs. He went on to say that HP: (1) stands behind the safety of its products; (2) has been active with two of the world's leading independent authorities on the subject; (3) tests its print cartridges and paper products for dust release and emissions and that they comply with applicable international standards; and (4) has determined that emissions from printing systems (unclear that he means HP printing systems) have been consistently below recognized occupational exposure limits.

Overall, Mr. Tran's response was reasonable for someone in his position. However, a perusal revealed that some statements are arguably misleading and others appear to be unsubstantiated. Two examples, with the quotes first, are provided below:

- "While we recognize ultrafine, fine, and coarse particles are emitted from printing systems, these levels are consistently below recognized occupational exposure limits."

  Initially, the occupational exposure limits he was referencing were unclear, but HP's responses to DHR inquiries disclosed various mass-based standards encompassing total (all fractions of) particulate. It is crucial to understand that the relative mass of the UFP fraction of total particulate is virtually nil in comparison to that of larger fractions because UFPs are so small in size/mass. State and federal total particulate exposure limits are also based on particle mass, and there are no such limits or standards for UFPs. So, it is questionable that the mass-based exposure limits that HP claims printing systems emissions consistently meet meaningfully apply to UFPs at all.

- "Currently, the nature and chemical composition of such particles whether from a laserjet printer or from a toaster cannot be accurately characterized by analytical technology."

  The technology to analyze such particles, both quantitatively and qualitatively, clearly exists and has been around for decades. It's just very sophisticated and expensive, so only organizations with lots of resources can afford it. This technology was substantially applied in research that distinguished tobacco smoke UFPs from those in diesel exhaust, both of which have since been confirmed as carcinogens. Moreover, researchers in the previously mentioned EPA-funded study also ". . . performed lab analyses to assess how the size and chemical composition of the particulates affect changes in the body." HP's assertion that the technology does not exist is patently untrue.

DHR submitted multiple questions to HP to help in independently evaluating whether or not their printers – classified as medium- and high-level emitters – posed a health risk and/or warranted actions under the State's Safe Drinking Water and Toxic enforcement Act of 1986 (Prop 65). HP's responses revealed that: (1) some HP printer/toner cartridges contain carbon black, a chemical that is listed on California's Prop 65 List and has been classified as "possibly carcinogenic to humans" by the International Agency for Cancer Research (IARC). However, the carbon black is in a chemical state that renders it inert, and the prospect of exposure is moot until future research suggests otherwise; and (2) HP claims to comply with various standards and exposure limits that are based on total particulate, which includes the ultrafine fraction. If HP does comply with such standards, it is in the strictest technical sense because the ultrafine fraction is part of the total particulate. However, HP acknowledged that ". . . UFPs do not substantially change the measurements taken under these standards." This acknowledges the standards' limited applicability to UFPs because they are so light-weight and the standards are mass-based. HP also acknowledged the lack of limits or standards that apply solely to UFPs.

The Bottom Line

Historically, epidemiological studies on large-scale exposures to UFPs from industrial sources have generated majority of the information on UFPs and have provided most of the evidence linking exposure to them to serious adverse health effects (e.g., respiratory illness, exacerbation of cardiovascular disease, and cancer). There is comparatively scant evidence of potential adverse health effects associated with exposure to UFPs generated by indoor sources. It is unlikely that printer emissions (a common indoor source) pose an acute health risk; otherwise, an elevated incidence of adverse health effects would have been detected in worker populations long ago. There seems to be universal concurrence that printers emit some UFPs when they operate, but the public has been barraged with the industry mantra: No harmful emissions. Now, new research findings contravene the industry mantra – indicating that laserjet printers emit high and potentially harmful concentrations of UFPs.

So, what does all of this mean? Well, so far, science has confirmed that: (1) UFPs from diesel exhaust are carcinogenic; (2) tobacco smoke contains harmful agents; and (3) ultrafine air pollutants cause cell damage in humans. If health impacts are mostly a function of the UFP composition, then the evidence regarding the aforementioned harmful agents cannot be applied to laserjet printer emissions because there is currently no evidence that they contain such agents. Without such evidence, it would be irresponsible to claim that ultrafine emissions from laserjet printers are harmful. If, on the other hand, potential adverse health effects are primarily associated with particle concentration, then concerns about indoor emissions from laserjet printers may be warranted, as suggested by Dr. Morawska, but more research is needed to bear this out. So, "The jury is still out." However, the science is working its way toward definitively resolving these key questions and others.

Departmental Guidance

In the meantime, while the experts are dukin' it out, what should the City do? There are a number of Cal/OSHA regulations, state and local health and safety codes, statutes, and City policies that obligate the City to identify, evaluate and control workplace hazards. However, there is currently no scientific basis to assert that particulate emissions from laserjet printers pose a health risk, and there won't be until sufficient research has been conducted and withstood extensive scrutiny and criticism from the science world. The City needs to be proactive and take reasonable steps to prevent and/or control exposures to printer emissions. Departments that use any of the printers listed below, it may continue using them contingent upon a "good faith" effort to comply with guidelines below. The following HP laserjet printer models were identified in the study as medium- and high-level emitters:

HP Color LaserJet 4650dn
HP Color LaserJet 5550dtn
HP Color LaserJet 8550N
HP LaserJet 1320N
HP LaserJet 1320n
HP LaserJet 2420dn
HP LaserJet 4200dtn
HP LaserJet 8000DN
HP LaserJet 8150N
HP LaserJet 1020
Toshiba Studio 450
HP LaserJet 5(a)
HP LaserJet 4250n

Procurement

- City departments are advised that purchasing any of the printer models listed above may increase users' risks of exposure to ultrafine laserjet printer emissions. While the new

study's findings do not provide confirming data that the listed printers pose a health risk and various other factors (e.g., printer age, toner cartridge age, type or brand of toner) that were not comprehensively evaluated may play an important role in elevated emissions, departments may choose to purchase other HP printer models that are not listed above or unlisted printer models made by other manufacturers, until a consensus emerges. Before purchasing a printer, departments should consider its power usage, noise level, maintenance and repair costs, reliability track record, and its printing speed. Departments should consider purchasing a single high-volume printer that can adequately support a desired level of productivity, instead of multiple printers of lesser capacity, as it is thought that fewer emissions will be generated. DHR will amend the list above, or possibly abolish it, when it obtains additional credible data indicating that such printers pose or do not pose an elevated risk of generating hazardous emissions due to composition and/or emissions in potentially harmful concentrations.

- *Disposal of Printers and Printer Cartridges*

  Although this policy does not encourage decommissioning listed printers, that alternative is available to City departments, especially if they have the resources to maintain a desired printing capacity despite the reduction in printers. When a City department decommissions a printer, it has the option of storing it on the premises, perhaps indefinitely, or contacting recycling advisors at the Department of Environment (415/355-3772) to arrange having the printer(s) collected and sent to the City's virtual warehouse.

  To properly dispose of spent toner cartridges, departments may surrender them to Office Depot delivery personnel, when they come to deliver purchased products. The City has a contractual arrangement with Office Depot to collect spent printer cartridges and dispose of them in accordance with applicable environmental requirements. For assistance or more information on this, you may contact a recycling specialist at the Department of Environment (415/355-3726).

Environmental Controls

- Generally, it is prudent to ensure that the environment where a printer is located is not confined and has adequate ventilation (e.g., open windows or mechanical ventilation). Ventilation rapidly dilutes the concentration of emissions and reduces the risk of them reaching levels that could elicit unpleasant symptoms or pose a health risk. Open areas are preferred over confined areas, which allow the build up of emissions by impeding airflows and the dissipation of emissions. Departments that choose to continue using listed printers should:

  - Assure mechanical ventilation systems are functioning in accordance with specifications and applicable requirements and are properly maintained (Title 8 CCR 5143).
  - Departments using laserjet printers frequently or continuously, it should ensure that they are not located in a confined area and/or areas that lack adequate ventilation. Printers should be placed in locations that are ventilated to the outdoors, so that emissions are carried away from occupants. In a confined area with compromised airflow, it may help to set up ordinary fans to maintain air circulation, but this is not preferred over the aforementioned actions.
  - Factors such as deferred maintenance, use of certain stationery causing increased emissions, jams, and breakdowns, and/or occupants remaining in

close proximity to printers for prolonged periods should be evaluated and controlled.

- Departments are encouraged, but not obligated, to retrofit or equip confined or isolated spaces containing two or more such printers with mechanical ventilation that provides an adequate number of air changes per hour and collects and redistributes the air to the outdoors.
- Large numbers of printers and should be located in isolated spaces with a dedicated ventilation system that exhausts to the outdoors. Care must be taken to ensure that exhaust air from high-volume printing operations is not recirculated into the building's HVAC system. Listed printers should not be located near return air ducts and should be turned off when not in use for any length of time.
- New printers may warrant additional ventilation within the first few weeks of operation because many typically emit noticeable levels of chemical vapors until they "cure" within weeks to months.

Literature Cited

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(4) Li, N.; Sioutas, C.; Cho, A.; Schmitz, D.; Misra, C.; Sempf, J.; Wang, M.; Oberley, T.; Froines, J.; Nel, A. Ultrafine Particulate Pollutants Induce Oxidative Stress and Mitochondrial Damage. Environmental Health Perspectives. 2003, 111 (4), 455

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