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Socially Efficient Control of Carcinogen Emissions from Open Top Vapor Cleaners in Indiana

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Economics

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Emissions of air pollutants have been a matter of concern for many years. Section 112 of the 1970 Clean Air Act directed the Environmental Protection Agency to establish national emissions standards for hazardous pollutants (NESHAPS). By the late 1980s only seven NESHAPS had been established by the EPA under the authority of section 112. Dissatisfaction with the slow progress of regulation led to passage of much more stringent provisions in the 1990 revisions of the Clean Air Act. Under those provisions, 189 toxic pollutants are to be listed and controlled by the maximum achievable control technology (MACT). The goal of the regulations is the reduce emissions of these chemicals by 90% below uncontrolled levels by 2003. Many of the listed pollutants are carcinogens, and one source of some of these carcinogens in the atmosphere is industrial vapor cleaners. Some of these machines use carcinogenic solvents which escape into the atmosphere, and these solvents are to be listed and controlled by the EPA. In November 1992, the EPA is expected to publish new regulations for the solvents used in vapor cleaners. The expectation by state regulators is that emission reductions of approximately 90% will be ordered by the EPA.

Optimal control of an airborne carcinogen requires that each source of the carcinogen be controlled to the point where the Marginal Cost of Controlling emissions (MCC) is equal to the Marginal Damage from emissions (MD) that applies to that source. The MCC is likely to increase as the degree of control increases, and the most reasonable assumption seems to be that the MD is a constant for any given source. Thus, there will be a unique optimal level of control for a given source. Both the MCC function and the MD are likely to differ among sources, however. This means that the optimal amount of control will generally differ from source to source. Consequently, a uniform percentage reduction in emissions or a uniform rule for the type of control to be installed will be inefficient. Because MD's differ among sources, even a uniform emission charge would be inefficient.[2]

This paper examines the benefits and costs of controlling emissions from open top vapor cleaners in Indiana. Making use of EPA engineering estimates of costs and effectiveness of a variety of control technologies, I estimate a marginal control cost schedule for several representative cases. Using Indiana data on the location of open top vapor cleaners, and the GEMS (Graphical Exposure Modeling System) computer program for estimating exposure to risk by the population surrounding each source, I estimate the dollar value of the damage to society from the emission of each pound of solvent for each location. There are three main empirical results. First, the marginal control cost schedule is a step function, and in each of the eight hypothetical cases examined, the first branch exhibits negative marginal control cost. This means that it is in the financial interest of owners to install at least some controls. Second, because of differences in population density in the areas surrounding different sources, there is substantial variation in the marginal damage caused by the emission of a pound of pollutant, depending on the location of the source. Third, in six of the eight hypothetical cases examined, the first positive branch of the marginal cost of control schedule exhibited a marginal control cost above any plausible value for marginal damage. For these cases, the socially optimal amount of control would be carried out by profit-maximizing firms. For the others, socially efficient control is only slightly more stringent than that which would be carried out voluntarily. Furthermore, this optimal control is invariably less stringent than that proposed in the 1990 Clean Air Act.

Many manufacturing firms use machines called vapor cleaners to clean metal parts during processing. Vapor cleaners use special solvents (often carcinogens) to clean metal parts. In an uncontrolled environment, the vaporized solvents escape into the atmosphere, causing risks to persons in the vicinity of the facility. The amount of emission depends on how the machine is used (i.e., how many hours per week the machine is used to clean parts, how many hours it is turned on but not actually

cleaning parts (idling), and how many hours it is turned off) since emissions occur at different rates for different types of use. There are numerous control technologies that can be used individually or in combination to slow the rate of evaporation of the solvents (the EPA has proposed six such technologies). Because it is costly for firms to replace solvent lost from vapor cleaners, it may be privately efficient for them to install systems which recover some of the solvent. This is because the dollar value of the solvent recovered by using a control technology might exceed the cost of installing and using that technology. If this were to happen, the marginal cost of control would be negative for that control technology. However, because there is an externality, the socially efficient amount of control may be greater than the amount that it would be profitable for an unregulated firm to install. This would happen if the marginal damage were higher than at least some of the positive branches of the marginal control cost schedule.

Although it is possible to install any combination from one to six of the available controls on any machine, the proportional reduction in emissions is not the sum of the proportional reductions which the individual technologies would yield. Suppose controls 1 and 2 would separately reduce emissions by $R_1 = 90\%$ and $R_2 = 20\%$, respectively. Then the reduction obtained by installing controls 1 and 2 together would be $R_1 + (1 - R_1)*R_2 = R_1 + R_2 - R_1*R_2 = .9 + (1-.9)*.2 = .92$. Similar expressions apply to any combination of controls.

The EPA document[3] provides the information necessary to estimate the annualized cost of installing any control technology, given the operating schedule and given the size of the unit. Using the EPA estimates of proportional reductions in emissions for each of the control technologies, and assuming a particular operating schedule (a certain number of hours per year working, a certain number idling, and a certain number shut down) one can calculate the total reduction in annual emissions and the annual cost that could be expected from installing any package of one or more controls.

My procedure for calculating the Marginal Control Cost (MCC) is to determine the lowest cost order in which to add controls. First, assume a certain operating schedule (i.e., a certain number of hours of cleaning, idling and shut down) with no controls in place. Calculate the annual cost for each control technology alone. Calculate the recovery of solvent for each control technology alone. Calculate the recovery of solvent that each control would provide if applied alone. Net out the dollar value (evaluated at the purchase price) of the recovered solvent from the gross cost. Divide the net cost by the amount of recovered solvent (in pounds). Choose the technology with the lowest cost per pound. That cost is the first "step" of the Marginal Control Cost schedule. With that technology assumed in place, recalculate the net cost per pound of additional recovery for the remaining remaining technologies. The net cost per pound for each of the remaining technologies will be no lower than it would have been in the first round, and it will be higher for any technology which controls the same kind of emissions as the first technology chosen. Since the first technology chosen had, by construction, the lowest cost per pound of any technology, given no prior control, the lowest cost per pound of the remaining group must be higher than that for the first technology chosen. Thus successive steps of the MCC schedule must be ascending. Continue to add technologies from those remaining until all have been employed. The cost per pound of reducing emissions using each successive technology represents the *contingent* marginal cost (contingent on having employed the least costly contingent strategy in each previous step).[4]

One unusual result of the calculation of Marginal Costs for controlling emissions from open top vapor cleaners is that the first technology employed has a negative marginal cost in each of the eight hypothetical cases examined. As noted above, this happens because the dollar value of the solvent recovered because of control exceeds the gross cost of the first stage of control. Thus it would be in the interest of owners to undertake some control even if it were not required. Note also that, because of the way I constructed it, the Marginal Control Cost rises as the degree of control increases. Additionally, as one approaches 100% reduction in emissions, the Marginal Control Cost rises dramatically (in one case to over $20 per extra pound of emission reduction). While it would be possible in every case I studied to employ enough controls to reduce emissions by at least 80% (and usually more than 90%), the rapidly rising Marginal Control Cost schedule means that this would be inefficient unless the Marginal Damage from emissions was exceedingly high.

The results of using the EPA's control effectiveness, cost and operating schedule assumptions are shown in Table 1. The table shows eight MCC schedules. This corresponds to the possibilities when there are two possible operating schedules, two possible sizes of machine, and high and low estimates for the control effectiveness of some control technologies. Figure 1 illustrates graphically how the MCC increases as successive controls are added for case 1.

TABLE 1

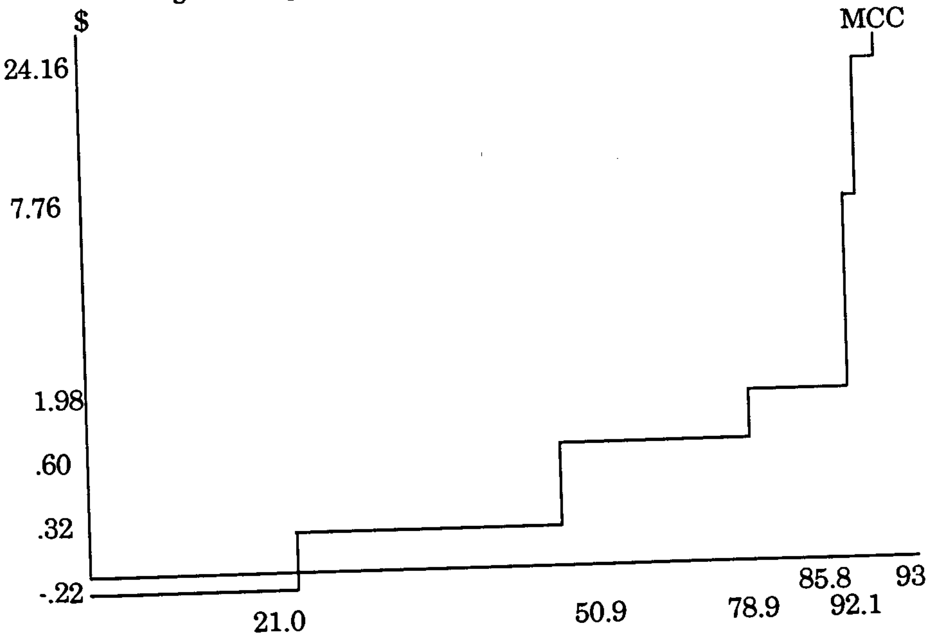
Marginal Cost of Control Schedules for Eight Scenarios

Case	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6	
	% Red.	MCC	% Red.	MCC	% Red.	MCC	% Red.	MCC	% Red.	MCC	% Red.	MCC
1	21.0	-.22	50.9	.32	78.9	.60	85.8	1.98	92.1	7.76	93.0	24.16
2	20.4	-.21	41.9	.38	69.9	.60	77.0	2.58	85.2	6.48	86.4	16.37
3	21.0	-.32	73.4	-.25	84.6	.40	92.7	1.52	95.8	7.45	96.5	15.18
4	19.3	-.31	73.1	-.25	79.5	.99	87.5	1.52	92.3	4.72	93.0	14.91
5	26.6	-.10	54.6	-.05	70.0	.001	85.8	.87	91.1	2.86	92.4	6.66
6	26.6	-.10	54.6	-.06	70.0	.01	81.0	1.17	85.2	4.33	86.4	7.15
7	66.4	-.34	81.9	.14	90.0	.21	92.7	1.23	95.8	2.11	96.5	5.98
8	66.4	-.34	74.4	.21	81.1	.27	88.5	.67	92.3	1.80	93.0	5.87

Case 1: Small, Op. Sched. A, High Est.
Case 2: Small, Op. Sched. A, Low Est.
Case 3: Small, Op. Sched. B, High Est.
Case 4: Small, Op. Sched. B, Low est.
Case 5: Large, Op. Sched. A, High Est.
Case 6: Large, Op. Sched. A, Low Est.
Case 7: Large, Op. Sched B, High Est.
Case 8: Large, Op. Sched. B, Low Est.

Small = 4.5 sq. ft. in area; Large = 16.0 sq. ft. in area. Op. Sched. A = Work 2 hrs. per day, five days per week; idle 6 hrs. per day, five days per week; shut down the rest of the time. Op. Sched. B = Work 12 hrs. per day, five days per week; idle 4 hrs. per day, five days per week; shut down the rest of the time.

Fig. 1. Marginal Control Cost Schedule for Case1.



Because of the cooperation of the Indiana Department of Environmental Management (IDEM), I was able to obtain data on the location, size, hours of operation, current controls of place, type of solvent used, and many other facts about the open top vapor cleaners in use in Indiana. In addition, I employed the PC version of the Graphical Exposure Modeling Systems (PC–GEMS). This program, developed under contract to the EPA, uses location of the source, height of the exhaust stack, type of solvent, speed at which pollutants exit, and quantity of emissions to estimate the ambient concentration of the solvent in regions surrounding the source. Using population density in the surrounding regions and cancer dose-response estimates for the solvent, GEMS then calculates an estimate of the number of cancer deaths the persons surrounding the source could be expected to suffer during their lifetime due to one year's exposure to the solvent at the ambient level that results from that source's annual emissions. If one multiplies this by an assumed dollar value for the saving of a "statistical" life, the result is the total dollar value of cancer damage from a year's worth of emissions from the source in question. To obtain the damage per pound emitted (Average Damage), divide by the number of pounds emitted in one year. Since the dose response curve is usually assumed to be linear, the Average Damage will be constant and equal to the Marginal Damage.

For illustrative purposes, I assumed a value of life-saving of $3 million per life.[5] Assuming the solvent is Trichloroethylene (the most common of the carcinogenic solvents considered), the Marginal Damage per pound emitted per year ranges from $.001 to $.04, with an average of $.014. Except for the two cases of the large lightly used cleaner, these Marginal Damages fall below the lowest positive Marginal Control Costs.

Although exposure factors differ among sources by a factor of about 45, the optimal amount of control of open top vapor cleaners in Indiana is usually unaffected by the level of exposure. In most cases, the amount of control that would be undertaken by a well-informed profit-maximizing firm is the socially optimal amount. This is because (with "reasonable" assumptions) the Marginal Damage caused by the emission of a pound of solvent is usually substantially less than the level of Marginal Control Cost when it first becomes positive. The policy implication seems to be that the best strategy, at least in Indiana, is to inform owners of open top vapor cleaners of the benefits, in the form of reduced solvent purchase costs, of certain controls, depending on the size and operating schedule of the machine. Then they should be allowed to decide for themselves what the proper level of control is.

NOTES

1. I wish to thank the Holcomb Research Institute (HRI) for generous support of this project during the summer of 1989. I also wish to thank the Indiana Department of Environmental Management (IDEM), particularly Bob Bierman and Barry Titus, without whose help and encouragement this project would have been impossible. In addition, I wish to thank an anonymous referee and Albert Nichols for valuable comments and J. Patrick Meister for research assistance and counsel. Candee Carter generously helped me understand how vapor cleaners are used in practice. The opinions expressed in this paper are mine and do not necessarily reflect those of HRI or IDEM, nor should they be held responsible for any errors.
2. Nichols, *Targeting,* Chapter 6, especially pp. 85–86.
3. U.S. Environmental Protection Agency, *Alternative Control Technology Document.*
4. Albert Nichols has pointed out to me that this procedure only approximates the true marginal cost of control schedule. It ignores the possibility of intermediate steps in the control process. For example, suppose uncontrolled emissions are 100, and there are two control technologies, A and B. Suppose A alone would reduce emissions by 80 at a cost of $400, or $5 per unit, while B alone would reduce emissions by 90 at a cost of $630, or $7 per unit. My procedure would have two steps. The first would be to reduce emissions by 80 with a marginal control cost of $5 per unit (A), and the second would be to increase control from 80 to 98, by adding control B to control A, at a marginal cost of $35 per unit. Nichols points out that an intermediate step would be to employ B *instead of* A and increase control from 80 to 90, at a marginal cost of $23 per unit. Then the move from an emission reduction of 90 to 98 would be accomplished by adding back control A, at a marginal cost of $50 per unit. My $35 marginal control cost is the weighted average of $23 and $50. Thus my approach is cruder than the correct approach. Instead of three steps of $5, $23 and $50, my marginal control cost schedule has two steps of $5 and $35. This could perhaps increase the amount of control which firms would carry out on their own, but it would not change the main conclusions of the paper.
5. Nichols, *Targeting,* at 136, argues that it is difficult to rule out values per life saved of from several hundred thousand dollars to several million dollars. A figure of $1 million to $2 million in 1980 dollars, while high, is not completely unbelievable. Thus a figure of $3 million in 1989 dollars is, while probably on the high side, conceivable. Note the reasoning used by Bailey, *Reducing.*

REFERENCES

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