

Occupational Exposure and Health in the Informal Sector: Fish Smoking in Coastal Ghana

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<https://doi.org/10.1289/EHP9873>

Introduction

Fish preservation by smoking is an occupation where workers (primarily women) are exposed to gases and particles from wood smoke for more than 5 h daily (Adeyeye and Oyewole 2016). The scale of this issue is large; we estimate that there are 6 million fish smokers on the West African coast (uncertainty: 0.8–10 million).

Methods

We used a cross-sectional design to explore differences in exposure and self-reported health symptoms between women engaged in occupational fish smoking (fish smokers, $N = 308$) and those in other occupations, including business- and tradeswomen, fish salters, tailors, hairdressers, and others (controls, $N = 152$). Households were randomly selected from two small coastal cities in Ghana (Moree and Elmina). Fish smoker and control households were geographically well mixed at an $\sim 2:1$ ratio.

A structured survey was used to collect sociodemographic and health symptom data from each household's highest income earning woman. The health questionnaire was modeled on the Ghana Demographic and Health Survey and included 1-y and 2-wk symptom recall (Table 1).

Twenty-four-hour carbon monoxide (CO) and fine particulate matter (PM_{2.5}) concentrations were collected near the breathing zone from a subset of participants (CO: $N = 151$, PM_{2.5}: $N = 26$). CO sensors (Lascar Electronics, Model EL-USB-CO) were calibrated before and after fieldwork (198 ± 4 ppm CO in standard air), and data synthesized into 24-h and sub-24-h averages (maximum 8-h, 1-h, and 15-min). PM_{2.5} samples were collected on 2- μ m polytetrafluoroethylene membrane filters, using a personal air sampling pump (SKC Inc., model AirChek XR5000) connected to a single-stage impactor (MSP Corporation, Model 200 Personal Environmental Monitor).

The association between exposure and fish smoking was assessed using *t*-tests and ordinary least squares regression models, controlling for household and individual level variables, including proximity to other sources of combustion pollutants (Table 1). Relationships between health symptoms and fish smoking were tested with χ^2 tests and logit models that controlled for the same variables as the ordinary least squares

models. Exposure differences due to ventilation and improved smokers were tested with *t*-tests.

Results and Discussion

Pollutant Exposure

CO (24-h) and PM_{2.5} exposures were both ~ 2.6 times greater for fish smokers compared with controls (CO: 2.69, $p < 0.001$, PM_{2.5}: 2.61, $p = 0.09$; Figure 1A and E). Likewise, 8-h, 1-h, and 15-min CO exposures were significantly higher for fish smokers ($p < 0.001$, $p < 0.001$, $p = 0.007$, respectively; Figure 1C). The regression model shows fish smoking was a significant determinate of CO exposure [$\beta = 4.0$; 95% confidence interval (CI): 0.2, 0.6; $p = 0.004$]. PM_{2.5} was strongly correlated with CO (Pearson's $r = 0.89$). All PM_{2.5} exposures were greater than the annual World Health Organization safe guideline (10 $\mu\text{g}/\text{m}^3$) and 92% were greater than the interim guideline (35 $\mu\text{g}/\text{m}^3$; Figure 1E).

Exposures experienced by fish smokers were higher than from household cooking in nonfishing villages in Ghana. Fish smokers had 24-h CO exposure that was seven times greater than from household cooking in Eastern Ghana (1.1 ppm) (Lee et al. 2019); PM_{2.5} exposures were four times greater (129 $\mu\text{g}/\text{m}^3$) (Van Vliet et al. 2019). Controls also had higher exposure than typical from cooking (2.6 times greater for CO and 1.5 times for PM_{2.5}) (Lee et al. 2019; Van Vliet et al. 2019). A possible explanation is that fish smoking increases local ambient pollution, raising the baseline exposure of nonfish smokers.

Better ventilation may reduce exposure for fish smokers (Figure 1D). Women who used open air smokers were exposed to less than half the CO compared with those using indoor smokers ($p < 0.01$); Flintwood-Brace (2016) also found high indoor fish smoking exposures (18 ± 13 ppm). However, even women who used open air smokers had higher exposures compared with controls ($p = 0.01$). Counterintuitively, users of improved smokers (with chimneys) had the same level of CO exposure as users of traditional smokers (6.9 ppm and 7.0 ppm, $p > 0.05$), and higher PM_{2.5} (866 $\mu\text{g}/\text{m}^3$ vs. 306 $\mu\text{g}/\text{m}^3$, $p < 0.001$).

Symptom Prevalence

Symptoms were more prevalent in fish smokers compared with controls (Table 1). Yet, even for controls, rates were high compared with other populations. For example, the prevalence of difficulty breathing and concentrating were 2 and 3.3 times higher, respectively, compared with biomass cooks in Malawi (Das et al. 2017).

Highly Significant Associations: Eye, Neurological Symptoms, and Burns

Poor eyesight, burning eyes, and dizziness were all strongly correlated with fish smoking and these symptoms were also associated with CO exposure (Figure 1F). These symptom associations with both fish smoking and exposure are

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The authors declare they have no actual or potential competing financial interests.

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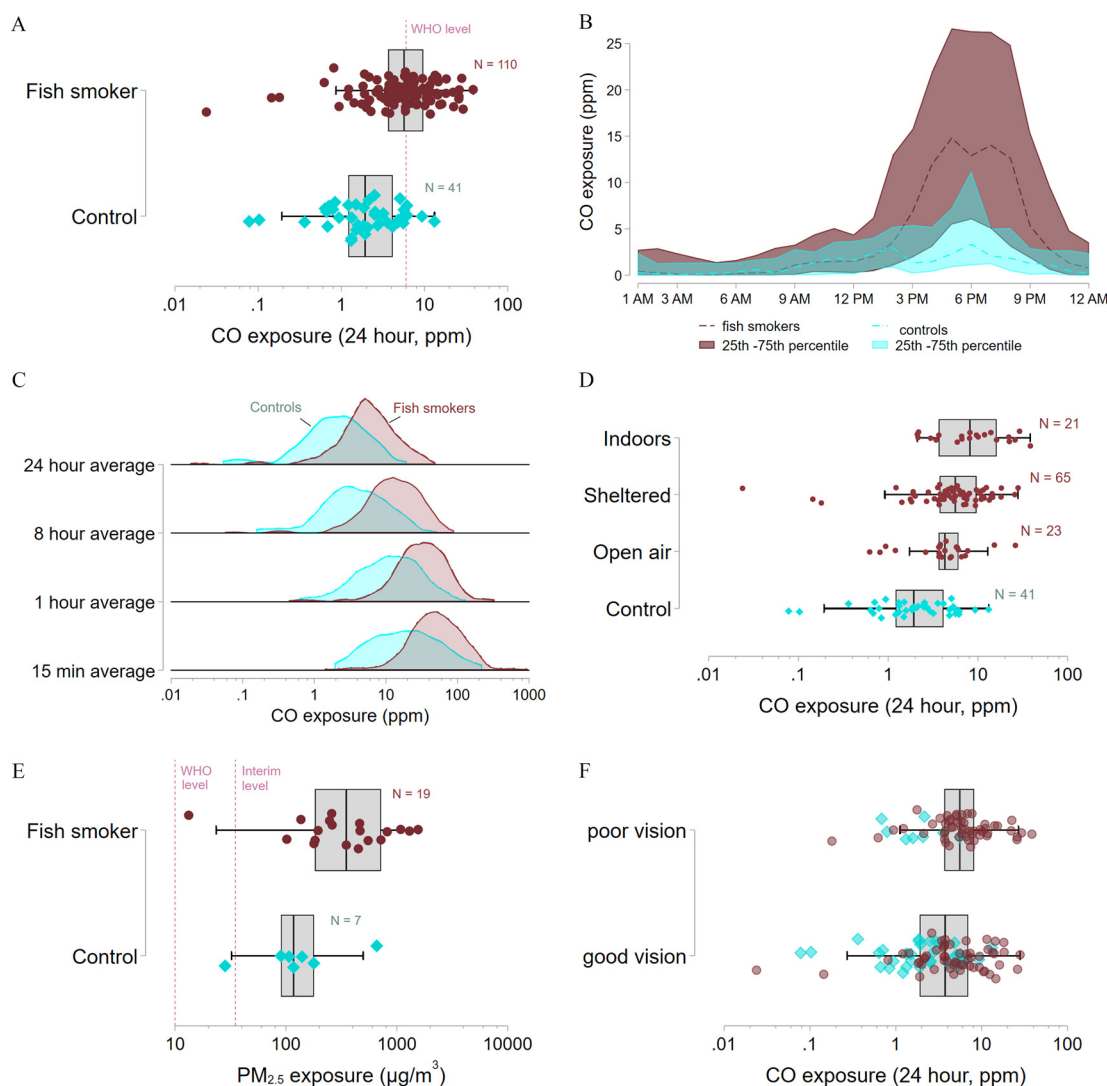


Figure 1. (A) Box plot of 24-h CO exposure on a log scale. Points represent individual women's exposures and are jittered vertically to better show each point. Occupational fish smokers were exposed to 7.7 ± 6.9 ppm (median = 5.7 ppm), and controls were exposed to 2.9 ± 2.6 ppm (median = 1.9 ppm, $p < 0.001$). The WHO safe guidance level for CO is 6 ppm and is shown as a vertical dashed line. (B) Mean hourly CO time series for fish smokers and controls, generated using 1-min data. From 1400–2100 hours, fish smokers experienced over three times greater CO concentrations compared with controls. (C) Probability distributions of CO exposure for 24-h, 8-h, 1-h, and 15-min averages. Mean values for fish smokers and controls were 16.7 ± 13.2 ppm and 5.7 ± 6.0 ppm for the 8-h, 41.0 ± 37.1 and 16.4 ± 16.1 ppm for the 1-h, and 71.5 ± 84.5 and 31.0 ± 33.8 ppm for the 15-min averages, respectively. (D) CO exposure for fish smokers using open air (5.6 ± 5.4 , $p = 0.009$ ppm), partially ventilated (sheltered, 7.2 ± 5.5 ppm, $p = 9.0 \times 10^{-6}$), and indoor smokers (12.0 ± 10.2 , $p = 1.1 \times 10^{-6}$ ppm), relative to controls (2.9 ± 2.6 ppm). (E) Box plot of 24-h $PM_{2.5}$ exposure on a log scale. Fish smokers were exposed to an average of 490 ± 430 $\mu g/m^3$ and controls to 190 ± 210 $\mu g/m^3$. The WHO guidance level for $PM_{2.5}$ is 10 $\mu g/m^3$ (interim target, 35 $\mu g/m^3$), shown as vertical dashed lines. (F) Box plot of CO exposures for women reporting good or poor vision (5.5 ± 5.4 ppm, and 7.6 ± 7.5 ppm). Points are distinguished as fish smokers (circles) and controls (diamonds). Note: CO, carbon monoxide; $PM_{2.5}$, fine particulate matter ($PM \leq 2.5$ μm in aerodynamic diameter); WHO, World Health Organization.

consistent with the hypothesis that occupational fish smoking can cause higher exposure to pollutants, leading to a greater health burden.

Fish smokers have substantially higher rates of impaired vision that impacts daily functioning (odds ratio = 6.8; 95% CI: 3.6, 12.9). The literature supports that smoke exposure may cause or exacerbate poor eyesight, including from cataracts, age-related macular degeneration, and refractive error (Hankinson et al. 1992; Seddon et al. 1996; Bourne et al. 2013; Stone et al. 2006).

Fish smokers were more likely to have burns compared with controls, despite having fewer burns from cooking. Burns reported to be caused by fish smoking tended to be mild (no scars, 70%) compared with those caused by cooking (50%). Three percent of fish smokers had a severe burn in the past year, and 15% had one in their lifetime (83% were from fish smoking).

For headaches, we observed associations with fish smoking and with CO exposure, but only for the 2-wk recall period. We hypothesize that because nearly all women experienced a headache over 1-y, a shorter recall would be required to discern an association. Future studies using self-reported health symptoms should aim to match recall periods with the likelihood of symptoms (e.g., fatigue should have a shorter recall, and coughing blood, longer).

Respiratory Symptoms

Symptoms that are indicative of severe respiratory distress of various causes were more prevalent in fish smokers compared with controls, including shortness of breath, difficulty breathing, wheezing, and cough with phlegm. Chronic cough was associated with $PM_{2.5}$ exposure ($p = 0.04$), but not with fish smoking.

Table 1. Symptom prevalence in controls (C) and fish smokers (FS).

Symptoms	Symptom recall in past year and symptom relationship with										Symptom recall in past 2-wk and symptom relationship with									
	Fish smoking					CO					Fish smoking					CO				
	C (%)	FS (%)	χ^2 (<i>p</i> -value)	Logit [OR (95% CI); <i>p</i> -value] ^b	PM _{2.5}	C (%)	FS (%)	χ^2 (<i>p</i> -value)	Logit [OR (95% CI); <i>p</i> -value] ^b	PM _{2.5}	C (%)	FS (%)	χ^2 (<i>p</i> -value)	Logit [OR (95% CI); <i>p</i> -value] ^b	PM _{2.5}	C (%)	FS (%)	χ^2 (<i>p</i> -value)	Logit [OR (95% CI); <i>p</i> -value] ^b	PM _{2.5}
Eye symptoms																				
Poor vision ^c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Very impaired vision ^c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Burning eyes	60	88	1 × 10 ⁻¹²	7.8 (4.0, 15.2); 1 × 10 ⁻⁹	0.01	0.01	0.03*	0.28	0.03*	0.03*	48	80	2 × 10 ⁻¹²	6.2 (3.5, 11.0); 5 × 10 ⁻¹⁰	0.18	0.10	0.28	0.18	0.10	0.28
Sticky eyes	13	18	0.15	2.1 (0.9, 4.7); 0.08	0.94	0.94	0.75	0.84	0.75	0.84	8	13	0.09	1.9 (0.7, 4.9); 0.18	0.45	0.28	0.81	0.45	0.28	0.81
Neurological symptoms																				
Headache	89	92	0.33	1.7 (0.7, 4.0); 0.24	0.15	0.15	0.12	0.31	0.12	0.31	66	76	0.02	2.2 (1.2, 3.8); 0.01	0.05	0.03	0.64	0.05	0.03	0.64
Difficulty concentrating	60	66	0.23	1.2 (0.7, 1.9); 0.57	0.20	0.20	0.21	0.07	0.21	0.07	45	54	0.08	1.4 (0.8, 2.3); 0.20	0.20	0.19	0.77	0.20	0.19	0.77
Dizziness	45	58	0.009	2.8 (1.6, 4.8); 2 × 10 ⁻⁴	0.03	0.03	0.03	0.68	0.03	0.68	26	36	0.03	1.9 (1.1, 3.4); 0.02	0.22	0.25	0.43	0.22	0.25	0.43
Forgetfulness	71	73	0.51	0.9 (0.5, 1.7); 0.84	0.56	0.56	0.78	0.75	0.78	0.75	55	64	0.07	1.1 (0.7, 1.9); 0.63	0.15	0.15	0.57	0.15	0.15	0.57
Approx. neurological impact ^d	28	40	0.02	2.4 (1.4, 4.3); 3 × 10 ⁻³	0.25	0.25	0.22	0.11	0.22	0.11	14	18	0.34	1.5 (0.7, 3.0); 0.30	0.43	0.45	0.71	0.43	0.45	0.71
Skin issues																				
Burns	35	46	0.02	1.4 (0.9, 2.4); 0.16	0.02	0.02	0.01	0.03	0.01	0.03	8	19	0.001	2.9 (1.2, 6.6); 0.01	0.06	0.05	0.45	0.06	0.05	0.45
Burns from cooking ^e	34	6	5 × 10 ⁻¹¹	0.11 (0.05, 0.3); 6 × 10 ⁻⁷	3 × 10 ⁻⁴	3 × 10 ⁻⁴	2 × 10 ⁻⁵	—	—	—	—	—	—	—	—	—	—	—	—	—
Moderate and severe burns ^e	18	16	0.47	0.6 (0.3, 1.2); 0.18	0.17	0.17	0.11	0.01	0.11	0.01	—	—	—	—	—	—	—	—	—	—
Rashes	10	15	0.17	1.4 (0.7, 3.0); 0.38	0.29	0.29	0.25	0.33	0.25	0.33	7	11	0.16	1.9 (0.7, 4.9); 0.20	0.96	0.91	0.33	0.96	0.91	0.33
Skin irritation ^f	49	58	0.08	2.3 (1.4, 3.8); 2 × 10 ⁻³	0.40	0.40	0.39	0.12	0.39	0.12	30	35	0.27	1.8 (1.0, 3.1); 0.04	0.78	0.63	0.16	0.78	0.63	0.16
Respiratory infection symptoms																				
Fatigue ^g	97	99	0.30	19.3 (0.7, 501); 0.08	0.06	0.06	0.10	—	—	—	86	91	0.11	1.3 (0.6, 2.8); 0.52	0.22	0.13	0.68	0.22	0.13	0.68
Vomiting ^g	45	41	0.46	1.1 (0.6, 1.8); 0.78	0.07	0.07	0.04	0.29	0.04	0.29	25	23	0.61	1.0 (0.6, 1.8); 0.96	0.97	0.77	0.57	0.97	0.77	0.57
Fever ^g	78	80	0.72	1.4 (0.8, 2.8); 0.27	0.51	0.51	0.63	0.12	0.63	0.12	46	49	0.57	1.2 (0.7, 1.9); 0.59	0.90	0.85	0.42	0.90	0.85	0.42
Chest infection	67	79	0.006	2.0 (1.1, 3.5); 0.02	0.22	0.22	0.15	0.64	0.15	0.64	53	63	0.03	1.8 (1.1, 3.0); 0.03	0.66	0.79	0.91	0.66	0.79	0.91
Approx. respiratory infection ^h	58	68	0.04	1.7 (1.0, 2.9); 0.06	0.64	0.64	0.45	0.62	0.45	0.62	30	34	0.41	1.4 (0.8, 2.4); 0.21	0.43	0.66	0.97	0.43	0.66	0.97
Approx. resp. infection with cough ⁱ	27	37	0.02	2.1 (1.2, 3.7); 0.01	0.53	0.53	0.36	0.07	0.36	0.07	9	13	0.17	2.2 (1.0, 5.1); 0.06	0.99	0.15	0.90	0.99	0.15	0.90
Respiratory distress symptoms																				
Shortness of breath	53	57	0.55	2.4 (1.3, 4.3); 0.01	0.08	0.08	0.09	0.48	0.09	0.48	43	43	0.90	1.7 (0.9, 3.0); 0.08	0.55	0.48	0.47	0.55	0.48	0.47
Difficulty breathing/chest tightness	32	45	0.007	1.9 (1.1, 3.1); 0.02	0.65	0.65	0.72	0.75	0.72	0.75	28	35	0.13	1.5 (0.9, 2.6); 0.13	0.45	0.59	0.37	0.45	0.59	0.37
Wheezing or whistling in chest ^j	12	22	0.007	2.8 (1.3, 5.9); 0.01	0.71	0.71	0.68	0.38	0.68	0.38	—	—	—	—	—	—	—	—	—	—
Chronic cough	53	56	0.42	1.3 (0.8, 2.2); 0.32	0.98	0.98	0.83	0.04	0.83	0.04	33	36	0.31	1.3 (0.7, 2.2); 0.40	0.04	0.06	0.32	0.04	0.06	0.32
Cough with blood	1	2	0.34	—	—	—	—	—	—	—	0	2	0.24	—	—	—	—	—	—	—
Produced phlegm	57	70	0.003	2.4 (1.4, 4.3); 2 × 10 ⁻³	0.57	0.57	0.46	0.14	0.46	0.14	40	52	0.02	1.8 (1.1, 3.0); 0.03	0.88	0.90	0.29	0.88	0.90	0.29
Approx. COPD ^k	1	5	0.08	13.4 (0.9, 196); 0.06	0.86	0.86	0.90	0.71	0.90	0.71	1	3	0.38	2.1 (0.1, 53.6); 0.67	0.87	0.76	—	0.87	0.76	—
Approx. asthma ^l	1	2	0.40	—	—	—	—	—	—	—	1	1	0.96	—	—	—	—	—	—	—
N	152	308		460	151	151	151	26	460	151	152	308		460	151	151	26		460	151

Note: Each symptom's association with fish smoking was tested using chi squared tests and logit models for 1-y and 2-wk recall periods (odds ratios and 95% confidence intervals shown). The association between each symptom and CO exposure (24- and 8-h) and PM_{2.5} were assessed with *t*-tests. —, statistical test could not be conducted; Approx., approximated; CI, confidence interval; CO, carbon monoxide; COPD, chronic obstructive pulmonary disease; OR, odds ratio; PM_{2.5}, fine particulate matter (PM ≤ 2.5 μ m in aerodynamic diameter).

^aSymptom vs. CO exposure *t*-tests were conducted with log-transformed CO. * indicates *p* < 0.05 on a non log-transformed scale.

^bControl variables included household characteristics (i.e., size, town, number of children), wealth indicators (i.e., assets and home quality), personal characteristics of the woman (i.e., age, marital status, education), and environmental risk indicators (household cook, cigarette smokers in the home, charcoal cooking, kerosene lighting, use of an improved cookstove, number of fish smoking ovens owned, number of unowned ovens in a 20-m radius, and if they lived/worked within 20 m of trash burning).

^cThe vision question was asked in the present tense and did not have a recall period.

^dApproximated neurological impacts are cases with all of headache, difficulty concentrating, dizziness, and forgetfulness.

^eSources of burns and severity were only asked for the 1-y recall period.

^fSkin irritation effect likely from fish handling.

^gSymptoms may have caused other than respiratory diseases.

^hRespiratory infection was approximated as present if all of fatigue, fever, and chest infection were experienced.

ⁱRespiratory infection with cough are considered present if all symptoms of respiratory infection occurred as well and cough and phlegm.

^jWheezing symptoms were not asked for 2-wk recall.

^kApproximated COPD are cases with chronic cough, phlegm, shortness of breath, difficulty breathing, wheezing, and are >40 years of age.

^lApproximated asthma are cases with chronic cough and wheezing, without produced phlegm or coughing up blood.

Respiratory symptoms associated with fish smoking did not have a relationship with CO exposure, although they are known to be associated with smoke exposure in other contexts (Van Vliet et al. 2019). We hypothesize that this is because day-to-day exposures were variable and 24-h measures only weakly represent the exposures that drive chronic health outcomes.

Conclusion

Occupational fish smokers experienced an elevated health burden. Rates of self-reported symptoms in fish smokers were higher than those in other occupations, most notably increased rates of poor vision. In addition, because exposure rates in controls were also high, the true health effect estimates of fish smoking relative to a clean environment may be greater than reported here. Fish smoker health may be improved by working in well-ventilated spaces and using improved smokers field tested to verify emission reductions.

The health burden from fish smoking likely impacts millions of workers and is just one of many occupations that use polluting solid fuel combustion. We show here that working with wood combustion for about 5 hours per day has measurable health and exposure associations, even when used outdoors. Millions of workers in low-income countries are engaged in informal sector occupations that use solid fuel for many hours daily (e.g., brick kiln workers, charcoal producers); exposure and health measurements are needed to understand this health burden, especially in the African context.

Acknowledgments

We are grateful to P. Morgan, Alan Feduccia Professor Emeritus of Sociology and Emeritus Director of the Carolina Population Center, University of North Carolina at Chapel Hill, for his encouragement and support on this project. Funding for this research came from the Paul Humphrey Award at the Carolina Population Center (USA), the International Development Research Center (Canada), and the Environmental Protection Agency (Ghana). This research received support from the Population Research Infrastructure Program awarded to the

Carolina Population Center (P2C HD050924) at the University of North Carolina at Chapel Hill by the Eunice Kennedy Shriver National Institute of Child Health and Human Development and a grant from the International Development Research Centre titled “Climate Change Adaptation Research Training Capacity for Development” (106548). This research also received support from the National Science Foundation, Partnerships in International Research and Education Program (1743741).

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