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EO Supplementary Materials

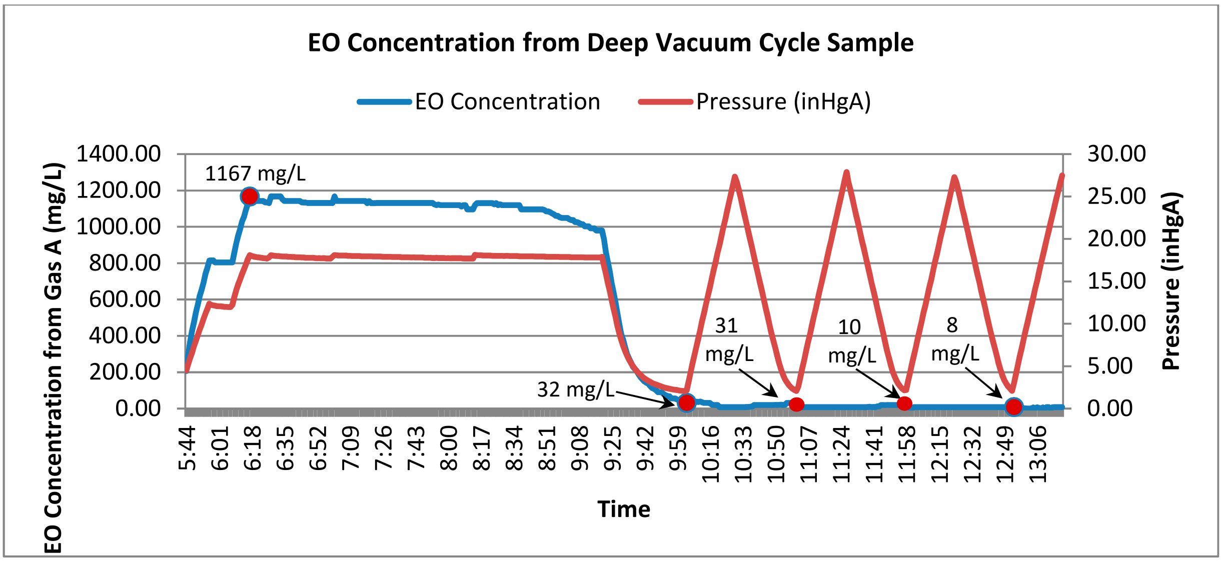

Figure S1. Ethylene oxide (EO) concentration in the chamber volume of a proprietary commercial sterilizer injected with 100% EO in relation to time, after application of 0–4 deep-vacuum cycles and subsequent corresponding air washes. The indicated residual EO concentrations are equivalent to 17,800, 17,200, 5560, and 4,440 ppm, respectively.

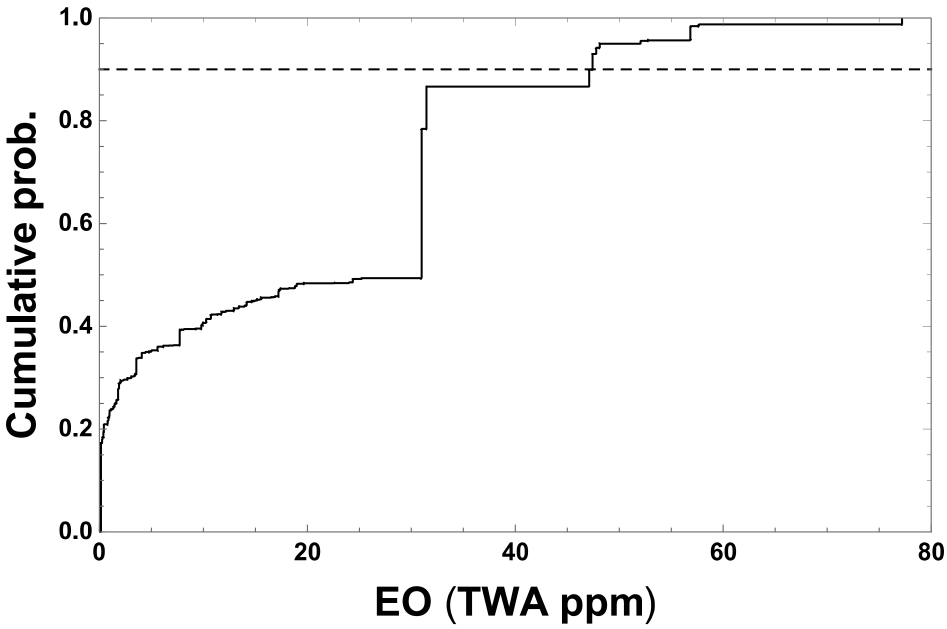

Figure S2. Cumulative distribution of NSR-model estimates of facility- and job-category-specific 8-hour TWA EO exposures in the NIOSH cohort of sterilizer workers during the year 1978 (n = 1,806), the first year for which such estimates were validated based on a large sample of personal-air EO measurements [29,30]. Dashed line shows 90th percentile.

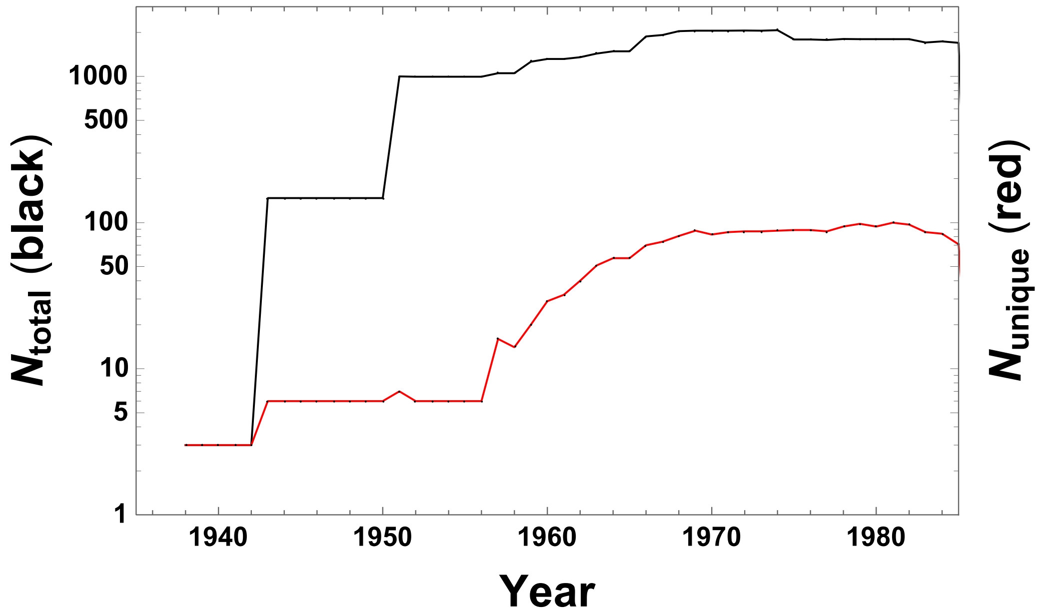

Figure S3. Total and unique numbers (N_{total} and N_{unique}, respectively) of NSR-model facility- and job-category-specific estimates of EO concentration (reported with three decimal digits of precision) to which NIOSH cohort members were exposed from 1938 to 1985 (data source: NIOSH [30]; Lehman [29]).

Table S1. Practices Relevant to Worker Exposure at 21 Spice Industry Sites in ~1978-1981.

Row	Site	Vstz (m3)	Nstz	Agent	Vent	Topen (h)	Stor	Tstor	Nvac	Vste (m3)	AERste	Vsto	AERsto
1	A	10.87	1	100	S	0	Y	NS	2	152.9	15.56	NS	NS
2	B	7.22	2	12	SA	1	N	0.25	1	815.5	4	NS	NS
3	C	8.83	1	12	A	2	Y	1.5	2	2038.8	1	NS	R
4	D	28.25	2	100	S	0.75	Y	5	NS	732.7	10.05	NS	NS
5	E	15.09	1	12	SA	0	N	5	3	4893.2	1.08	NS	NS
6	F	15.09	1	12	A	0.75	N	NS	2	2038.8	23.33	NS	NS
7	G	15.86	1	100	S	0	Y	NS	2	453.1	5.62	NS	NS
8	H	9.34	1	12	S	NS	Y	NS	1	199.4	10	NS	R
9	I	34.69	4	100	S	0.17	Y	NS	3	603.1	14.09	NS	4
10	J	7.93	1	12	A	0.33	Y	NS	2	2293.7	0.07	NS	4
11	K	7.45	1	12	S	0.33	NS	NS	3	1962.4	4	NS	NS
12	L	26.08	1	12	SA	0.5	N	2	3	11326.7	2	NS	NS
13	M	18.41	1	12	SA	0.51	N	2	3	11326.7	1	NS	R
14	N	7.96	1	12	A	0.33	NS	NS	2	1019.4	5	NS	R
15	O	11.19	1	100	S	0.17	N	NS	2	224.3	30	NS	NS
16	P	7.05	1	100	NS	NS	Y	NS	3	1186.9	12.17	NS	NS
17	Q	3.4	1	12	A	NS	N	NS	3	672.8	2	NS	NS
18	R	39.64	1	100	S	0.17	N	NS	3	815.5	10.42 R	NS	4
19	S	45.31	1	100	SA	0.17	N	NS	3	679.6	12.5 R	NS	4
20	T	31.15	1	100	SA	0.17	N	NS	3	611.6	13.89 R	NS	4
21	U	31.15	2	100	SA	0.5	N	Y	1	380.6	4	NS	NS
MEDIAN		15.09	1	~50% ea.	‘66% to sewe	0.33	N		2.5	815.5			
										2115.6	Average		
										3071.39	Average Stor = N		

Notes

Source: Goldgraben R, Zank N. 1981. Mitigation of Worker Exposure to Ethylene Oxide. Report prepared for the U.S. Environmental Protection Agency. MTR-80 W333, March 1981. The Mitre Corp., McLean, VA. Appendix C-10: Practices Relevant to Worker Exposure at Spice Industry Sites, pp. C153-C175.

stz = sterilizer

ste = sterilization room

sto = storage room

Agent = P (= P% EO)

Vent = S (sewer drain), A (atmosphere), SA = both

Topen = hr after end of sterilization cycle at which chamber door opened

(0.51 if noted that operator not present when door opens)

Stor= Separate storage room for treated pallets (Y=Yes, N=No)

Tstor = treated pallet storage duration (d); "short" estimated as 0.25 d

Nvac = # vacuum and/or air-wash cycles (max)

Vx = vol (x = stz, ste, or sto) reported in ft3 if unspecified (or in specified unit)---- here converted to m3 (see below)

AER = air exchange rate reported in cu ft/min if (cfm) if unspecified; per unit time if time unit specified; ---- here converted to fraction/hr (see below)

Open or Cross-Ventilated= 4/h, Passive= 2/h, R = PPE including respirator used

NS = not specifed (or not applicable if Stor = N)

Median numeric height (18 ft) over all sites is listed for Site B for which height was not reported

Reported ft3 here converted to m3; reported AER here converted to 1/hr

Average Value of a Linear-Model Single Compartment at Dynamic Equilibrium

A 1st-order (linear) input-output model $X(t)$ for which $\mathrm{d}X(t)/\mathrm{d}t = A\, k_{in}\, e^{-k_{\mathrm{in}}t} - k_{\mathrm{out}}\, X(t)$ has the solution $X(t) = k_{in}\, A(e^{-k_{\mathrm{out}}t} - e^{-k_{\mathrm{in}}t})/(k_{in} - k_{out})$, or $A\, k\, e^{-k\, t}$ if $k_{in} = k_{out} = k$, implying a corresponding $X(t)$ integral from $t = 0$ to ∞ (i.e., "area under the curve" or AUC) equal to A/k_{out} independent of k_{in}. In the case of repeated instantaneous inputs A at intervals t_A, with each input subject to loss at 1st-order rate k, at time t after the n^{th} input $X_n(t) = (A - X_{n-1}(t))e^{-k\,t} =$ $A(1-e^{-k\,t})/(e^{k\,t}-1)$, from which it can readily be shown that in the limit as $n \to \infty$ (i.e., at dynamic equilibrium) the TWA value of $X_n(t)$ over time $t = 0$ to $t = T$ is the input-to-output ratio $A/(k\,T)$, as required for any linear time-invariant closed (e.g., mass-conserving) system, including any one-compartment model with multiple inputs and outputs that occur at 1st-order rates k_{in} and k_{out}, respectively, as long cited and proven mathematically in the case of periodic inputs at equal time intervals (e.g., Levy [33]; Boroujerdi [32]). However, this result applies equally to the case of sets of N irregularly spaced inputs of equal magnitude A per averaging period, conditional on equal values of the product $N \times A$, as illustrated in Figure S4 using various values of N, A, and k_{in} conditional on k_{out} = 2/hour. Figure S4 was plotted using *Mathematica*® 11.0 software [31] to solve numerically for the function $X(t)$ defined as

$$\mathrm{d}X(t)/\mathrm{d}t \;=\; R_{\mathrm{in}}(A, k_{in}, N) - k_{\mathrm{out}}\, X(t), \;\; \text{where}$$

$$R_{\mathrm{in}}(A, k_{in}, N) = \sum_{j=0}^{n} \sum_{i=0}^{N-1} \Delta(t - i - j\; dt)\;\; A\, k_{\mathrm{in}}\; e^{-k_{\mathrm{in}}(t-i-j\; dt)}$$

in which A, N, k_{in}, and k_{out} were defined above, T = 8 h, (s) denotes a unit-step function increasing from 0 to 1 at time s, and the number n of repeated N-input cycles is sufficiently large (e.g., 15) to ensure attainment of approximate dynamic equilibrium after n cycles within a selected tolerance (e.g., 10^{-6}).

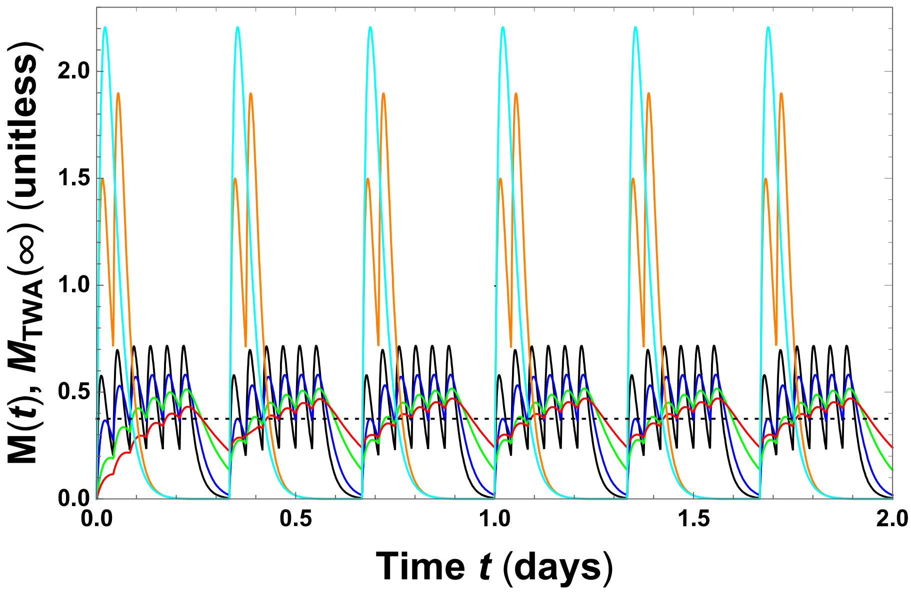

Figure S4. Plots of the function $X(t)$ using parameter sets $\{A, k_{in}, N\}$ = {1, 3, 6} (black, 3), {1, 1, 6} (blue, 3), {1, 1/3, 6} (green, 4), {1, 1/6, 6} (red, 7), {3, 2, 2} (orange, 2), {6, 1, 1} (cyan, 2), where after each parameter set the list (color, *m*) specifies a corresponding plot color and number *n* of cycles required to attain dynamic equilibrium within 10^{-6}. Note that in each case $A \times N = 6$, k_{out} = 2/hour, and $T = 8$ h. The dashed line shows that the TWA value $\bar{X}$ of each plotted function $X(t)$ over averaging period T at dynamic equilibrium has the same value, $\bar{X} = (A \times N)/(k_{out}\, T) = 6/16 = 0.375$, which is in each case the input-to-output ratio over time T.