#4470

# AN ASSESSMENT OF POTENTIAL HEALTH RISKS OF HUMIDIFIERS

Bela T. Matyas
Rhode Island Dept. of Health
Providence, Rhode Island
U.S.A. 02908-5097

Robert R. Vanderslice
Rhode Island Dept. of Health
Providence, Rhode Island
U.S.A. 02908-5097

The potential health risks associated with the use of tap water in ultrasonic and 'warm mist' humidifiers are assessed relative to the risks of normal household exposures to tap water contaminants and constituents. This assessment predicts that, except for certain situations involving lung-toxic nonvolatile contaminants, ultrasonic humidifiers do not represent a significant source of exposures relative to general household ingestion and inhalation exposures. For Rhode Island community water systems in particular, and for public water supplies in general, use of tap water in humidifiers appears to be safe.

## INTRODUCTION

The use of humidifiers to regulate humidity is a common practice during those months when heating of commercial and residential buildings causes drying of the indoor air. The risks of humidifiers regarding the production of bacteria, molds, and other allergens are well established (1,2). There has been concern recently that ultrasonic humidifiers, in particular, produce harmful aerosols containing toxic agents and carcinogens. However, these risks are less clear.

The use of distilled, demineralized water for humidifiers has been strongly advocated by the U.S. Consumer Product Safety Commission (2). This recommendation, however, does not appear to account for inhalation exposures to tap water contaminants associated with general household activities. This study assesses exposures to aerosols generated by 'warm mist' and ultrasonic humidifiers in relation to general household ingestion and inhalation exposures. The relative risks of 'warm mist' and ultrasonic humidifiers using tap water are then assessed.

## MATERIALS AND METHODS

For purposes of this analysis, exposures are assessed separately for the following categories: ingestion of tap water; inhalation of volatile tap water contaminants in showering, bathing, and other general household activities; inhalation of aerosols generated by ultrasonic humidifiers; and inhalation of volatile tap water contaminants released by 'warm mist' humidifiers. The category "general household exposures" includes both ingestion exposures and inhalation exposures due to general household activities. Both ingestion and inhalation exposures are expressed as liters

of tap water per day; for ingestion exposures, this represents the volume of tap water actually consumed, while for inhalation exposures, this represents the volume of consumption equivalent to the pulmonary exposure. Humidifier inhalation risks are assessed for two exposure scenarios, humidifiers vented to the entire house (whole house) and humidifiers used in an enclosed room (enclosed bedroom).

It is assumed that only ultrasonic humidifiers will aerosolize metals, minerals, and other nonvolatile contaminants and naturally-occurring tap water constituents. The inhalation risks for these nonvolatile agents are therefore assumed to be negligible for general household activities and 'warm mist' humidifiers.

The exposure assessments are calculated as follows:

Ingestion exposures. For metals, minerals, and other nonvolatiles an average daily consumption of 2 liters per day (L/day) is assumed based on total tap water consumption for the U.S. population (3). For radon, volatile organic compounds, and other volatile agents (Rn/VOCs), water used in cooking and prepared beverages is assumed to contribute little to the ingestion exposures due to volatilization. Therefore, exposure to Rn/VOCs is based on the average direct tap water ingestion rates for the U.S. of about 1 L/day (4). It is expected that some Rn/VOCs in this 1 L/day may be lost due to use of tap aerators and volatilization losses while drinking.

Inhalation exposures due to general household activities. An average household occupancy rate of 75%, an inhalation rate of 20,000 L/day, and a transfer coefficient of 1:10,000 for Rn/VOCs (i.e., the indoor air concentrations will increase by 1 unit for each 10,000 units found in water) are assumed. This transfer coefficient is based on data for radon. The VOCs used as examples in this analysis have similar physical properties as radon and thus are assumed to have similar transfer coefficients (3,5,6).

Inhalation exposures due to ultrasonic humidifiers. It is assumed that 100% of the volatile and nonvolatile contaminants and constituents in the source tap water are volatilized and/or aerosolized. Exposures are given as a daily average during the heating season. For chronic health risks such as cancer, it is assumed that humidifiers are used for 6 months/year, reducing the exposure estimates by a factor of 2. For whole house exposures, the use of one humidifier with a use rate of 10 L/day of tap water, an average house volume of 100,000 liters of air per person, an average air exchange rate of 0.5 exchanges per hour, and an average household size of 2.7 are assumed, yielding a transfer coefficient of 1:324,000 (7,8). An inhalation rate of 20,000 L/day and an occupancy rate of 75% are also assumed. For enclosed bedroom exposures, it is assumed that the humidifier use rate is 10 L/day, the room volume is approximately 20,000 liters (3 m x 2.7 m x 2.5 m), exposures occur for 8 hours per day (35% occupancy; i.e., humidifier used only at night), the air exchange rate is 12 exchanges per day, and the inhalation rate is 11,000 L/day, corresponding to rest (7,9).

Inhalation exposures due to 'warm mist' humidifiers. As 100% of the Rn/VOCs in the source tap water are assumed to volatilize, daily pulmonary exposures to these agents under whole house and enclosed bedroom conditions are expected to be equal to the respective exposures calculated for ultrasonic humidifiers.

The risk assessments are calculated as follows:

General household exposures by ingestion and inhalation are combined

to yield general household total risk for each agent. A reasonable worst case risk due to ultrasonic humidifiers is calculated for each agent by combining enclosed bedroom exposures (for nighttime exposure) with two-thirds of whole house exposures (for daytime exposure). For each agent, the total relative risk is calculated by summing the products of the appropriate relative inhalation and/or ingestion exposure and respective cancer potency factor and the conversion factors 70 kg for average weight, 20,000 L/day for average inhalation rate, and 0.5 for ultrasonic humidifier cancer risk (see above), as appropriate.

## RESULTS AND DISCUSSION

Table 1 indicates that exposures to Rn/VOCs are predicted to be identical for ultrasonic and 'warm mist' humidifiers, and that exposures to metals, minerals, and nonvolatile agents in tap water are predicted to be significantly higher for ultrasonic humidifiers.

Table 1. Relative inhalation and ingestion exposures to drinking water contaminants.

| | General household exposure | | Ultrasonic humidifier | | 'Warm mist' humidifier | |
|---|---|---|---|---|---|---|
| Contaminant | Ingest (L/day) | Inhale (L/day) | Whole house (L/day) | Closed bedroom (L/day) | Whole house (L/day) | Closed bedroom (L/day) |
| Rn/VOCs | 1.0 | 1.5 | 0.05 | 0.16 | 0.05 | 0.16 |
| Metals/minerals | 2.0 | n* | 0.05 | 0.16 | n | n |

* n = negligible.

By contrast, total (direct ingestion and indirect inhalation) general household exposures are predicted to be almost 15-fold greater for Rn/VOCs and almost 12-fold greater for nonvolatiles than exposures calculated for humidifiers. In general, then, humidifier exposures are not expected to be a significant addition to background general household exposures.

However, many agents are specific lung toxins or appear to exhibit greater toxicity through pulmonary versus oral exposures (e.g., radon, chromium (VI), nickel, cadmium, asbestos, methylene chloride, chloroform). For these types of agents, inhalation exposures may pose a significant potential risk, and ultrasonic humidifiers may represent an important source for such exposures.

For volatile agents such as radon, chloroform, and methylene chloride, general household total risks of such sensitive chronic endpoints as cancer are still predicted to be 15-fold greater than the risks for ultrasonic humidifiers under reasonable worst case conditions (Table 2). The risks due to ultrasonic and 'warm mist' humidifiers are predicted to be equivalent.

Table 2. Risks of cancer by inhalation and ingestion of agents with lung-specific toxicity.

| Agent | Inhalation cancer potency factor[1] | Ingestion cancer potency factor[1] | General household total risk[2] | Ultrasonic humidifier worst case risk[2] |
|---|---|---|---|---|
| Radon | 0.00018 | na* | 13 | 0.84 |
| Chloroform | 0.081 | 0.0061 | 1.8 | 0.11 |
| Methylene chloride | 0.014 | 0.0075 | 0.41 | 0.019 |
| Asbestos | 0.00023 | na | n** | 0.0011 |
| Chromium (VI) | 41 | n | n | 56 |

[1] units for radon are $(Bq/m^3)^{-1}$, for asbestos are $(f/L)^{-1}$, and for chromium, chloroform, and methylene chloride are $(mg/kg/day)^{-1}$; Ref 3;
[2] see text for definitions; units for radon are risk x $10^6/Bq/m^3$, for asbestos are risk x $10^6/f/L$, and for chromium, chloroform, and methylene chloride are risk x $10^6/ug/L$;
* na = not available, assumed to be negligible compared to inhalation;
** n = negligible.

For nonvolatile lung toxins such as asbestos and chromium (VI), however, general household total cancer risks are predicted to be significantly lower than the risks predicted for ultrasonic humidifiers. These types of agents represent the greatest potential health risks specific to ultrasonic humidifiers.

In order to put these potential risks into perspective, Table 3 compares predicted lifetime cancer risks for these agents at three tap water concentrations: the respective drinking water maximum contaminant level (MCL) or proposed MCL; the highest concentrations of these agents detected in Rhode Island community public water systems (1986-present); and the concentrations of these agents found in the Scituate Reservoir (1986-present), which provides drinking water to 60% of Rhode Island.

General household exposures to tap water containing radon or chloroform at the MCL will result in lifetime cancer risks significantly greater than $10^{-4}$. The use of ultrasonic humidifiers under reasonable worst case conditions is predicted to exceed the $10^{-6}$ lifetime cancer risk level at the MCL concentrations for radon, asbestos, chromium (VI), and chloroform. However, in none of these cases do ultrasonic humidifiers represent a significant specific source of risk to users of community public water in Rhode Island. Chromium and asbestos are not known to be present in detectable concentrations in Rhode Island community water systems. In addition, although high absolute risks are predicted for radon and chloroform for ultrasonic humidifiers using worst case Rhode Island community water sources, these risks are small compared to the risks from general household exposures to these same tap waters.

In summary, except for nonvolatile lung-specific toxic agents, if tap water is safe to drink, it can be safely used in ultrasonic humidifiers. The lung-specific risks of such nonvolatiles as asbestos and chromium are theoretically significant for the use of ultrasonic humidifiers under reasonable worst case conditions even at concentrations somewhat below the current or proposed drinking water MCLs for these agents. However, typical

Rhode Island tap water has nondetectable or very low concentrations of such nonvolatile lung toxins as chromium, nickel, and cadmium, so that in practice the use of this tap water in ultrasonic humidifiers appears to be safe.

Table 3. Estimated lifetime cancer risks for exposures to agents with lung-specific toxicity at U.S. EPA Maximum Contaminant Levels and at levels found in Rhode Island public water supplies.

| Agent | Concentration type | Concentration level | General household total risk[1] | Ultrasonic humidifier worst case risk[1] |
|---|---|---|---|---|
| Radon | MCL[2] | 20,000 Bq/m$^3$ | 260 | 17 |
| | wc[3] | 1.2 x 10$^6$ Bq/m$^3$ | 16000 | 1000 |
| | SR[4] | ND | — | — |
| Chloroform | MCL | 100 ug/L | 180 | 11 |
| | wc | 68 ug/L | 120 | 7.8 |
| | SR | 6 ug/L | 11 | 0.68 |
| Methylene chloride | MCL | 5 ug/L | 2 | 0.1 |
| | wc | 1 ug/L | 0.41 | 0.02 |
| | SR | ND | — | — |
| Asbestos | MCL | 7.0 x 10$^6$ f/L | — | 7700 |
| | wc | * | — | — |
| | SR | * | — | — |
| Chromium (VI) | MCL | 50 ug/L | — | 2800 |
| | wc | < 5 ug/L | — | < 280 |
| | SR | ND | — | — |

[1] see text for definitions; units are risk x 10$^6$; correction for aspect ratio of asbestos and speciation of chromium not performed;
[2] MCL = current maximum contaminant level for drinking water for chromium (NIPDWR) and chloroform (THM), proposed level for asbestos and methylene chloride, and an intermediate proposed level for radon; Ref 3;
[3] wc = highest concentration found in a Rhode Island community public water system, 1986-present; chromium risk based on limit of detection; Ref 10;
[4] SR = concentration detected in the Scituate Reservoir-supplied water systems in Rhode Island; Ref 10;
ND = none detected; * = no data available.

## CONCLUSIONS AND RECOMMENDATIONS

The potential inhalation exposures to drinking water contaminants and their ensuing risks have been documented by several research groups (6,11). The results of this analysis are in general agreement with past studies, with the exception that, under certain situations, ultrasonic humidifiers should be considered separately as a significant source of exposure to some lung-toxic nonvolatile tap water contaminants. Although 'warm mist' humidifiers pose no significant risk of exposure to chemical tap water contaminants, they have a greater propensity for biological contamination. Consequently, unless tap water is contaminated with significant

concentrations of certain key nonvolatile agents, ultrasonic humidifiers may present a safer alternative. In addition, in view of the analysis for typical Rhode Island public drinking water, the Consumer Product Safety Commission's recommendation that deionized, demineralized water be used in humidifiers does not appear to be warranted. However, private well owners should test their well water for these agents.

The results of this analysis have important implications for officials responsible for evaluating the safety of drinking water. Typically, the assessment of drinking water safety relies upon EPA MCLs and Health Advisories (HAs), which are based on ingestion risks alone. EPA also provides inhalation reference doses and cancer potencies for assessing inhalation exposures. Because these two types of guidance are developed independently, problems may arise when assessing multi-route exposures to a given agent. The evaluation of combined ingestion and inhalation risks of drinking water contaminants, for example, can result in the counter-intuitive conclusion that a water supply is safe to drink but poses unacceptable hazards for such household uses as bathing and laundry. Until the multiple components that comprise such an assessment are integrated, this type of inconsistency will persist.

REFERENCES


1. Anderson K, et al (1989) Climate, intermittent humidification, and humidifier fever. Br J Ind Med 46:671-4.
2. US Consumer Product Safety Commission (1988) Dirty Humidifiers may cause health problems. Consumer Product Safety Alert. US CPSC, Washington, DC.
3. US EPA (1989) Integrated risk information system (IRIS). On-line computer data base. ECAO, US EPA, Cincinnati, Ohio.
4. Ershow A, Cantor K (1989) Total Water and Tap Water Intake in the US: Population Based Estimates of Quantities and Sources. US Environmental Protection Agency, Washington, DC.
5. US EPA (1987) Radon Reference Manual. US EPA Office of Radiation Programs, Washington, DC (EPA 520/1-87-20).
6. McKone TE (1987) Human exposures to VOC's in household tap water: the indoor inhalation pathway. Environ Sci Technol 21:1194-1201.
7. Nazaroff WW, Doyle SM, Nero AV, Sextro RG (1987) Potable water as a source of airborne radon-222 in U.S. dwellings: a review and assessment. Health Physics 52:281-295.
8. US Bureau of the Census (1989) Current Population Reports Series P-25, No. 1044. State Population and Household Estimates, with Age, Sex, and Components of Change: 1981-88. US GPO, Washington, DC.
9. ICRP (1975) ICRP Publication 23. International Commision on Radiation Protection, Task Group Report on Reference Man. Pergammon Press, Oxford.
10. Available from the Division of Drinking Water Quality, Rhode Island Department of Health, 3 Capitol Hill, Providence, RI.
11. Andelman JB (1985) Human exposure to volatile halogenated organic chemicals in indoor and outdoor air. Environ Health Perspec 62:413-8.