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Assessment of the need for low emission performance standards for residential wood-burning devices in the airshed of Missoula Montana

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An Assessment of the Need For
Low Emission Performance Standards
For Residential Wood-Burning Devices
In the Airshed of Missoula, Montana

By

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The problem of air pollution will never be 'solved'. But if man is willing to recognize that the problem exists, if he is prepared to bring to it his political wisdom, scientific knowledge, and technological skills, and if he is willing to work with nature instead of against it, then he can leave for his children and his children's children something more valuable and more necessary to human life than any of the manufactured products of his civilzation. He can bequeath to them the blessing of clean air.

American Association for the Advancement of Science, 1965, <u>Air Conservation: A Report</u>

Therefore, the necessity for a general awakening to the nature, sources, dangers, costs, and means of control of air pollution . . . and for a widespead assumption of private and public responsibility persists. Recent developments notwithstanding, [once again] virtually everything remains to be done in order to remedy air pollution in Missoula.

G.L.Owen, 1968, <u>Air Pollution in Missoula</u>

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Introduction

During February and March of 1980, the air quality sampling program in Missoula, Montana, was carried out as usual. However, some of the collection filters from this period were subjected to more than the usual examinations. Filters from 12-18 days were submitted to four different laboratories for extensive analysis. The days tested were assumed to be representative of a typical winter, so that from the results of these tests it was possible to determine the major sources of Missoula's wintertime particulate pollution.

The results of the four independent analyses manifested strikingly similar findings. Although the specific categorical designations were different in each study, they all generally concluded that residential wood burning (RWB) was <u>the</u> major contributor to Missoula's wintertime total suspended particulates (TSP). In addition, the three studies which differentiated for particle size found that between 68 and 76% of the highly respirable particles less than 3.5 micrometers were generated by RWB. These findings may even be low due to the sampling procedures used.

These results were made public in November 1980 in a series of front page newsstories that also described the health risks associated with this type of air pollution. Consequently, several hundred people attended the November 13 meeting of the Missoula City-County Air Pollution Control Board (Board), at which the findings were presented to the Board, to see and hear what could be done to alleviate the problem. From that beginning, four committees of interested citizens were established and charged with examining the problem, and making recommendations as to what could be done so as to meet the Board's goal of reducing the average levels of TSP during each subsequent winter. The four committees studied (1) residential wood burning, (2) health effects related to Missoula's air pollution, (3) transportation related pollution, and (4) future problems and solutions. I served on the RWB committee.

The four committees met throughout the winter of 1981 and issued a number of reports and recommendations in April 1981. The major focus of this work is examining the urgency and need of one of those recommendations, the establishment of low emission performance standards for residential wood-burning devices. In addition, three other of the committees' recommendations will be examined insofar as they relate to the main focus. The specific topics that will be reviewed are as follow.

(1) All four committees urged the establishment of a massive, comprehensive public education campaign regarding the nature and causes of, possible solutions to, and health risks associated with Missoula's wintertime air pollution. The potential effects of the public education program that has been initiated will be evaluated.

(2) Two committees recommended revising and making more stringent Missoula's existing Air Stagnation Plan, which is designed to alert the public to the health risks associated with serious air pollution episodes and stimulate actions to keep air contaminant levels from rising

further. Such action has been initiated. Now however, the revised pl has been singled out by a small, organized special interest as being both the only necessary action (other than education) to solve the problem, and as their administrative and/or judicial test case issue t assay the strength of their position opposing regulation. For these reasons, I will briefly address the changes in the plan in relation to the need for wood-burning performance standards.

(3) The RWB committee urged the establishment of a system to license the use of residential wood-burning devices (RWD's) within the Missoula airshed. This was conceived as a method to generate monies t fund the other aspects of the recommended program. The need for such a system, as it relates to performance standards, will be examined.

(4) The RWB committee also recommended establishment of a New Source Performance Standard (NSPS) for all residential wood-burning devices in the Missoula airshed. The standard proposed would establish particulate emission limitations for new RWD's such that no new installation could emit more than a given amount of pollutant (i.e., particulate) per unit of wood burned. Probing the need for and possib effects of such a standard makes up the body of this work.

It must be noted from the outset that standards such as NSPS are not applied in "vacuum," and must be examined within the context of other changes that might occur. The focus of this work on NSPS should not be construed as negating the importance of other ideas for reducing Missoula's air pollution. In addition, the following discussion cente almost exclusively on suspended particulates. This is due primarily t the availability of this type of data, and is not intended in any way to diminish the importance of the need to consider other criteria pollutants. Instead, the presence of particulates and especially those in the respirable range, should be viewed as an indicator of the presence of other substances associated with them. The relationship of these other substances, which also result from combustion processes (e.g., a number of carcinogenic and co-carcinogenic compounds), is well documented in several recent studies.

The decision in this matter now rests with the Board. It (they) must choose whether to act upon the recommendations, what limitation on emissions to use, and the effective date of the regulation. The purpose of this paper is to assess the need for the establishment of NSPS in terms of the potential impacts on particulate emissions of the alternatives before the Board in 1981. This assessment is intended to provide the Board with some of the information necessary to render these important decisions. Because the Board is the specific intended audience, matters with which they are intimately familiar are assumed to be known, and will not be explicated in detail.

Chapter 1

The Missoula Airshed--A Shrinking Resource

Changes Since The Good Ol' Days

By 1917, Missoula was a thriving city of about 18,000 with cheap electric power from the Milltown dam and 22 miles of electric street railway track. Everything was within easy walking distance, and the business district was heated by centrally generated steam. A gas plant supplied heat and light to "those preferring it."[1] Missoula had been dubbed the "Garden City" and toasted as the "cleanest city in the northwest."[2]

Many things have changed since then, for it is no longer possible to see "many snow capped and wooded mountains, visible at all times through the clear atmosphere," as was declared possible in a 1917 publication.[3] Energy sources have changed, business has boomed and subsided, and the population has more than tripled. Means of transport have been revolutionized, and the "several miles of paved streets" have become at least several hundred.[4] The use of coal waxed and waned, lost to the clean convenience of piped natural gas and electric resistance heat. The city kept growing and changing and simultaneously lost more and more of its reputation for pristine beauty.

By the early 1960's, Missoula was being unfavorably compared to

Los Angeles. In 1964, L.A.'s air pollution control officer came to Missoula for a seminar on air pollution. During that proceeding he said, "I smelled something . . . this morning that if it was smelled by a large portion of . . . the people in L.A., the switchboard down at the office would light up like a Christmas tree . . . until it was reduced."[5] Since then, even more has changed. Population has grown and pollution sources have become more numerous.

What follows then is an inquiry, from various perspectives, into the sources and nature of Missoula's particulate air pollution during the last twenty years. Examination of earlier periods is not possible owing to the lack of data. In fact, as will be seen in due course, even the data from the first comprehensive study of the air in Missoula (1961-62) are not particularly reliable. However, it is from this study that all data points begin. Not coincidentally, this is also about the same time that one long time Missoula resident recalls as being the worst he ever saw.[6] However, others claim the worst air ever was last winter (1980-81).[7]

The difference in these contentions is the heart of the present controversy: is the air now as bad as it was during the bad old days before the advent of industrial air pollution control? Constructing a partial answer to that question is one of the aspects of this work. But that answer can not be definitive, because no reliable samples of the collection filters from those days have ever been carefully analyzed. However, it is possible to look at the historic sources of Missoula's air problem and the difference in the nature of the pollution they produced. From this information, it will be possible to make some logical deductions as to the answer to the preceding question. Understanding this answer is essential to appreciating the differences in air pollution then and now.

A Limited Airshed

It has been said that Missoula wouldn't have an air pollution problem, except for the weather, and that may well be true.[8] This sent ment stems from our location in a mountain valley which has both the advantage of mild winters and the concomitant disadvantage of being sub ject to frequent thermal inversions. Unfortunately, the urban area mus remain where it is, constrained by the natural limitations of its clima

Inversions are defined as "a departure from the normal decrease in temperature which is usually associated with an increase in altitude."[9] During an inversion, a layer of cold air (the inversion layer) of varying thickness or depth becomes trapped below a layer of warm air. This disrupts normal atmospheric dispersion by interfering with the vertical mixing that ordinarily occurs due to the rising of warm air. This creates an envelope of stagnant air which must absorb and contain whatever contaminants are discharged into it until the stagnation is dispelled. Unfortunately, in the Garden City, thermal inversions are a normal and very frequent occurrence.[10]

To appreciate what happens in the Missoula airshed during an inversion, it is necessary to understand the variation in the thickness of the layer of available air which becomes trapped and stagnant. This depth is measured from the ground surface to the height at which normal temperature decrease (with increased altitude) once again begins to occur. This level is called the mixing height and its altitude represents the ceiling or lid of the inversion layer. The volume of air under this lid is the bowl into which we spew all our air contaminants and the same space in which we all must live. Consequently, the size of that volume is critical to any consideration of the potential pollutant concentrations that may result from what is being put into Missoula's air for us all to breathe.

Air dispersion in Missoula was examined from May 1978 through November 1979 as part of the Montana Air Pollution Study (MAPS).[11] Data from a one year segment of that study (July 1978 - June 1979) show that although thermal inversions are a common occurrence in Missoula, there is great seasonal variation in the average altitude of the inversion ceiling. This means that the volume of air under that ceiling varies as well, with the volume being least during the winter.

Computing from the MAPS data, the arithmetic means of the average morning and afternoon mixing heights show that the inversion ceiling is 67.5% lower during the winter than during the rest of the year. This means that the thickness of the winter inversion layer (the depth of our bowl) is only about 1/3 that of the rest of the year. But what of the other aspects of the volume?

If the airshed were like a box, the volume would vary directly proportionally to the height of the lid. But since the Missoula valley is not as regular as a box, estimating the variations in the volume is quite complex. To make this determination, I consulted a computer expert who was interested in the problem and had been developing a program to answer this same problem.[12] Based on his programmed digitization of the land elevations in and around the Missoula valley, the computer was able to provide estimates of the airshed volumes under different mixing heights. The results went even further toward explaining our winter air pollution problem.

Based on an average yearly morning and afternoon mixing height of 1075 meters above ground level (AGL)[13], the average volume of the Missoula airshed is about 152.7 cubic miles (see Appendix A for a description of the area used in the calculation). However, during the winter when the average morning and afternoon mixing height is only 349 meters AGL[14], the average airshed volume is reduced to 29.5 cubic miles, which represents a reduction of 80.7%. This means that during the year that was monitored, the average wintertime volume of the airshed was about 1/5 the size it was the rest of the year.

These calculations are based on estimates and averages of the conditions that occur in this valley, but they still provide an adequate model to illustrate one of the "natural causes" of Missoula's wintertime air pollution. Additionally, due to the virtual absence of vertical mixing, and decreased horizontal air movement during prolonged inversions, the air within our airshed cannot move from place to place as usually. Therefore during extended inversions, since cleaner air from outside the city cannot move in and either disperse or dilute pollutants, the effective volume of the air that is available to breathe and into which pollutants can be discharged, is even less than the volume calculated above.[15]

Growth in the Number of Users

Another aspect of the current air pollution problem is the size of the population within the airshed and the sheer number of polluting sources. To put this aspect into perspective, I assembled the data in Table 1. It shows the urban area populations of both people and motor vehicles for four years in the past and projections for two years in the future. It also shows the annual average volume of available air over time on a per vehicle, per household, and per capita basis.

The table demonstrates that there has been tremendous growth in the numbers of both people and motorized vehicles, with a concurrent decrease in the "share" of the air available to each. For example, reading the last two columns to the right shows that there was a decrease of about 39% in the "per capita air supply" from 1960 to 1970. In addition, those people in 1970 were sharing the air with 66% more motor vehicles. A computation from the data in Table 1 that reveals, <u>from 1960 to 1980 there was a 112% increase in Missoula's population and a 246% increase in the number of motor vehicles.</u>

Certainly these changes due to growth represent a basic difference in many conditions then and now, including air pollution. Presently, there are many more pollution sources and breathers competing for clean air. The resulting decreases in available air are graphically illustrated in Figure 1 (page 12).

The graphs in Figure 1 show the effects of increasing the number of users of a fixed volume of air by using two sets of labels on the vertical axis. The whole numbers in increments of 10 represent the thousands of users of Missoula's air. The exponential numbers show the number of cubic miles of available air.

Clearly, since 1960, growth alone has dramatically altered the situation for users of the limited airshed. As the graph illustrates,

Table 1

The Missoula Airshed--Average Yearly Available Volumes Over Time

						Airshed Volume (mi^3)--Yearly Average[a]					
Year	Population[b]	% >	No. of Vehicles[c]	% >	H.S.[d]	Per Vehicle ($x10^{-3}$)	% <	Per Household ($x10^{-3}$)	% <	Per Capita ($x10^{-3}$)	% <
1918	18,000[e]	-	I.D.[f]	-	I.D.	-	-	-	-	8.49	-
1960	30,907	71.7	18,050	-	I.D.	8.46	-	-	-	4.94	-41.8
1970	50,669	63.9	30,047	66.5	3.08	5.08	-39.9	9.28	-	3.01	-39.0
1980	65,476	29.2	62,493[g]	10.8	2.49	2.44	-51.9	5.81	-37.4	2.33	-22.6
1984	68,502	4.6	69,818[g]	11.7	2.49	2.19	-10.49	5.55	- 4.4	2.23	- 4.4
1990	73,042	6.6	82,448[g]	18.1	2.49	1.85	-15.3	5.21	- 6.2	2.09	- 6.2

[a]Assume an average airshed volume of 152.74 cubic miles.

[b]Population of the Missoula urban area. Source: historic census data, 1980 census data, and projections by the State Department of Community Affairs, Helena, Montana.

[c]Source: Registrar's Office, Motor Vehicle Division, Department of Justice, Deer Lodge, Montana. Assumes the Missoula urban area contains 80% of county wide vehicle registrations, which would exclude all out-of-county vehicles traveling through Missoula.

[d]Household size, the average number of persons in each household.

[e]Missoula Chamber of Commerce, 1918.

[f]I.D. = insufficient data.

[g]Assume a growth rate of 2.81% per year (half the average growth rate for the year 1960-75) added to the vehicle count for 1978 which is the last year such information can be discerned from the available data.

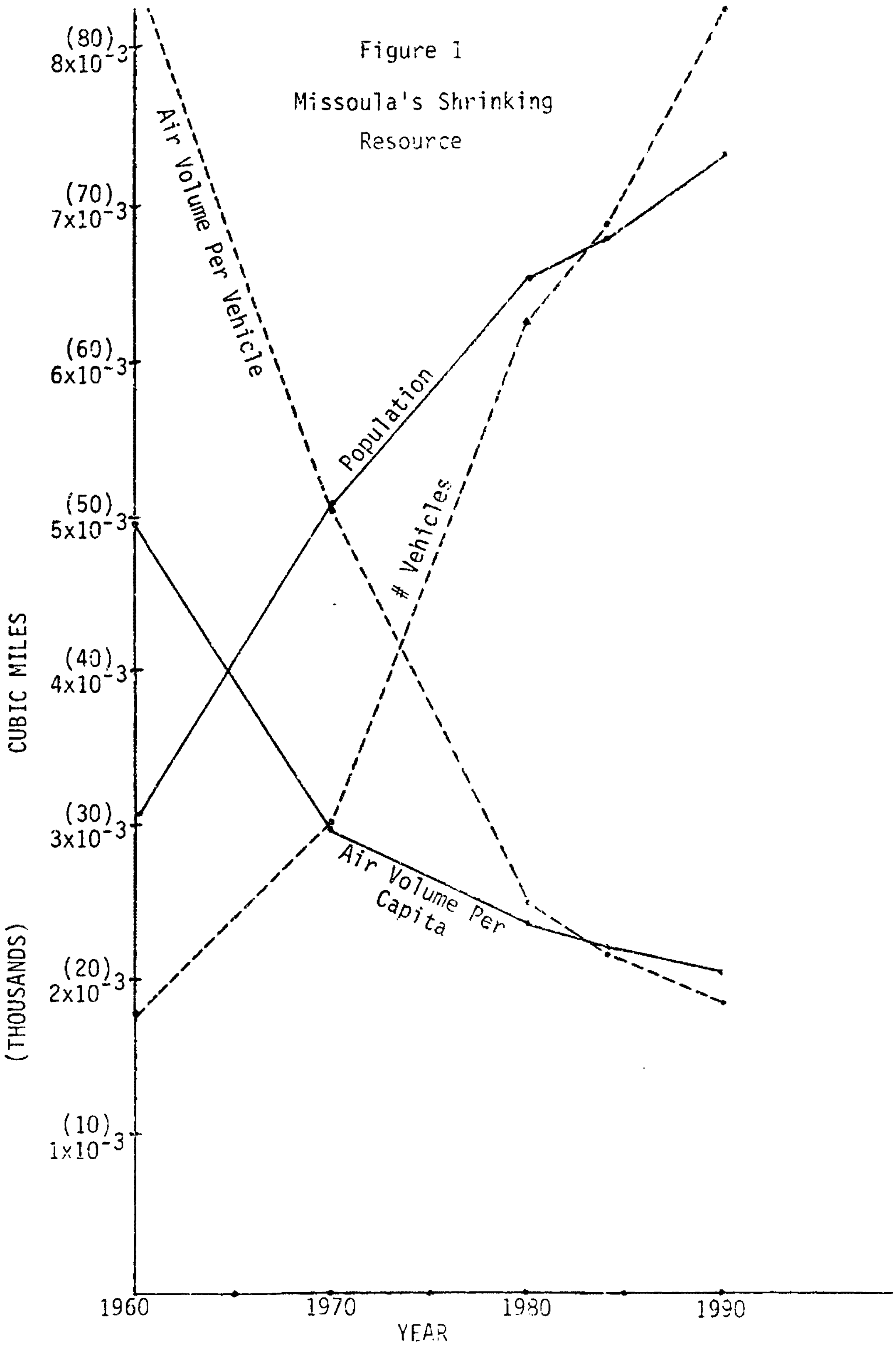


Figure 1
Missoula's Shrinking
Resource
(80) 8x10-3
(70) 7x10-3
(60) 6x10-3
(50) 5x10-3
(40) 4x10-3
(30) 3x10-3
(20) 2x10-3
(10) 1x10-3
CUBIC MILES
(THOUSANDS)
Air Volume Per Vehicle
Population
Vehicles
Air Volume Per Capita
1960
1970
1980
1990
YEAR

based on the model of available air in an annual average fixed volume, in the last twenty years the volume has decreased 52.8% per capita and 71% per vehicle, while the number of breathing people has more than doubled. Although the resulting effects on air quality can not be quantified beyond general comparisons, the growth in the very number of users of the airshed would seem to represent a fundamental difference between "then" and "now." This substantive difference stands alone as an appropriate reason to look at our present situation in order to assess thoroughly the legacy we are planning for breathers and other constituents of our environment during the next twenty years.

Changes in Sources of Emissions

In addition to the increases that have occurred in the numbers of "air-using" populations of the valley, there has also been a shift in the sources of air pollution. This change can be seen by a review of several historic emission inventories of source categories within the Missoula airshed. These are compiled in Table 2. The numbers shown in this table stem from two major sources, with updates and recalculations of several of the key figures.

As noted in the table, the 1961 data are from the first comprehensive study of the air in Missoula, conducted by the State Board of Health (SBH 1963). This study was extensively reviewed, and because some of the numbers seemed questionable, attempts were made to verify them. Unfortunately this could not be accomplished because apparently no records from this study still exist. However, in discussing the report with a representative of the Montana Power Company, I discovered that several of the values used in key computations were grossly in error.[16] In addition, discussion with members of the Missoula City-County Health Department's Air Quality Unit (AQU) led me to question the validity of the "measured" values as well, due to the sampling methods used and the lack of quality assurance prevalent in the early days of air pollution monitoring. Consequently, the data from this source are presented for comparison purposes, because they are the only such figures available. They should be taken only as indicators of the emission levels of that time and not as precise values.

The other major source of the information in Table 2 is the 1981 Church study of residential wood burning in the Missoula valley. Except where noted, all the figures for 1974 and 1980 are from that report. The changes represent updated figures for industrial (point source) emissions, and a recalculated estimate of the contribution from residential wood burning for 1980. This recalculation utilized the amount of wood burned estimated by Church, but applied a very different set of emission factors for particulates (i.e., the pounds of pollutant generated by each ton of wood burned). These critical factors will be discussed later in this report.

Table 2 shows that since 1961 a dramatic shift has occurred in the sources of Missoula's wintertime particulates. The qualifications of the 1961 data (stated above) notwithstanding, there is still a strong indication that the major contributors at that time were industrial point sources. This is not surprising given the lack of air pollution control generally, and the extent to which the numerous wood mills were simply burning their waste products. When these conditions changed, due

Table 2

Winter Months Emission Inventory--TSP (120 days)

	1961[a]		1974[b]		1980[b]	
Source	Tons/Day	% of Total	Tons/Day	% of Total	Tons/Day	% of Total
Industrial	19.45	82.4	4.89	50.1	5.90[c]	27.0
Resident. Fuel[d]	1.76	7.5	1.08	11.1	1.24	5.7
RWB	1.32	5.6	2.05[e]	21.0	11.97[f]	54.7
Transportation	1.07	4.5	0.49	5.0	0.61	2.8
Unpaved Roads	I.D.[g]	--	0.75	7.7	0.47	2.1
Paved Roads	I.D.	--	0.51	5.2	1.70	7.8
TOTAL	23.6	--	9.77	--	21.89	--

[a] Source: SBH, 1963. Values shown for industrial sources do not include fugitive sources or substantial emissions from the pulp mill, see notes 19 and 22; other figures somewhat uncertain, see text.

[b] Source: Church, 1981, except as noted.

[c] Source: Air Quality Bureau, Department of Health and Environmental Sciences, Helena, MT. Point source total excluding asphalt plants. The difference in the point source totals for 1974 and 1980 are due in part to the exclusion of the emissions from the Champion facilities in Bonner and Frenchtown in the former, and their inclusion in the latter. The change was made because both operations affect TSP in the airshed, a fact reflected in their inclusion in the official Missoula Air Stagnation Zone. See Appendix A.

[d] residential fuels other than wood

[e] This figure is probably quite low, stemming from the use of conservative emission factors.

[f] This figure was derived using data from Church, 1981 in conjunction with emission factors developed in WMSCPI, 1981. See Appendix B.

[g] I.D. = insufficient data

to the advent of both hog fuel boilers that use the "waste" wood and the installation of pollution control devices, there was a substantial reduction in particulates from these sources. Consequently, the fraction of total particulate emissions from point sources was reduced significantly by 1974 and again by 1980. Although a strict comparison of the actual outputs is not possible (due to the uncertain quality of the 1961 data, if not that of 1974[17]), the reduction is clear.

Also apparent from Table 2 is the dramatic rise in residential wood burning's contribution to wintertime particulate pollution. Again, direct comparisons can not be made, due to the uncertainty of the 1961 data and the "reduced" nature of the 1974 figure (see note e). Were the 1974 figure corrected[18], the increase in wood burning from 1961 to 1974 would be even more dramatic and the increase from 1974 to 1980 would not be as marked. However, it is still quite clear that a shift in responsibility for Missoula's wintertime particulate has occurred. Where residential wood combustion was but a minor contributor in 1961, by 1974 it had moved into second place and by 1980 had taken the lead. This fact is no longer news to Missoula, but the rest of this table might be.

A look at the total outputs in tons of particulate per day reveals that by 1980, total particulate emissions were approaching the level reached in the days before the advent of point source pollution control. And this fact remains, in spite of the uncertainty of the 1961 data, which was almost certainly biased towards the low side.[19] The significance of this finding becomes even more pointed when the probable size of the particulates is considered.

This aspect of the problem was brought to light by the 1961

Pennsylvania report that was the main source document for the 1963 SBH study. This work, "Pure Air For Pennsylvania" is still cited in recent USEPA documents.[20] According to this paper, the geometric mean size of particles from conical wood burners (teepee burners) was about 16 micrometers in diameter.[21] Since such burners were one of the main sources of Missoula's particulate pollution in 1961, this may be a reasonable estimate of the average size of particles from fuel combustion at that time.[22]

In contrast, recent studies have documented that the mean size of particles generated by residential wood burning is in the highly respirable range of less than 2.5 micrometers.[23] Additionally, the particulates that are still emitted by industrial point sources are also generally in this size range, because fine particles are much more difficult to control.[24] Particle size then is an important difference, because as the total emissions (i.e., tons emitted) of smaller, lighter particles begin to approach the same mass as previously reached by larger, heavier particles, the resulting pollution may be worse, due to the much greater number of very small, breathable particles.

Based on this significant difference in size distribution, it can be concluded that the nature of the particulate pollution now is different, with an increased potential for causing adverse health effects.[25] Therefore, it would seem that during the last ten years, Missoula's air quality has been regressing even further from healthful, clean air, back towards the levels of particulate emissions of the time prior to the advent of point source pollution control. But now the effects of those particulates may be even greater.

Historical Wintertime TSP

Table 3 is a compilation of the levels of total suspended particulates (TSP) that have been measured in Missoula's winter air.

Table 3

Wintertime TSP Levels[a] (ug/m^3)

Winter	Nov.	Dec.	Jan.	Feb.	Arithmetic Average	Days >150 ug/m^3
1961-62[b]	312	144	151	182	197.25	--
1970-71	87	75	64	161	96.75	--
1971-72	85	66	62	103	79.0	--
1972-73	99	59	94	108	90.0	--
1973-74	55	73	66	135	82.25	--
1974-75	76	98	77	81	83.0	--
1975-76	92	94	116	108	102.5	$\geq$14
1976-77	110	153	118	148	132.25	40
1977-78	109	86	94	119	102.2	$\geq$16
1978-79	111	68	122	86	96.75	19
1979-80	118	94	96	145	113.25	20
1980-81	95	101	103	93	98	18

[a]Courthouse roof.

[b]Source: SBH, 1963; accuracy uncertain.

The levels shown in Table 3 are the averages of concentrations that occurred in the ambient air as the result of the combination of particulate emissions and meteorological conditions. As indicated earlier, the importance of meteorology in this situation can not be overstated. In fact, the complexity of the weather's contribution precludes all but general comparisons of the figures shown in Table 3. The levels themselves can be compared, but the relationship between them and total emissions can not be fully explained. Consequently, while it can be said that the winter of 1976-77 was the worst in recent years in terms of days with high concentrations of particulates, that does not reflect upon the fact that the total emissions of particulates during the winter of 1979-80 were greater. As a result, no specific predictions of ambient air quality in the Missoula airshed can be made based on the predicted output of particulates. However, the following observations are reasonable:

(1) Missoula has had higher wintertime particulate concentrations during the past few years than during the early 1970's.

(2) As stated in the previous section, the current particulate pollution may be fundamentally different and more dangerous due to the increasing presence of respirable particles.

(3) The pattern of change in pollution roughly corresponds to growth in the use of wood for residential heating, and that growth is continuing.

(4) Further growth in residential wood burning will continue to increase the total particulate load into the Missoula airshed, and this will increase the potential for higher concentrations of particulates to occur.

(5) Exactly when high particulate concentrations will occur cannot be predicted, but if the expansion of the problem remains unchecked, Missoula's air quality and the health of her people will continue to be left to the whims of the weather.

Footnotes

1. Missoula Chamber of Commerce, 1917, Montana's Garden City, Missoula, MT.

2. Ibid., pg.6

3. Ibid., pg.3

4. Ibid.; and Robert Holm, Missoula County Engineering Supervisor

5. Western Montana Medical Society, 1965, Pollution Seminar Proceedings: Missoula, MT. December 2 and 3, 1964

6. R.B.Lewis, 1981, personal communication

7. Lyle Berg, 1981, personal communication. This claim was erroneous.

8. Jim Carlson, Missoula City-County Health Department, 1981, personal communication

9. Harold Robbins et al., 1980, "Missoula Valley Dispersion Study," Montana Air Pollution Study, Air Quality Bureau, Environmental Sciences Division, MDHES, Sept, 1980

10. Conclusion based on Robbins et al., 1980

11. Robbins et al., 1980

12. Robert Boldi, Environmental Studies Laboratory, University of MT.

13. Robbins et al., 1980

14. Ibid.

15. Ben Myren, 1981, statement at Board meeting of 8/20/81, Air Sampling Technician who worked on the MAPS study

16. Don Mourich, Montana Power Company, 1981, personal communication; discussion revealed that the estimated use of natural gas was far beyond the range of possibility, being about six times greater than the amount used during 1980.

17. The 1974 data are based on projections made by PEDCo Environmental, Inc. of the numbers of people burning wood. I feel their results are questionable due to their total dependence on computer modelling.

18. This figure cannot be corrected and still be meaningful due to the obscurity of the original projections and the need to apply different emission factors to different types of wood-burning devices.

19. This assessment is based on examination of a subsequent report in which all pollution sources in the valley were considered. This was not done in the 1963 SBH report which only estimated pollutant outputs from the pulp mill. When Owen (1974) updated the 1961 emission inventory, he found that the total paticulate output into the airshed during 1961 was about 29.6 tons/day. See Owen, 1974, Table 2, page 24

20. USEPA, 1977, Compilation of Air Pollution Emission Factors, Third Edition, Office of Air and Waste Management, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.

21. David M. Anderson et al., "Pure Air for Pennsylvania--A Joint Study of the Extent and Nature of Air Pollution in Pennslvania," Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, Nov. 1961

22. This estimate does not include particles generated from processes other than fuel combustion such as those stemming from the conversion of SO_2 into suspended (solid) sulfates. Particles resulting from this process are very much smaller than those produced by teepee burners, usually forming in the respirable range <2.5 microns.

23. David R. Rossman and F. Glen Odell, 1980, "Evaluation of Wood Stove Emissions," Prepared for Oregon Dept. of Environmental Quality and the USEPA, Dec. 1980. Additionally, this point has been sufficiently corroborated that DeCesar, 1981, used it in his calculations.

24. Scott Church, AQU, personal communication, 1981

25. Health Effects Committee, 1981, "Report on Particulates," in Full Report: Citizens' Air Pollution Working Groups, Presented 15 April 1981 to the Missoula City-County Air Pollution Control Board, Missoula City-County Health Department, Missoula, Montana

Chapter 2

The Present Wood-Burning Situation and Potential Increases

Since the 1973 oil embargo, the extent of Missoula's wood-burning population has been examined by two different surveys.[1] Both documented substantial increases in the number of households burning wood. Table 4 summarizes these and earlier findings and makes projections for further expansions.

Table 4

Historic and Projected Expansions in Residential Wood Burning

Year	Percent Households Burning	Number Households Burning	Percent Greater	Total WBD's	Percent Greater	Tons Wood Burned	Percent Greater
1970[a]	1.6	266	--	I.D.[b]	--	I.D.	--
1974[c]	32.3	7,478	2,711.3	I.D.	--	21,760	--
1976[d]	37.6	8,029	7.4	11,570	--	23,366	7.4
1979[e]	53.1	11,667	45.3	13,671	18.2	52,195	123.4
1981[e]	54.8	13,205	13.2	15,488	13.3	61,908	18.6
1983[f]	59.0	14,583	10.4	17,124	10.6	74,932	21.0
1990[f]	68.9	18,280	25.4	21,199	23.8	95,776	27.8

[a] Source: 1970 Census, cited in PEDCo, 1975
[b] I.D. = insufficient data
[c] Source: PEDCo, 1975
[d] Source: Otis, 1977
[e] Source: Church, 1981
[f] Author's projections

Table 4 and Figures 2 and 3 demonstrate the increases that have occurred in residential wood burning (RWB) in Missoula since the early 1970's. As shown, both the percentages of households burning and the real numbers of burners have been increasing. Note the large growth in both the numbers burning and in the tons of wood burned that took place between 1976 and 1979 (45% and 123%, respectively). Not only did more people turn to wood, they also burned more of it, in spite of the relative mildness of the winter of 1979-80.

These phenomena are explained by the fact that during this same period, there was a 611% increase in the number of households burning wood for primary heat, a 51% increase in those burning for auxiliary heat, and a 13% decrease in those burning strictly for enjoyment.[2] This would seem to indicate that the people who are turning to wood are doing so with the serious intent of relying heavily on their wood-burning devices for their heating needs.

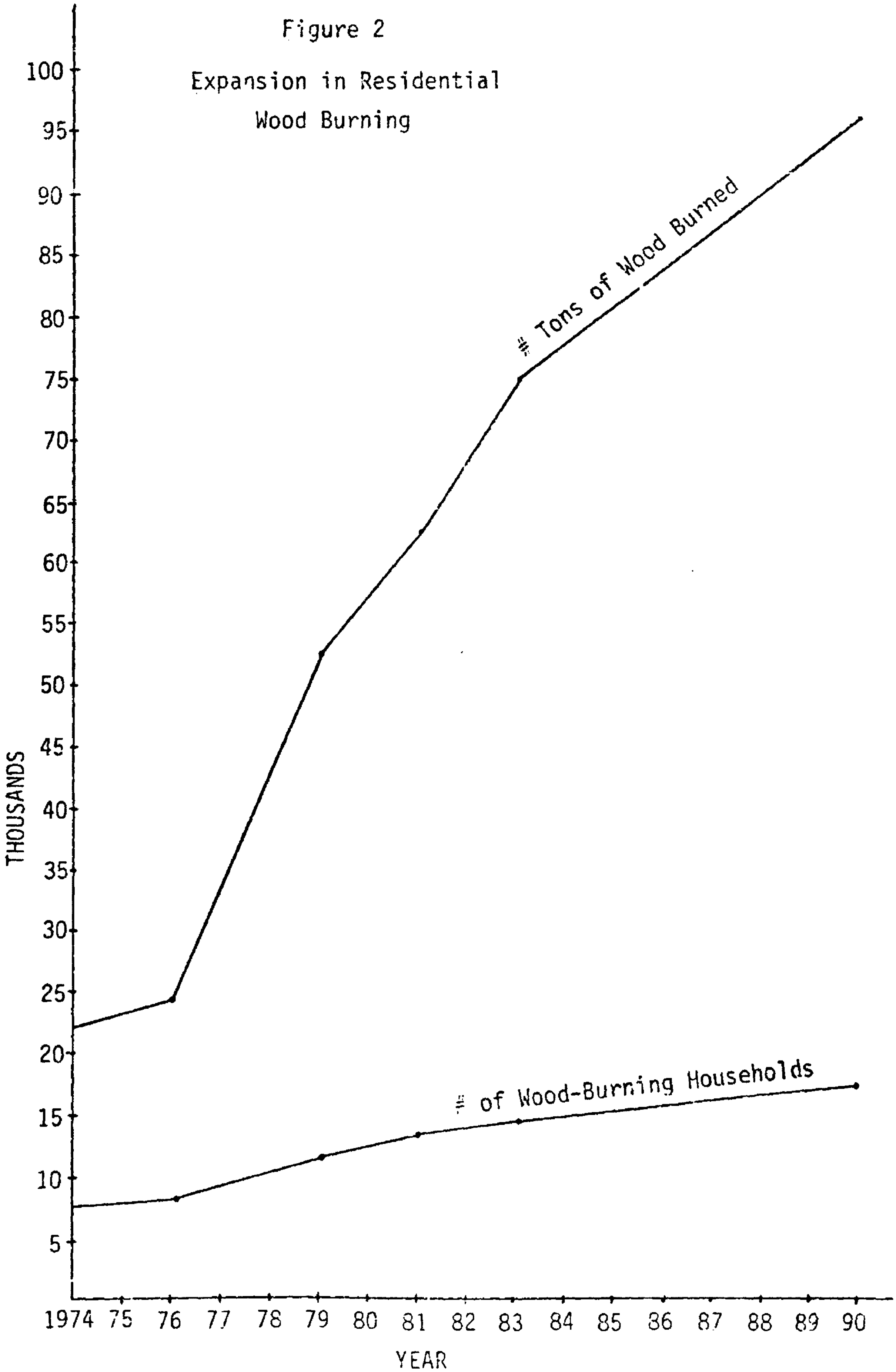
One final noteworthy finding of the 1981 Church study regards where and how the expansion in wood burning occurred. He found that of all those who switched to wood between 1976 and 1979, 73% had installed RWD's into existing housing, while only 27% of the growth was due to installations in new construction. As will be seen later, this point is important in distinguishing among the several NSPS options before the Board. Obviously, any effective approach must in some way deal with the area of largest growth: retrofits.

Projections for Growth

The projections for increases compiled in Table 4 (above) are the

Figure 2

Expansion in Residential Wood Burning



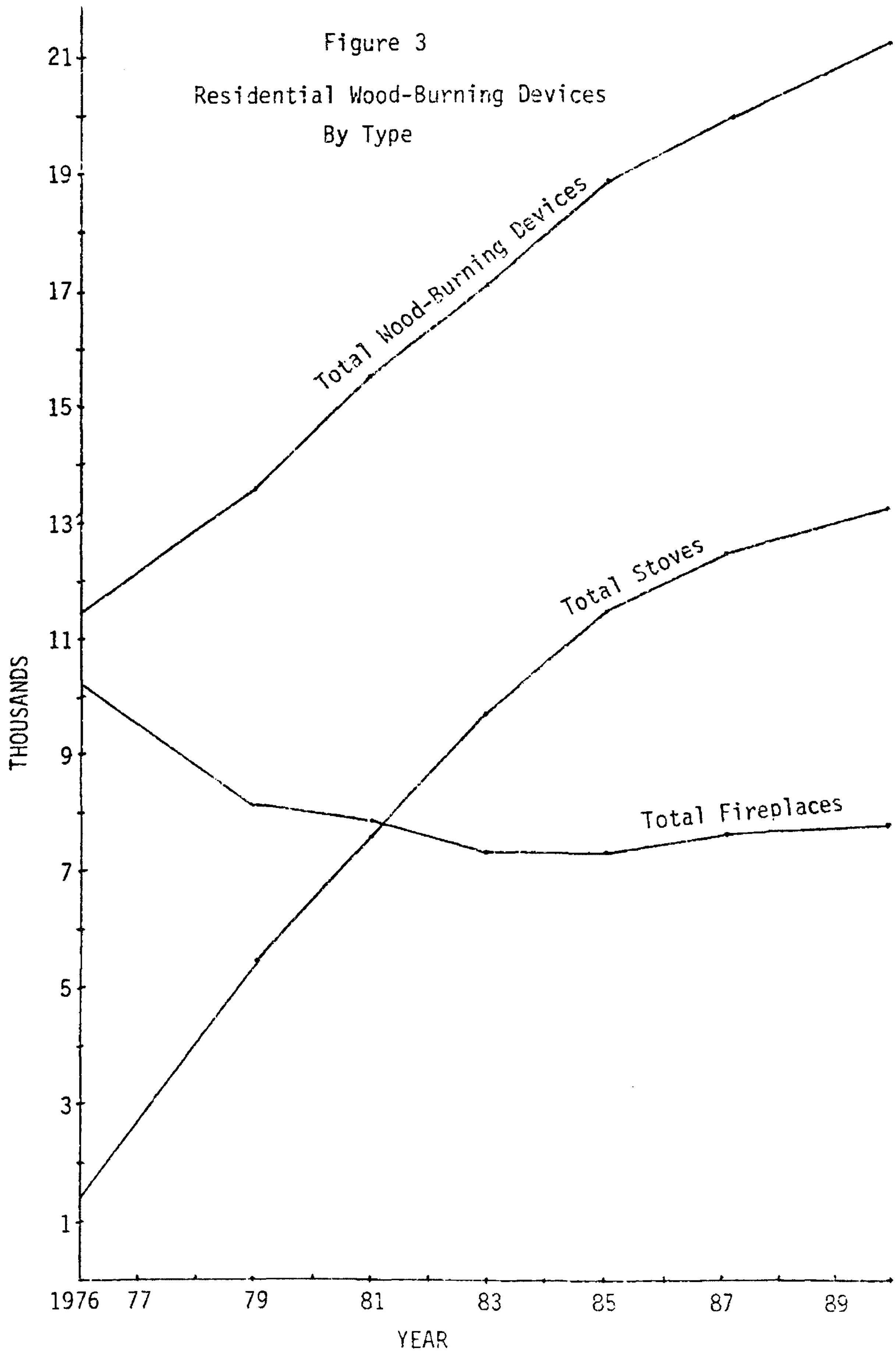


Figure 3
Residential Wood-Burning Devices
By Type
Total Wood-Burning Devices
Total Stoves
Total Fireplaces
THOUSANDS
21
19
17
15
13
11
9
7
5
3
1
1976
77
79
81
83
85
87
89
YEAR

heart of the issue. They were made with a bias towards being conservative, so as to keep the numbers as "deflated" and believable as possible. The assumptions upon which the projections are based are grounded on the findings of the 1981 Church study except where noted. They are as follow.

(1) Projections of population growth were estimations by the Montana Department of Community Affairs, based on the 1980 Census.[3]

(2) Average household size was assumed to remain the same through 1990 (2.49 persons per household). This was done in lieu of any other estimations. Historically, household size has been decreasing, so holding it constant tends to deflate the number of future households. This may make all projections somewhat conservative.

(3) The rate of new housing construction was assumed to maintain its depressed 1980 pace of 154 new units per year through 1990. This is far below the normal rate of almost 500 per year and may be twice the number of units built in 1981.[4] If the housing construction market recovers during the projection period, the estimates of new units may prove to be extremely low.

(4) It was assumed that 90% of the new housing units built would be equipped with a fireplace. This is lower than the 95% found by the Church study, but is the figure he used due to his small sample size.[5]

(5) Installations of RWD's among households currently burning wood was assumed to continue at a rate of 9.4% every two years through 1985 and then stop completely. This premise assumes all possible retrofits will be accomplished by 1985, which may not be the case. If for example housing construction were to return to normal, there would be a

much larger number of housing units suitable for retrofitting. Coupled with the fact that rising fuel costs may persuade increasing numbers of people to opt for wood, results of this assumption may be conservative.

(6) RWD installations among those households not presently burning wood was assumed to proceed at the rate of 10.1% every two years through 1990. This is the least conservative of all the basic suppositions, but is justified by the extreme conservatism of the others. In addition, this percentage increase is affecting a constantly decreasing number of households that is naturally deflated by the projection for new construction. These factors serve to make the assumption realistic.

(7) The rate of decommissioning of existing fireplaces was assumed to continue at the rate of -10% every two years through 1985. By that time, most of the plugging, destruction or conversion of fireplaces in older houses should have been accomplished.

(8) The amount of wood burned per wood-burning device was assumed to remain constant through 1990 (1.5 cords/fireplace and 3.5 cords /stove). This assumption is conservative in two ways. First, it assumes that the utilization patterns among wood burners (i.e., their reasons for burning, such as for primary heat) will remain constant. As noted earlier, this was definitely not the case between 1976 and 1980 when instead, many more people opted to increase their reliance on wood. Were this trend to continue, the amount of wood burned per household would almost certainly increase. The second conservative aspect of this assumption is that the baseline winter of 1979-80 was relatively mild. This probably made wood consumption during that winter less than normal

and could deflate projections of future use.

(9) As was indicated by the 1980 data, thermostatic air-tight stoves were assumed to comprise 30% of the total (non-new) wood stove population until 1985 and drop to only 15% by 1990. This assumption was made based on the hope that such a change will occur and, not evidence that it will. To the contrary, one stove dealer indicated that about 50% of her customers are still seeking this kind of stove.[6] Consequently, use of this assumption may make the projected 1990 particulate outputs very low by deflating the number of these polluting stoves.

(10) The number of stoves in operation in 1981-82 was used as a baseline and 2.5% was subtracted from that total after the 1983-84 projection and before the calculation for 1989-90.[7]

(11) A retrofit into both burning and non-burning households was taken to mean the installation of one wood-burning stove.

In spite of the "collective conservatism" of these assumptions, the projections in Table 4 (above) still present a picture of further increases in RWB. The projections for 1983 predict another 10% increase over the number of households burning wood in 1981 and a 21% increase in the amount of wood being burned. This translates into a 25% increase in wood-burning households during the four years following the 1979-80 study. This compares to the documented increase of 45% that occurred during the three years preceding the study. In terms of the tons of wood burned, the 1983 projection shows a 44% increase in four years compared with the documented 123% increase in three. The conservativeness of these projections enhances their credibility; one hopes they are not so cautious as to diminish their usefulness.

The projections for 1990 are further into the future and therefore especially susceptible to errors in the basic assumptions. This fact notwithstanding, these projections are also grounded on the basically conservative estimates listed above and can be taken to represent one possible future.

The above assumptions do not consider all possible elements that may affect the future of wood burning in Missoula. One obvious omission is an indepth consideration of economic factors which might either encourage or discourage future reliance on wood. This consideration is beyond the scope of this work, but this limitation should not be construed as invalidating the projections of wood use. In fact, the opposite may be true. For example, the assumptions of growth do not take into account the fact that the price of both natural gas and electricity will almost certainly continue to escalate. Were such factors considered, the projected increases in the number of people turning to wood might be even higher. Consequently, the projections for growth represent conservative estimates of future wood-burning populations in Missoula. If they are even close to being a picture of what will occur, they spell out a grim future for air quality in Missoula.

Footnotes

1. Ted Otis, 1977, "Wood Burning and Particulate Air Pollution in the Missoula Valley," Missoula City-County Health Department, Missoula, MT 59801; and

   Scott Church, 1981, "Residential Wood Burning and Its Impact on Particulate and Carbon Monoxide Emissions in the Missoula Urban Area: 1979-80," Air Quality Unit, Msla. C-CHD, Msla., MT 59801

2. Author's calculation based on Church, 1981

3. Provided by Mike Kress, Msla C-C Planning Department

4. Dan Obermeyer, Msla C-C Planning Dept., 10/81, personal communication

5. Church, 1981, 9

6. Harlene Fortune, 1981, personal communication

7. Author's estimate of the number of stoves that might be decommissioned during the 10 years included in the projection period: 1981-1990.

Chapter 3

New Source Performance Standards

Emission Factors

Before the concept of low emission performance standards can be explicated, it is necessary to define the "normal" rates of particulate generation by residential wood-burning devices (RWD's). These levels are gauged in terms of an emission factor (EF), measured as a unit of particulate generated per unit of wood burned. The unit of pounds of particulate per ton of wood burned (lbs/ton) will be used through the remainder of this work.

The choice of which EF to apply to which RWD under a variety of burning conditions is of critical importance to the consideration of particulate outputs and to the choice of NSPS. The method and reasoning used to choose appropriate emissions factors for use in Missoula are explained in Appendix B. For here, suffice it to say that an EF of 30 lbs/ton was used to represent particulate output from fireplaces, 50 lbs/ton for wood stoves fired at a high to medium burn rate, and 100 lbs/ton for a smoldering stove.

NSPS--Introductory Comparison of Alternatives

Citizen recommendations

Two of the aforementioned citizen advisory commitees made recommendations in the area of new source performance standards for residential wood-burning devices. The committee on health effects recommended the establishment of an opacity standard for smoke from RWD's, and stated generally, "Missoula needs no new particulate sources . . ."[1] Together, these indicate the belief that something needs to be done at the level of the individual RWD to clean up the present pollution and to curb increases of new sources. An NSPS would concentrate on the latter part of this need.

The citizen committee on residential wood burning specifically recommended the promulgation of an NSPS to be applied to all RWD's installed in the Missoula airshed after 30 September 1981. The intent was to include under the standard all new installations (as opposed to only new construction), and the recommended limitation was set at 20 lbs/ton.[2] Additionally, the committee acknowledged that the implementation of their plan would necessitate establishing an RWD permitting system. As stated by the committee, both recommendations were intended to curb the worsening air pollution problem so as to preclude, "more draconian regulatory measures . . . in the future in order to control a much less tractable pollution problem in our valley."[3]

AQU Staff response

Following the presentation of the citizen committee recommendations, the staff of the Health Deparment's Air Quality Unit (AQU) reviewed the recommendations and responded with suggestions of their own. This resulted in another recommendation for new source performance standards. The staff supported the concept of NSPS, going so far as to say, "the staff supports the recommendation . . . but feels strongly that a more stringent standard of 5 g/kg [10 lbs/ton] is necessary to prevent an already serious problem from getting worse." They went on to conclude that, "the maximum success of stategies for reducing pollution is contingent upon a strict standard."[4] However, from this point of agreement, the staff diverged sharply from the RWB committee's recommendation.

The staff concluded that enforcement of an NSPS that applied to new installations in existing dwellings, "would be almost impossible." On the other hand, they speculated that "applying this standard [to] installations in new construction . . . would be relatively easy."[5] They therefore recommended that an NSPS of 10 lbs/ton be applied to installations of RWD's in new construction after 1 January 1982.

This is the final, formal staff recommendation to date. Although charged by the Board to present an NSPS alternative that would allow "the best stoves currently available in the valley" to continue to be sold, the AQU decided that this was not possible given the paucity of applicable source test data. They therefore reaffirmed their earlier recommendation.

StefProp

In response to the divergence of the alternatives before the Board, I decided to assess more fully the need for NSPS in the Missoula airshed. That assessment resulted in yet another recommendation to the Board (subsequent to a presentation of a summary of my findings on 8/20/81), which is called "StefProp" in later sections. The explication of this proposal is the topic of this work, and the remainder of this chapter explains how that assessment was carried out.

Factors Pertinent to an Assessment of the NSPS Alternatives

Certain factors had to be taken into account while trying to determine whether there was a need for NSPS in Missoula. These included: (1) other citizen caused air pollution; (2) proposed changes in Missoula's Air Stagnation Plan; (3) possible advances in wood-burning technology; (4) projections of growth in wood burning; (5) the possible effects of the current public education campaign to reduce pollution; and (6) several other miscellaneous considerations. Each of these points is discussed below and its function (if any) in the following predictive calculations explained.

Other Citizen Caused Air Pollution -- Transportation

Transportation's contribution

According to the 1981 Church study, the largest single annual source of citizen generated air pollution besides RWB is transportation. Pollution from this source stems from the exhaust of combustion engines, and from the various particles that are produced and/or become airborne due to the physical action of tires on roadways and winds from vehicle passage. Church estimated that 60% of the annual total suspended particulate was generated by paved and unpaved roads and highway motor vehicles.[6] However, during the winter, this contribution is reduced to about 21% according to Church,[7] and to only 10% according to my recalculation from Church's data. (See Table 2, page 15)

This range of 10-21% is similar to the findings of two of the four 1980 studies as to transportation's contribution to the respirable fraction of suspended particulates (RSP). Cooper attributed 6% of the RSP to auto exhaust and 9% to the "mineral or soil" category.[8] Hedstrom found that 24% of the RSP was attributable to "mineral," but the bottom range of her optical instrument was only 1.3 microns, which would have left out many wood-burning particles.[9] Had this not been the case, a larger attribution to the "combustion" category would have lowered the percentages in the other categories.

Additionally, the 1980 winter days for which the filters were tested, may have been atypical of usual winter conditions, as the weather was relatively warm and dry (average temperature of the 12 days for which optical microscopy was done = 34.8°F). This would have tended to deflate the contribution from wood burning and inflate that of dusty roads.[10] Consequently, the documented contribution to the RSP may be taken as the high end of the normal range.

In contrast to these findings, a much more exhaustive study of particulates in Medford, Oregon (a town with similar air pollution problems) found that only about 8% of their annual RSP was attributable to road dust and vehicle emissions.[11] The situation in Medford may not be strictly comparable because they do not have to sand their streets as is done in Missoula. However, the possible elevated nature of the Missoula data may indicate general comparability. Based on this data, and the above discussion, it is safe to say that in terms of wintertime respirable particulates, the current contribution from transportation is probably less than 10-15%.

Can education reduce this contribution?

The answer to this query is apparently "no" or at best, "a little, maybe." This conclusion stems from examination of two studies of the potential reductions in transportation related pollution from extensive, planned changes in established transportation patterns. One study focused on a specific program of changes, while the other projected impacts of various approaches to altering established transportation routines. Neither is very encouraging.

The first study reviewed the transportation control plan that was established in Philadelphia, Pennsylvania in 1973. The plan was far more extensive than anything yet envisioned for Missoula. It included a strict vehicle inspection program; establishment of at least 25 miles of bikeways; a computer match car-pool system; special busways and bus and trolley lanes; and creating areas of limited street parking in order to discourage driving. In spite of this massive effort to maintain clean-burning engine efficiencies, and to reduce vehicle miles travelled (VMT), the entire projected reduction in the emission rates of carbon monoxide (CO) was only 7.1%. With most of the plan in operation, the actual reduction was even less.[12] If CO emissions are taken as an indicator of vehicle use, it can be concluded that the Philadelphia program had very little impact on VMT. Since our local problem relates directly to VMT, only very small reductions in air pollution could be expected from a similar program here.

The second study was a 1978 U.S. Department of Transportation report that projects the potential effects of programs designed to reduce total vehicle miles travelled. It shows that efforts such as encouraging ridesharing, a 50% expansion of local bus systems, variable work hours, and even changing to a four day work week would only have the cumulative effect of reducing VMT by about 1.5%.[13] Since transportation related pollution is intimately linked to VMT, such small successes would have little impact in reducing air pollution.

Transportation not to be considered further

After reviewing the above two studies, I concluded that the remainder of this paper need not be concerned with assessing reductions of transportation related pollution in relation to NSPS. For one thing, such pollution plays only a small role in creating wintertime respirable particulates. For another, the progressing public education campaign can seemingly have but a minute impact on reducing VMT and related pollution. Transportation related air pollution is not therefore factored into the calculations scenarios for future particulate loadings. This is not intended as a statement as to the importance of stimulating eventual changes in local, personal transportation habits to conserve energy and to reduce waste generally. But it is to conclude that further discussion in relation to the need for NSPS is not warranted.

Proposed Changes in Missoula's Air Stagnation Plan

The proposed changes in our Air Stagnation Plan must be noted and briefly discussed because the Plan is designed to alert the public to developing pollution episodes so as to bring about curtailment of pollution causing activities and foment pollutant reductions. However, because it is an emergency plan, meant to contend with reducing already serious pollutant concentrations, it is somewhat paradoxical to this overall discussion. If the plan works as is anticipated, it will reduce particulate outputs and possibly prevent higher concentrations of ambient poisons. If it does not work, more dangerous levels of pollutants might result. But in either case, whether effective or not, the Plan in no way reduces the number of sources or their potential to generate particulates. It is not in itself any kind of long term solution. Instead, the very use of such an emergency plan is evidence of a continuing serious problem. If the Air Stagnation Plan is evoked, it will be because meteorological conditions and particulate emissions have functioned together to push pollution concentrations beyond tolerable (i.e., safe) limits. During these occasions, the Plan will be necessary to treat the resulting problem (symptom), but it cannot affect the underlying causes.

On the other hand, establishing an NSPS can be part of the long term solution to the problem because such action could eventually reduce the emission production potential of the community. Therefore establishing such a standard is in accordance with the goal of the Board to reduce average particulate concentrations, and the Air Stagnation Plan remains essential in the interim. However, because the Plan deals with the apples of controlling dangerous ambient concentrations of particulates, while NSPS are intended to affect the oranges of reducing emission potential, consideration of the possible effects of the Plan is not germane to the NSPS point in question. But the reverse may not be true.

For instance, as long as the first stage of the Plan remains voluntary, its long term viability may depend on how frequently it is used. If evoked many times, the Plan's effectiveness may be reduced because people become tired of the inconvenience and/or oblivious to its importance. This may come to be increasingly important in the future, because as the potential in this valley to pollute the air continues to expand, the Plan will likely have to be used more often. Further, because an increasing number of sources will be able to push particulate concentrations to higher levels faster, the Plan may have to be used for longer periods at a time. Consequently, the long-term usefulness of the Plan may depend on decisions such as the establishment of NSPS and the part that such actions can play in the eventual reduction of pollution potential. The presence of the Plan is essential for now, and until some long-term solutions can be effected; but it cannot solve the reasons for our pollution problem, and should not be used to obstruct anything that might. Therefore the potential effects of the Plan for controlling high particulate levels are not built into the following calculations of future particulate generation capacities.

Technological Advances in Wood-Burning Devices

Advances in wood-burning technology would be the easiest solution to our problem of future RWD installations. Such advances are apparently on the horizon, and may make wood burning clean enough to tolerate in this valley. In fact, several new, clean-burning stoves are now available, including one that has been proven to emit less than 10 lbs/ton and another that very likely will.[14] This may at first seem like a paltry number of clean-burning devices, but it is still relatively early in the game. As stove dealers and manufacturers become increasingly aware of the need for low emission RWD's, high performance, low emission devices will almost certainly become more available due to the push in research to solve the problem of emissions.

In contrast, no add-on filtering devices have yet proven effective, and I suspect that none will be forthcoming in the near future. Small scale, economically feasible filtering systems are simply not practical at this time due to the complexity of the demands on such a system. An effective filter must capture not only very small particles but also condensible gases. These same requirements took years of engineering initiative to solve, even at the large industrial level where the combustion processes are all much more efficient and predictable. To expect similar achievements that are either structurally or financially applicable to small scale, individual stoves is not realistic.

The significance of this conclusion is that cheap add-on devices will not be able to solve our problem in time to keep Missoula from asphyxiating. Consequently, only fundamentally different RWD designs can. Such new designs will at least initially be more expensive than commonly available stoves, as would any stoves with add-on filters. Considering this apparent economic disincentive, the only way to ensure that clean-burning stoves are installed is to provide a powerful incentive that it be done. Establishing an NSPS is a likely means. This being the case, no factors reflecting possible advances in wood-burning technology were included in the predictive calculations that follow. However, I want to reemphasize that currently available low emission RWD's operate with EF's that can meet the proposed limitations (10 and 20 lbs/ton) which are used in calculating of the effects of the alternatives before the Board.

Growth

The assumptions used to make projections of growth in residential wood burning were detailed earlier in this work. (see page 23) The results of those projections are presented in Table 4 on page 22 above. To reiterate, the projections for growth are based on a set of assumptions that I believe make the resulting estimates conservative to realistic. Factors which would have tended to inflate the results (e.g., a turnabout in the housing construction market and/or further rapid increases in the price of heating energy) were intentionally not taken into account. The projections are therefore my best estimates of a realistic picture of growth in residential wood burning in Missoula.

Potential Pollution Reductions Through Education

As mentioned previously, all four citizen committees supported the idea of establishing a public education campaign regarding Missoula's air pollution. They felt that the public should be provided information relating to both health effects and precautions, and ways for individuals to reduce their contributions to the problem. The hope was (is) that once people are aware of the costs of air pollution and the potential benefits of some of the steps they can take to reduce it, they will respond and thus reduce the average levels of pollution.

As a result of this hope, a massive public education program has begun. The questions now are how well will it work and what reductions in air pollution can it bring about? Trying to answer these questions requires defining (1) which element of the problem to examine in relation to possible effects from education; and (2) the current situation (a baseline) and how it might change. Following is an explanation of how this was accomplished. The discussion is restricted to education vis-a-vis wood burning, since the possible effects of education in reducing transportation related pollution were covered earlier.

Choosing an element of the burning process to manipulate

Trying to project the potential impacts of the public education campaign in reducing wood-burning air pollution was one of the most complex aspects of this work. It was complicated by the number of variables that affect emissions and by the fact that they're all interrelated (see the discussion of factors affecting wood combustion emissions, Appendix B). Since each factor will in some way change emissions, and there is a range of possible effects associated with each factor, it is essentially impossible to estimate definitively what the effects of the educational campaign will be. There are simply too many junctures at which the program can fail (e.g., bad timing, ineffective messages, or the lack of funding). Consequently, another set of assumptions and estimates were used to narrow the scope of the inquiry to manageable size. Again, the basic assumptions were made with the intent of keeping the results believably conservative.

Instead of trying to model the effects of all the possible variables, one crucial parameter affecting emissions was chosen to manipulate within the various scenarios. Although it is not really the case, this single factor - air supply to the fire - was used as the sole determinant of emission rate. This model leaves out the effects of all other variables, and so may make the results of later manipulations very conservative. But this factor is an essential part of the efforts by wood burners to burn cleanly, and may, because it is simple to do and has clearly discernable effects, be the easiest single element of burning to manipulate through education. It is also the only critical variable for which any baseline information exists. Therefore, this one factor in the burning process will be used in the following manipulations to represent all other factors. This is an unfortunate but necessary step, because RWD emission testing has not yet been extensive enough to quantitatively differentiate among all the effects of the variables that affect emissions.

Choosing a baseline

One final, conservative assumption is the baseline chosen from which to measure changes due to education. This level was calculated from the raw data of the 1981 WMSCPI study. The baseline is the mean of the percentages of wood burners in four cities in Montana that stated that they usually do not close the air draft on their stoves. As stated in the WMSCPI report, the question to which they were responding did not account for thermostatically operated air tight stoves and may therefore have "masked the full extent of starved air burning."[15] Use of this average of the percentage of people who do not close their stoves' draft - 58.6% - as a baseline representing clean burners (EF=50 lbs/ton), is once again conservative. But it is the best estimate given available data.[16]

Having chosen an aspect of the problem suitable for change, and a place from which to begin measuring that change, it is feasible to approach the problem of predicting the possible effects of the education campaign. The one remaining question is, realistically, what percentage change can be expected as a result of the educational effort? Discussion of the choice of this critical variable follows.

Education: Can it work? -- The inherent problems

In trying to assess what amount of change in common burning practices might be attainable through an education campaign, I turned to the literature of education and behavior modification. In addition, I discussed the possibilities for change with both a sociologist and with the professional advertiser who was coordinating the marketing approach to the program. The results of this investigation were not encouraging, in that they brought the difficulties facing the education program to light.

The current thrust of the education program (Program) is directed towards accomplishing a very difficult educational feat: changing a number of learned/habitual behaviors and the attitudes from which they derive. For the program to be successful, the wood-burning public must first be reached by the Program in such a way that convinces them of the need to change. Second they must begin to regard their wood-burning activities as more than a simple, private act which affects no one but themselves. Finally, they must reflect this new attitude by changing the ways they have habitually operated their wood-burning appliances. This last point is the most important, but also the most difficult to achieve, because this change in habits will necessarily result in the greater personal inconvenience of spending more time gathering and curing wood, as well as tending the fire more often. Such inconvenience is necessitated by the numerous variables that can increase emissions, including the major failing of common wood stoves: when operated in a convenient, practical manner, they pollute.

Similar problems

The complexities of this situation are similar to those in the field of preventive health education in that they concern individuals changing personal actions for seemingly obscure reasons. These similarities can be summarily discussed by referring to an article from this discipline. In a 1979 paper, Graham Ward, the chief of the Education Branch of the National Heart, Lung, and Blood Institute of the National Institutes of Health, discussed the inherent difficulties of preventive health education.[17] I will quote, and as Ward points to four aspects of the problem, I will draw parallels.

(1) Preventive health care information, and information regarding residential wood burning, are unusual compared to most marketed products in that they are not well suited to traditional, media means of marketing. Of this, Ward says,

> When we use mass media, we start with one hand tied behind our backs. We cannot build awareness as quickly or maintain high levels of [advertising] frequency in most health efforts because we most often must . . . [rely on] public service rather than paid advertising. [In this area,] communicators and educators [and advocates of clean air] are limited by not having a sales force.[18]

These comments are totally applicable to the local Program, the generosity of the local media and the presence of a fulltime education coordinator notwithstanding. (The media blitz that is presently occurring is but a one time effort; once the crush of the present endeavor has subsided, the coordinator will revert to his former duties.)

(2) Health care and air pollution information are complex issues that cannot be communicated so as to reach the involved public by using single, standardized messages. Such messages must be tailored to be both acceptable and understandable to different target audiences. This of course takes funds. Ward sums up this problem by saying, "the most severe limitation is in securing adequate resources to produce the plethora of differing messages for differing personalities."[19] Cutbacks that have already been necessary in our Program due to budgeted funds suddenly being unavailable, demonstrate the magnitude of this problem in Missoula.

(3) In areas as complex as self health care and reducing wood-burning air pollution, certain new skills must be learned by the public. In such instances, simply providing information is probably not adequate. Ward says,

> Consumers . . . require not only information but [also] skill learning. The limitations in marketing these skills arise primarily from the fact that any given media can transmit only a limited amount of information in any given message unit. Thus we must develop a wide variety of messages and plan their delivery in an orderly and understandable sequence over an extended period of time. . . . A further limitation is that by the time we reach the final message, the first message may well have been forgotten, so that we must continually be aware of the need to reinforce all messages.[20]

These statements point out the serial and additive nature of the messages. For success in reducing wood smoke emissions, burners must be aware of the entire series of necessary steps. Therefore the whole program is only as effective as is each step of the process. Lower emission burning will result only if wood is cut early, stored properly and burned correctly in a relatively efficient device. Failure of the wood-burning public at any juncture will reduce the overall effectiveness of the program. Getting this message across will require a long-term commitment to working on solving the problem, as well as the resources to sustain an extended, effective media campaign. The Missoula Health Department has the commitment, but lacks the resources.

As a result, the fledgling education program suffered an early setback by failing to finish and distribute a wood-cutting and storage brochure until after wood burning had already begun. This greatly reduced the effectiveness of both that phase of the program and of the entire Program during the first attempt to reduce pollution. This is a clear example of the weakness the education effort suffers due to lack of resources.

(4) Finally, for an education campaign to work, the recipient public must be able to discern causes and effects of the problem and to perceive benefits from any actions they take. This is a very difficult proposition in the realm of air pollution, especially in Missoula, in spite of the fact that some of the public is aware of the problem and seemingly willing to take action.[21] Here, because the weather is as large a factor in air quality as any other single element, and because small changes in pollutant concentrations are impossible to detect without monitoring equipment, it will be difficult for people who change their burning habits to perceive any short term improvements in air quality. Additionally, the nebulousness of what an individual effort means, increases the difficulty of convincing the public of the need for such action over the long term. Since only <u>permanent</u> conversion to

cleaner wood-burning practices will solve the problem, the need for a continuous educational campaign is obvious.

Other studies

Studies by several other researchers point to additional difficulties that may be encountered during the education campaign. For example, one study in which behavior change messages were "hand tailored" to address individuals and delivered by persons highly respected by the target audience, an average of about 7% of the audience exhibited a contrast or "boomerang" effect and moved attitudinally in the opposite direction.[22] Had the communicators been either "neutral" or "negative" in the eyes of the audience, as may be the public's perception of the "communicator's" in Missoula's Health Department, the percentage of boomerangs probably would have been higher.[23]

A similar study that was trying to influence opinions (not attitudes) had an average of about 23% of the target audience move in varying degrees in the opposite direction of the way being advocated.[24] Observations of the comments and mood of some of the audiences at all of the Board's public meetings I have attended since the release of the committee reports, leads me to believe that this phenomenon may be occurring in Missoula.

Finally, two other studies presage yet another area of potential problems: the assumption that when the public is provided with information it will follow through by taking appropriate or "right" action. That this may not be the case is nicely summarized by a series of statements from two studies of the issue. Their applicability to our situation, speaks for itself. In 1976, Pettus found that,

> . . . developing proper attitudes and soliciting appropriate behavior for maintaining a suitable environment seems to lag behind environmental awareness. Solving environmental problems which may be caused by improper attitudes is difficult because the problems tend to be very complex, involving combinations of social, economic, ecological issues. . . . The evidence indicates that being better informed about environmental conditions does not necessarily mean that people will be more favorable toward enforcement of environmental controls [or inconvenient personal actions] designed to improve those conditions.[25]

Even more specifically, Force et al., concluded her report of extensive efforts to involve a community in air quality issues by saying, ". . . increased knowledge about the problem may not result in a commitment to improve air quality."[26] But, why is it the case that knowledge and understanding of a problem may not bring about a change in the offending attitudes and actions? Pettus concludes that the underlying reason is that,

> Even when people are aware of facts and know what behavior will bring about and maintain the desired conditions, elements like economics and convenience, as well as other factors will continue to dictate their responses.[27]

This is a very important point, because the changes necessary to reduce air pollution will result in both greater inconvenience and in the <u>perception</u> of greater expense.

The aspect of inconvenience involves the need to take more time in all phases of the use of wood for fuel. This includes: cutting early so that the wood has time to cure; splitting the wood before somehow stacking it off the ground in a way that allows good air circulation around it and so that it's protected from the elements; burning smaller, hotter fires; tending the fire more often; and not filling the stove to capacity only to restrict the air supply so as to avoid overheating.

Burning cleanly is not more convenient in most common RWD's, because it requires a certain amount of planning and dedication.

The economic side of the question is more nebulous in that the full costs of burning wood have never been definitively calculated. Since a complete economic analysis would have to consider the social costs of air pollution (e.g., such "externalities" as increased rates of morbidity and mortality), such a study would be both complicated and expensive. In the absence of a complete analysis, the public is left with the perception that burning wood is cheaper than using other fuels, because the wood itself is "free." Until this idea can be dispelled with documented statistics, any infringement on the use of wood may be perceived as either pinching the pocketbook and/or as a ploy by the power company. Given these obstacles, it will be difficult for the public education campaign to affect significant reductions in wood-burning related air pollution.

Professional opinions

Besides reviewing the above literature, I also discussed the issue of educational effectiveness with two professionals in the area of attitude change. The response of Dr. William McBroom of the U.M. Sociology department was considered but rapid when asked how effective our Program might be. He said, "what, five percent? Maybe."[28]

The response from the advertiser who was at the time coordinating the professional end of the educational campaign was slightly more optimistic. In response to the same question, Ann Mary Dussault of Nordbye Advertising noted that because of the "diffuse nature of the problem" (i.e., the complexity of trying to teach skills through the media, in addition to the range of topics that have to be covered,) the ". . . effects [of the education campaign] will be minimized." She estimated that if every aspect of the program were sufficiently funded and perfectly executed, as much as 40% change (i.e., improvement) might result. But she went on to conclude that a 10-15% change is a more likely result.[29]

A final example

Before leaving this section, I would like to point out one example of an education campaign that relates very specifically to the question of personal and/or public health versus changing attitudes and habits. That is, the 10 year long, federally funded, professionally orchestrated education campaign regarding hypertension. After that massive effort, a 1980 study of its effectivness found that 82% of the population with high blood pressure was aware of it. Of this group, 67% were trying to do something about it by at least beginning treatment. Of this group, about 33% were successfully controlling the problem.[30] That is an overall effectiveness rate of only about 18%, in an area where individual health risks have been clearly demonstrated. And this, after an ongoing educational campaign that far outstrips anything even conceived of locally. How effective can we hope to be?

The percentages used in the scenarios

After reviewing the literature and talking to several professionals, I opted to use four different categories of possible change due to education. These were: the "Best Possible Case" estimate

In relation to the possible effects of alternative energies, I talked with the Solar Coordinator of Montana Western Sun, Jim Borzym.[34] From that discussion I concluded that nontraditional energy sources will not significantly impact (i.e., decrease) reliance on wood within the projection period of this study. According to my calculations, at this point, less than 1% of the households in Missoula are even experimenting with alternative technologies, much less deriving significant benefits from them. However, as this changes, and traditional fuels continue to escalate in price, some people will be seeking more appropriate technologies for their energy needs. Hopefully this will be part of the long-term solution to Missoula's air pollution problem, but it cannot occur quickly enough to solve the dilemma that we face within the 5 to 10 years. Therefore this factor was not included in the projections for future wood burning.

Predictive Calculations -- How the Factors were Used

Once the factors dicussed above were selected, they were combined with the earlier projections of growth to calculate potential future outputs of particulates from residential wood burning. Four different options before the Board were investigated by considering each in conjunction with four scenarios of possible effects resulting from the public education campaign. This design is presented and summarized in Figure 4. Each set of factors was combined on a form work sheet, and the appropriate calculations performed (See Appendix C). The results of these calculations comprise the major findings of this work.

Figure 4

OPTION FLOW CHART

OPTIONS:

NO ACTION: no limitation on future RWD emissions

STAFF RECOMMENDATION: 10 lbs/ton limitation applied only to RWD's in new construction

RWBC RECOMMENDATION: 20 lbs/ton limitatation on all RWD's installed after effective date

STEFPROP: same as RWBC except with 10 lbs/ton limit

SCENARIOS:

BEST POSSIBLE CASE: using "Pie in the Sky" estimated impact of public education campaign; (30,50,100)* [40% improvement]**

BEST REALISTIC CASE: with common burning practices; realistic improvement due to education; (30,50,100)* [15% improvement]**

MID RANGE CASE: using half the amount of improvement due to education as in Best Realistic; (30,50,100)* [8% improvement]**

WORST CASE: no change due to education; (30,50,100)* [no change: 41.4% smolder burning]**

* Numbers in (30,50,100) are the emission factors used;

** Improvements in [ ] are amount attributed to education

Results

The results of the various combinations of factors are compiled in Table 5. It displays projections for two burning seasons: 1983-84 and 1989-90. Note that only three of the four options are shown. This is due to the fact that the projected results of the Staff recommendation are only slightly lower than those of the No Action option which is not shown.

Table 5 illustrates 12 possible futures for Missoula, each the product of a choice by the Board and various success rates from the education campaign. Under each outcome, the results are listed as "Tons Particulate" (the particulate generation capacities from RWB), "Tons/Day" (the average daily output over a 120 day burning season), "Percent Greater I" (%>I, the percent increase in the pollution potential over that of the present case: 1981-82), and finally "Percent Greater II" (%>II, the percent increase over that of the 1979-80 burning season).

These results represent conservative estimates of potential increases in the capacity of residential wood burning to generate particulates into the Missoula airshed. They do not consider any sources besides RWB, which are already present, and which might also increase. In addition, they do not seek to address what ambient concentrations of particulates are likely to result from these potential emissions. The projections only show increases in the capabilty or potential of wood burning to pollute.

However, since lower "pollution potentials" have in the past

Table 5

Projected Particulate Outputs from Residential Wood Burning

Option	Scenario	1983-84				1989-90			
		Tons Particulate	Tons/Day[a]	%>I[b]	%>II[c]	Tons Particulate	Tons/Day[a]	%>I[b]	%>II[c]
Staff	Best Possible	2117	17.6	13.4	47.4	2722	22.7	45.8	89.5
	Best Realistic	2219	18.5	18.9	54.5	2890	24.1	54.8	101.2
	Mid Range	2247	18.7	20.4	56.4	2937	24.5	57.3	104.5
	Worst Case	2279	19.0	22.1	58.7	2991	24.9	60.2	108.2
RWB Comm.	Best Possible	1980	16.5	6.1	37.8	2123	17.7	13.7	47.8
	Best Realistic	2071	17.3	10.9	44.2	2230	18.6	19.4	55.2
	Mid Range	2096	17.5	12.3	45.9	2260	18.8	21.0	57.3
	Worst Case	2125	17.7	13.8	47.9	2294	19.1	22.9	59.7
Stef Prop	Best Possible	1949	16.2	4.4	35.7	1973	16.4	5.7	37.4
	Best Realistic	2039	17.0	9.2	42.0	2080	17.3	11.4	44.8
	Mid Range	2064	17.2	10.6	43.7	2110	17.6	13.0	46.9
	Worst Case	2093	17.4	12.1	45.7	2144	17.9	14.8	49.3
	Present Case	1867	15.6	--	30.0				
	1980 Case	1436	11.97						

[a] Tons/Day based on a 120 day burning season

[b] Percent Increase I (%>I) computed from present case

[c] Percent Increase II (%>II) computed from 1980 case

resulted in very serious air pollution, it is logical to conclude that increasing the potential to pollute also increases the likelihood of even worse pollution, given similar meteorological conditions. Since we cannot control the weather, in order to curb the problem we must therefore manage the present potential, and impede its further expansion. This last point is particularly important, because, as noted above, these projections concern only wood burning and no other pollution sources.

As shown in Table 5, the potential of Missoula's RWB to generate fine particulates will increase regardless of which option is chosen by the Board. However, the magnitude of the potential increases varies sharply. In 1983-84, the strict limitations of the StefProp option still allow increases ranging from 4-12% over the current potential. This compares with increases under the Staff option (≐ No Action) ranging from 13-22% over the present. Both these ranges might seem moderate, until it is realized that they represent much larger increases over the levels of 1979-80. Making that comparison, the above options represent increases of 36-46% and 47-59% respectively. Both these comparisons demonstrate the differences between the two choices.

Examining the range of possible increases by 1989-90 shows the distinctions even more clearly. By that time, the StefProp option could hold expansion of the problem to increases of 6-15% over present levels. During the same period, the Staff option would allow increases of 46-60%. When 1979-80 and 1989-90 are compared, StefProp translates to increases of 37-49%, while the Staff option means increases of 90-108%, or about a doubling of the capacity to generate particulates.

The results discussed above are graphically illustrated in Figure 5. From this graph it is easy to see both that the problem capacity of wood burning to generate particulates will continue to expand, and that there are very clear differences in the options before the Board for how to begin dealing with the problem.

An RWD Permit System

A final point which must be considered in discussing NSPS is the probable concomitant need to establish a permitting system for wood-burning devices. Such a system would probably be necessary for effective implementation of any NSPS program that includes other than new construction.

The idea for wood-burning permits again stems from the recommendations of the citizen's committee which considered residential wood burning. As originally conceived, the main focus of that recommendation was to generate funds to administer the other proposals made by that committee.[35] When examined from that perspective, one of the major drawbacks of a permit system is that it might consume 60% of the revenues it generated during its first two years in operation.[36] However, I am approaching this question from a slightly different perspective.

I would argue that a such a system should not be viewed strictly in terms of its capacity to generate revenue, but also as a necessary constituent of an effective NSPS program. From that perspective, a permitting program is very important. In addition, according to the AQU staff, a properly designed system could provide "valuable data" regarding many aspects of wood burning that could be used in future

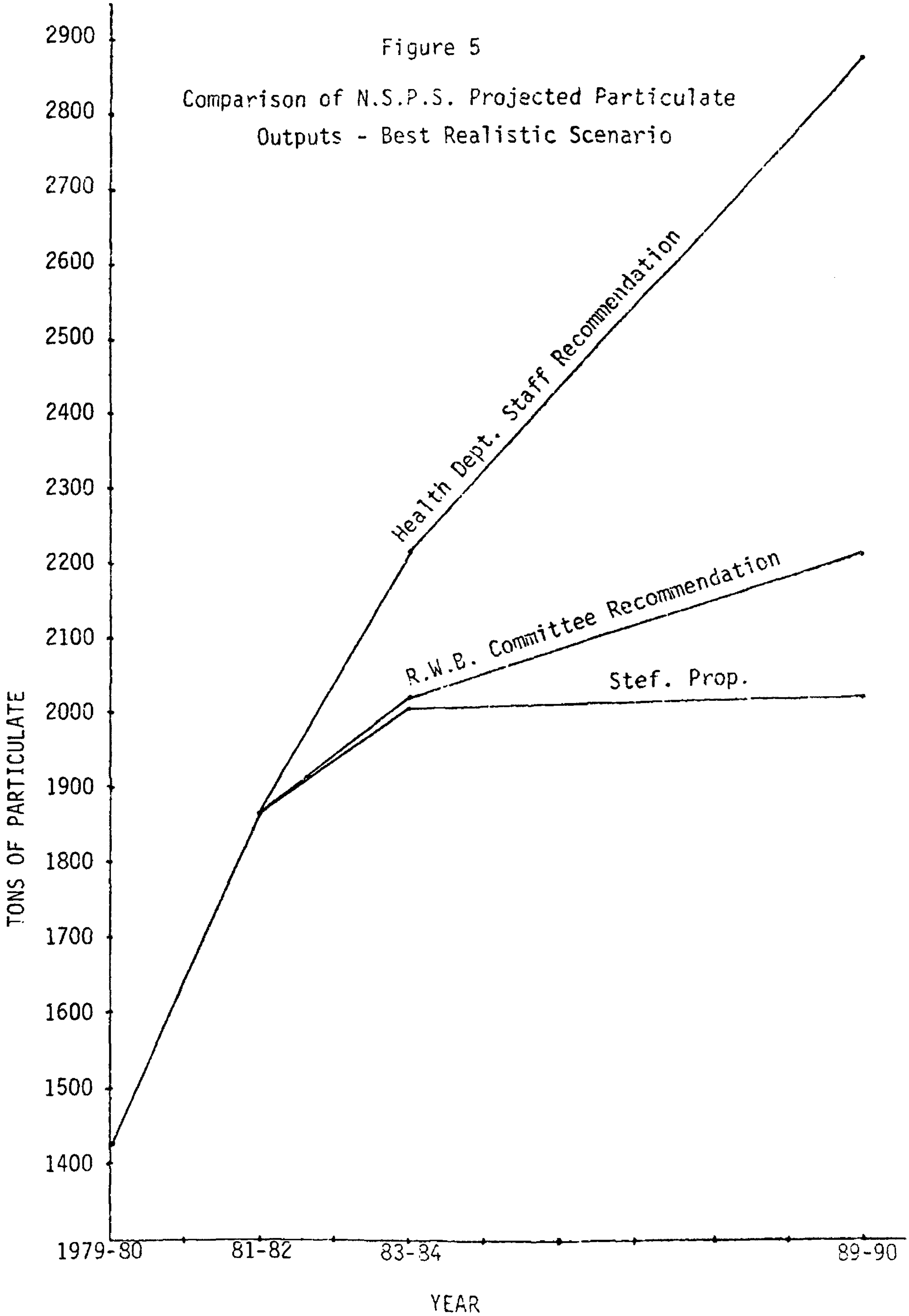


Figure 5
Comparison of N.S.P.S. Projected Particulate
Outputs - Best Realistic Scenario
TONS OF PARTICULATE
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
Health Dept. Staff Recommendation
R.W.B. Committee Recommendation
Stef. Prop.
1979-80
81-82
83-84
89-90
YEAR

studies of our air pollution problem. They also declared that such a system would be a "potent education[al] tool" regarding ways to reduce emissions from wood burning.[37] All these reasons point to the importance of establishing an RWD permit system.

In spite of this, the AQU recommended against establishing such a system. Their arguments are discussed below.

(1) The AQU staff argued that establishing a permit system would be met by community resistance that might make enforcing such a system "an administrative nightmare."[38] Of course there would be some resistance and hostility, but possibly not as much as the AQU imagined. This conclusion stems from the findings of a June 1981 opinion poll that revealed that about 72% of those polled favored the use of both voluntary and mandatory measures to "clean up" Missoula's air pollution.[39] When asked about establishing a permit system, 55% of the respondents supported the idea.[40] Although this response was not broken down to reflect whether or not the respondents burned wood, the result still indicated that a majority of Missoulians supported the idea of a permit system even before any campaign to stimulate community awareness of the need. This may mean that the problem of gaining community support for such a program might not be as difficult as first envisioned.

(2) The AQU found that the ". . . cost effectiveness of the permit system would possibly be in question . . . [during] . . . at least the first year or two."[41] They went on to say that the effort to enforce the program would require additional personnel and equipment that ". . . would detract from the [AQU] personnel's ongoing programs."[42] However, both these statements may be in error.

Taking the latter point first, the permit system was designed to pay for itself, including providing for the additional personnel and equipment to administer the program. The new costs were known to the staff, and built into their consideration of the plan that found that the program would be able to pay for itself (in its entirety) using about 60% of the monies it generated during each of the first two years. Additionally, this refutes the earlier assessment as to cost effectiveness, because obviously the program can pay for itself once it is set up. Cost is therefore not a satisfactory argument against the permit system.

(3) The AQU staff argued that placing the burden of a permit system on only wood burners would be "somewhat discriminatory," because wintertime air pollution also comes from sources other than just wood burning.[43] However, this point flies in the face of mounting evidence as to RWB's contribution to the problem. Recall that at least 68-75% of wintertime respirable particulates come from wood burning, while it also contributes 40-50% of wintertime carbon monoxide.[44] When this is considered, it does not seem at all discriminatory to ask the major polluters to pay for some of the effort to solve the problem. In fact, this is exactly what happened in the past, when industrial sources had to pay millions of dollars for pollution control equipment and still pay for permits to operate. Now that the responsibility for pollution has shifted, it seems reasonable to have some of the costs of the control program borne by those now creating the majority of the problem.

Additionally, the perspective on this point and also on (2) above changes when a permit program is considered not only in terms generating revenue, but also as an essential tool in reducing air pollution. From this vantage, the arguments as to cost effectiveness and where to place the "burden" of a permit fee are even less relevant, because the permit system then becomes an essential means toward a necessary end: reducing air pollution.

For these reasons, and because a permit system is essential to the operation of an effective NSPS program, I am convinced that although complicated and initially difficult to set up, the benefits of an RWD permit program outweigh the negative aspects.

Footnotes

1. Health Effects Committee, 1981, "Report on Particulates," in Full Report: Citizens' Air Pollution Working Groups, Presented 15 April 1981 to the Msla. C-C APCB

2. Residential Wood Burning Committee, 1981, "Final Report and Recommendations," in Full Report: Citizens' Air Pollution Working Groups, Presented 15 April 1981 to the Msla. C-C APCB

3. Ibid.

4. Air Quality Unit, 1981, "Staff Review of the Recommendations of the RWB Committee,"

5. Ibid, 11

6. Church, 1981, Table IX, pg. 23

7. Ibid., Table X, pg. 23

8. AQU, 1980, "Summary of Current Air Pollution Information for Missoula," presented at the Air Pollution Control Board Meeting 12/13/80, 7

9. Ibid.

10. Linda Hedstrom, Msla. C-C Health Dept., 1981, personal communication

11. Richard T.DeCesar and John A.Cooper, 1981, "Medford Aerosol Characterization Study," Final Report, Prepared for Oregon DEQ, Figure 7, pg. 64

12. Abdul C.Latif and R.K.Mufti, 1977, "Philadelphia Air Quality Control Region: Need and Recommendations for Revision of Transportation Control Plan," in Environmental and Conservation Concerns in Transportation: Energy, Noise and Air Quality, Transportation Research Record 648, Transportation Research Board, National Academy of Sciences;
This report does not address TSP per se, but CO and HC. However, since in transportation related air pollution both CO and TSP emissions are related to VMT, slight reductions in CO emissions from reducing VMT may be taken as creating similarly slight reductions in TSP.

13. Fred A.Wagner and Keith Gilbert, 1978, Transportation System Management: An Assessment of Impacts, US D.O.T., Wash. D.C. 20590

14. The OMNI, 1981 study found that the wood stick fired boiler emits less than 10 lbs/ton, and recent demonstrations in Missoula of the Meridian ceramic stove exhibited great potential, as it burned with no visible emissions.

15. WMSCPI, 1981, 75

16. The actual percentages of burners not closing drafts were: 57.1, 80.0, 48.4, 35.0, 56.9, 68.8, 51.1, and 70.1. The average of these value was selected as representative of Missoula because the relatively recent revelations about wood smoke pollution have not yet had time to have much effect. Therefore, burning habits throughout Montana can be assumed to be pretty much the same.

17. Graham W.Ward, 1979, "Can Preventive Health Care Be Marketed?", Am Pharmacy 19(1): 10-13

18. Ibid., 12

19. Ibid.

20. Ibid.

21. An opinion poll in December 1980 (Research Unit) found that about 80% of the Missoulians polled felt that air pollution was a major problem in Missoula. However, only about half of those asked knew the major contributor was RWB.

22. Carl I.Hovland and Henry Pritzker, 1957, "Extent of Opinion Change As A Function of Amount of Change Advocated," J Abn Soc Psy 54: 257-261

23. Ibid.

24. Carl I.Hovland, O.J.Harvey, and M.Sherif, 1957, Assimilation and Contrast Effects in Relation to Communication and Attitude Change," J Abn Soc Psy 55: 244-252

25. Alvin Pettus, 1976, "Environmental Education and Environmental Attitudes," J Env Ed 8(1): 48-51, pg.51

26. Jo Ellen Force, T.A.Setiga, and R.W.Swain, 1976, "A Community Environmental Education Program on Air Quality," J Env Ed 8(3): 32-39

27. Pettus, 1976, 51

28. William McBroom, U.M. Dept. of Socciology, 8/81, personal comm.

29. Ann Mary Dussault, Nordbye Advertising, 8/12/81, personal comm.

30. Aldemane, Green, and Flynn, 1980, "Hypertension Control Programs in Occupational Settings," in Public Health Reports; details as provided by Fran Alves, Health Educator, Msla. C-C Health Department

31. John Waverek, Assistant Timber Manager, Missoula District, USFS, 10/21/81, personal communication

32. Ibid.

33. Kevin Brown, Assistant Fire Management Officer, Missoula District, USFS, 10/21/81, personal communication

34. Jim X.Borzym, Solar Coordinator, MT. Western Sun, 7/81, pers. comm.

35. Residential Wood Burning Comm., 1981, 21

36. Air Quality Unit, 1981, 11

37. AQU, 1981, 11

38. Ibid., 12

39. Janice Hand, 1981, "Air Pollution Telephone Survey," Research Unit, Missoula City-County Health Department, June 8,1981, pg.3

40. Ibid., 7

41. AQU, 1981, 12

42. Ibid.

43. Ibid., 13

Chapter 4

Conclusions and Recommendations

Based on my involvement in air quality issues in Missoula, and more specifically on this investigation of the need to establish new source performance standards, I have arrived at a number of conclusions about Missoula's air pollution and ways to alleviate the problem. Attendant those conclusions are several recommendations I wish to make to the Air Pollution Control Board concerning possible solutions. These are listed separately and discussed as necessary below.

Conclusions

(1) During the mid 1960's and early 1970's, before the days of air pollution control by industry, many people agreed that the air here was bad and that something should be done about it. At that time, the pulp mill was emitting large amounts of odorous, reduced sulfur compounds and particulate matter, and the valley's numerous teepee burners were spewing out tons of smoke and ash. Together, these phenomena polluted the air with bad smelling gases and highly visible plumes of smoke. The sickeningly noticeable nature of the pollution then, is probably what made this period the point of reference for those who say that in comparison today's air quality is pristine. However, those who are still willing to make that claim are mistaken.

(2) Since those "bad old days," there has been a significant shift in both the sources of, and in those responsible for the majority

of Missoula's air pollution. The advent of pollution control by industry and a growing reliance upon wood heat by the people of Missoula resulted in the industrial emissions no longer being the main problem. Instead, residential burning is now the culprit. A fundamental change in the nature of the problem accompanied those shifts. As a result, even though the pollution may not be as noticeable (to some), the particulate fraction of it is now many times more dangerous. The basic reason for this: the vast majority of the particles generated by residential wood burning are very much smaller than those generated by teepee burners. The significance of that difference: these smaller particles are able to do what the larger particles could not, by pass the defense mechanisms of the upper respiratory tract and penetrate deeply into the lungs. This increases the potential for adverse health effects.

(3) Along with the change in particulates, there has been a constant growth in other sources such as transportation. Although these sources do not contribute significantly to wintertime respirable particulates, they do add other pollutants to the air. This increases the potential of particulates to act synergistically with the other pollutants, thereby exacerbating the problem. This too changes the nature of today's pollution compared with that of yesteryear. Consequently, even though controlling transportation related pollution will not significantly reduce wintertime particulates, there is still ample reason to control this type source for other pollutants.

(4) Missoula's wintertime air pollution fluctuates with the weather. During periods of good atmospheric dispersion, the problem will not occur. However, during extended inversions, pollutants can con-

centrate to health threatening levels. The reason for this is clear: an estimated average 80% reduction in the volume of the available air during wintertime inversions, coupled with expansive growth in the number of users of that air.

(5) Regardless of the dispersion that occurs during any specific winter, there is an ever present and constantly growing number of pollution sources. As seen in the past few years, but especially during the winter of 1976-77, when the weather conditions are "right," those pollution sources fulfill their potential to poison the air. In November-February 1976-77, there were some 40 days when the TSP levels exceeded 150 ug/m^3, and an average TSP concentration of over 132 ug/m^3. This winter (1981-82) there are over 5000 additional households burning wood than during 1976-77, with the potential to burn an additional 38,500 tons wood. We therefore have the potential to create worse air pollution than ever before. Consequently, if this winter, or any future winter has weather conditions similar to those of 1976-77, or any other poor dispersion winter, the resulting air pollution will be worse.

(6) Because of the expansion in residential wood burning, the cumulative particulate generation capacity of sources in the Missoula airshed is quickly approaching a level equalling or surpassing that of the days of uncontrolled industrial emissions. The situation is already recognized as being dangerous, and as the use of wood continues to proliferate, so grows the potential for Missoula to poison itself. At this point, the controlling factor is not us, but the weather. If action to reverse the expanding pollution potential is not taken, and very soon, the stated goals of the Air Pollution Control Board to reduce

pollution will not be realized, and the massive citizen committee effort at the Board's behest will have been more than an exercise in futility.

Solutions

(7) An education program regarding all forms of air pollution is an essential part of the needed process. It can help some and must therefore be pursued. But it cannot provide a large enough part of the of the solution in time, if at all, to stand alone.

(8) In addition to (3) above, I conclude that education can have but a very small impact in reducing transportation related pollution. Meaningful reductions in this area will require more stringent measures.

(9) Finally, I am forced to the conclusion that a comprehensive program to control the expansion of new pollution sources within our airshed is essential. Only action taken now, before a serious situation gets much worse, will enable Missoula eventually to become a place of relatively clean air. New Source Performance Standards and an RWD permit system are not quick or easy solutions to the problem, because particulate generation capacity will continue to increase for a time. Instead, they are an answer to the long-term problem of how to slow the proliferation of dirty wood stoves and fireplaces while still allowing those who want to burn to do so. Once that growth has been slowed, stove technologies and other alternative technologies will have a chance to catch up. Then as old stoves wear out to be replaced with new ones, and as solar energy and conservation retrofitting begin to provide for more of our heating needs, the pollution capacity will slowly subside. In the mean time, Missoula will continue to have the capacity to poison

her air, with the deciding factor not the wood burners, but the weather. Until this capacity is reduced, we stand at the brink of this town being an unfit place to live.

Recommendations

The above findings clearly demonstrate that extensive, high emission wood burning and Missoula's limited airshed are incompatible. Consequently, something must be done to curb the expanding use of all but low emission wood-burning devices. The longer that high emission units are tolerated, the more intractable the problem will become. If the Board's stated goals of reducing respirable particulates are ever to be realized, the currently snowballing problem must be faced head on. I therefore make the following recommendations.

(1) A new source performance standard of 10 lbs/ton should be established, to become effective 1 January 1983. This standard should apply to all residential wood-burning devices installed after the effective date. All existing units should be allowed to remain in use, but should only be replaced with equipment meeting the low emission limitation.

The specifics of this standard are not set in concrete, and are of course up to the discretion of the Board. However, it is imperative that the standard be set low enough to make a substantial difference. This choice is critical as regards long-term impacts; the lower the limitation, the better.

At this juncture, there is only one stove that has been proven to meet this emission limitation, i.e., the stick-wood fired boiler. But several others that are likely to meet it are presently being tested, and those results will be available to the Board prior to their decision. But whatever the results of those tests, the limitation should be set low enough to do the most good possible. Potential wood burners must wait for clean-burning technology, because breathers in Missoula can no longer afford to compromise.

(2) The implementation of an NSPS requires the concomitant establishment of a system to control the distribution of RWD's. For this, a permit system is essential. Such a system should be studied between now and early 1983, and all RWD's should be licensed by 1 January 1984. During the interim year, (1/1/83-1/1/84) the Board should enlist the cooperation of local stove and fireplace dealers to assure that they sell only low emission units.

Final Thought

I am fully aware that implementation of my recommendations will not be physically easy, politically popular, or in the short term, fiscally inexpensive. However, I believe that they are essential, because air pollution is still worsening, and because I concur with the opinion of the Board that a reduction is already necessary to protect public health. In my opinion, for that effort to be successful, actions along the lines of my recommendations must play a critical role. For though they are but a fraction of what must be done, without them all other efforts towards reducing particulate levels will be for nought.

Chapter 5

Board Action to Date

The original recommendations by citizen committees were made in a presentation to the Board on 15 April 1981. Since then, the Board has considered NSPS at several meetings, and at one point, almost initiated rule-making proceedings. On the verge of action, the Board stepped back, because they felt they had insufficient information as to where to set the limitation or as to what RWD's could meet the standard. At that time, the Board directed the staff to procure that information. In the interim, I prepared the larger portion of this work to assist them in their deliberations.

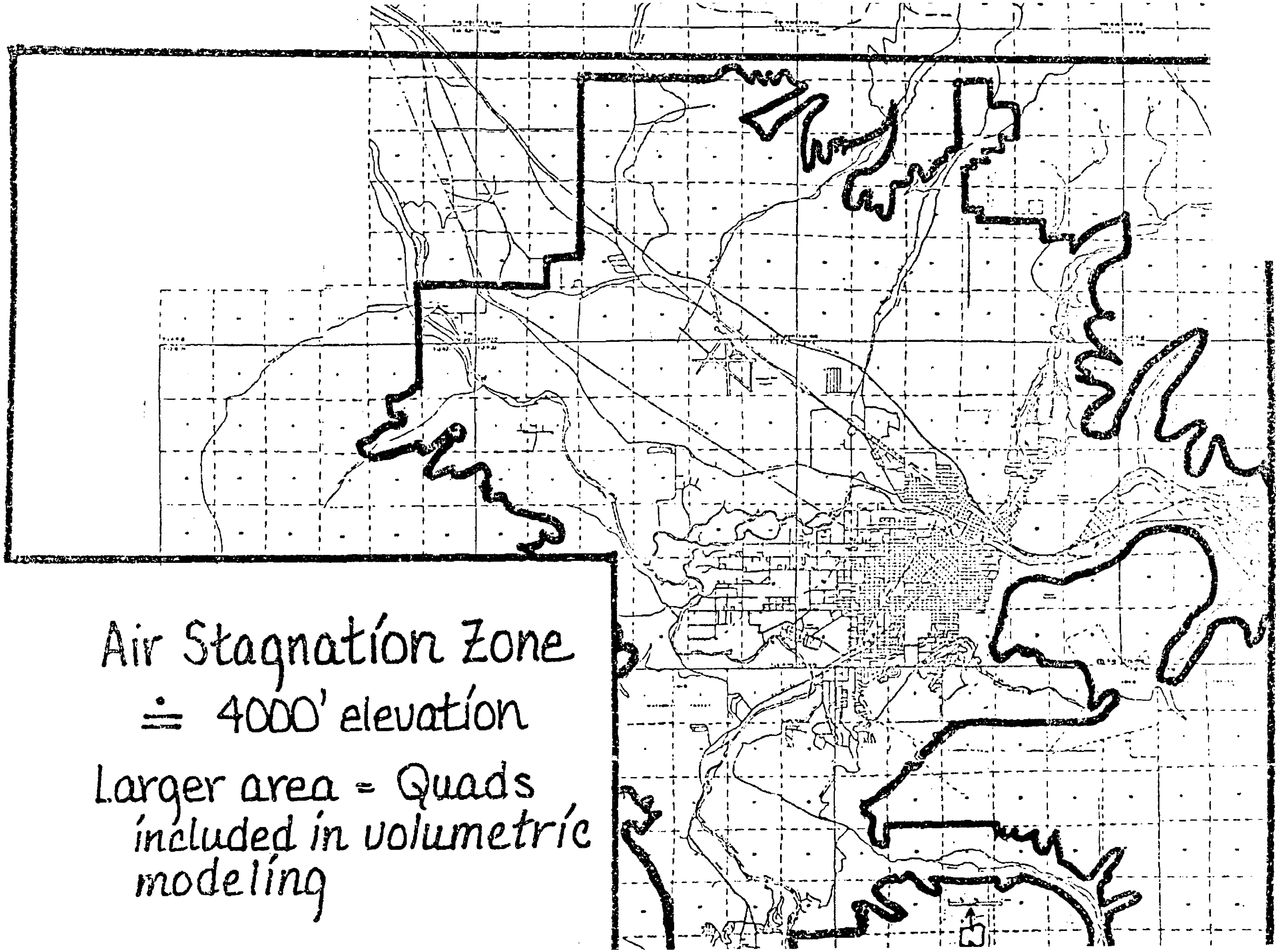
On 20 August 1981 I presented a summary of my findings to the Board, and made the same recommendations as above. The findings in this full version of my report are essentially the same, only the final Table and the last two figures having been changed.

Since the presentation of the summary report, no formal action has taken place because the Board turned their attention to other pressing matters. This issue is scheduled to resurface sometime in December 1981 for formal consideration. At that time I will reiterate the findings of this work, and hope that the data herein will assist the Board in their deliberations towards a healthy Missoula.

Appendix A

Calculations of Airshed Volumes

The map on the following page illustrates the area that was "digitized" by the computer and included in the calculations of volume discussed in chapter one. The outer, straight lines indicate the area used by the computer, while the inner, irregular area is Missoula's "Air Stagnation Zone," which was recently designated by the Air Pollution Control Board.


Air Stagnation Zone
≐ 4000' elevation
Larger area = Quads
included in volumetric
modeling

Appendix B

Emission Factors

The rate of emissions from wood combustion depends on a number of factors, all of which influence some aspect of the burning process. These factors include: air supply (e.g., amount, velocity, location of the inlet and resultant turbulence and mixing); qualities of the fuel charge (e.g., species, moisture content, heat potential, surface to volume ratio, shape); the amount of fuel charged; and the size and shape of the combustion chamber.[1] There are in fact so many variables which affect fire chemistry, that there are not yet any completely standardized methods for emission testing RWD's.[2] Given this lack of information, I reviewed all available emission test studies in terms of their treatment of certain critical variables. The results of these source test studies are presented in Tables B-1 and B-2, and each is discussed below.

Residential Fireplaces

Table 5 compiles the available emission test data from studies of residential fireplaces. All the studies listed used a modified EPA Method 5 sampling train to stack sample for particulates. This method is quite complicated and is not well suited to such testing for a variety of reasons, but it is the only reliable method currently available.[3] Several studies which used other test methods were also reviewed, but were deemed unsuitable for inclusion here due to the incomparability of the data they generated.[4] In addition, only data from the testing of woods generally comparable to those burned in Montana have been included.

Table B-1

Burning Conditions and Particulate Emission Factors for Residential Fireplaces

Reference	Wood Type	Percent Moisture	Burn Rate (lbs/hr)	Emission Factor (lbs/ton)	Comments
Snowden et al., 1975	Douglas Fir	10.6	12.6	23.0	
	"	"	9.0	28.8	
	"	"	18.3	17.6	
	"	"	14.8	27.0	Includes cold start up.
	Western White Pine	15.4	24.7	14.4	Constant tending, no smolder.
		"	30.9	13.0	
		"	24.5	27.2	
		"	20.1	16.2	
DeAngelis et al., 1980	Yellow Pine	5.2	25.1	15.4	Same as Snowden but no start up.
		29.6	21.2	24.0	
PEDCo, 1977b	Pine	7.5	10.6	42.0	
	"	"	18.1	33.2	
	"	"	8.6	19.6	
	"	"	7.1	41.6	Very dry wood.
	"	"	7.1	46.2	Full fire cycle.
	"	7.7	7.9	44.4	No smolder.
	"	"	15.6	40.0	
	"	"	10.6	38.8	
	"	"	10.1	52.6	
EPA	--	25	--	20.0	
Church, 1981	--	25	--	20.0	
WMSCPI, 1981	--	25	--	30.0	

The tests conducted by Snowden et al., used extremely dry wood burned at a very high rate. This would reduce emissions. Emission tests monitored cold start up, but once established, the fire was constantly tended (fueled and stoked) to prevent any smoldering. These EF's then are only representative of fireplaces operated in this manner, and probably do not depict common burning practices.

The tests by DeAngelis et al., were conducted in much the same manner, but only tested emissions from fuel charges added to an established bed of coals in a hot fireplace. This does not include emissions from either cold start up or from smolder burning and is therefore not a good picture of the field situation.

The PEDCo study tested the full fire cycle from cold start up to burn down using extremely dry wood. Extrapolating from the findings of Shelton et al., the low moisture content fuel may have elevated particulate emissions by over fuelling the fire due to very rapid pyrolysis. But correcting for moisture content does not lower the EF's much.[5] Further, as in the above cases, the test fires were maintained to prevent smoldering, which keeps particulate emissions much lower.

In 1981, Peters et al., sought to explain the differences in the findings of DeAngelis and PEDCo. They critiqued the latter study and reasoned that PEDCo's use of visual assessment of the fuel remaining at the end of a test would "tend to bias the error in weight determination toward the low side, and, hence, inflate the emission factor.[6] This may have been the case, but the resulting EF's still do not represent emissions from a smoldering fire. In addition, several other studies tend to support the findings of PEDCo, and thereby argue for the use of higher EF's so as to represent common burning practices.[7]

The figure shown for the EPA is the accepted EF for residential fireplaces. It is based on the work of Snowden et al., and is probably unrealistically low for all the reasons discussed above. Church used the EPA figure for calculating particulate loading in his 1981 study of Missoula. However, he points to the absence of test data for smoldering conditions and concludes that the use of 20 lbs./ton is conservative.[8]

Finally, there is the EF of 30 lbs/ton used in the 1981 study by WMSCPI. The present author chose this figure for that study because it is the approximate mean (29.7) of the values found in the other studies listed, and because I felt it to be more representative of common burning practices.[9] Although it may still be too low because none of the studies to date have explored the emissions from smolder burning, it is probably more characteristic of the field situation than any other previously used EF.

As a critical value in the WMSCPI study, this figure was presented to the Montana Department of Health and Environmental Sciences, and accepted as a better representation of particulate emissions from fireplaces than EF's used in previous studies. Discussion with the head of the air quality section of Oregon's Department of Environmental Quality revealed his opinion that 30 lbs/ton is a representative choice.[10] Based on the above reasoning that previously used EF's other than the WMSCPI figure of 30 lbs/ton are too low to represent common burning practices, calculations of particulate emissions from fireplaces in this paper use the WMSCPI figure.

Residential Wood Stoves

Table B-2 lists the findings of the three most pertinent source test studies of wood-burning stoves to date. All three used the modified EPA Method 5 to stack sample various types of stoves under several operating conditions.

Table B-2

Burning Conditions and Emission Factors for Residential Wood Stoves

Reference	Wood Type	Percent Moisture	Burn Rate (lbs/ton)	Emission Factor (lbs/ton)	Comments
DeAngelis et al., 1980	Yellow Pine	5.16	15.9	16.0	
		5.16	15.9	15.2	No start up.
		29.6	13.2	38.0	High fire.
		29.6	17.2	32.8	No smolder.
Rossman & Odell, 1980	Douglas Fir	14.0	8.3	47.8	Includes
		"	3.6	101.2	start up.
		"	8.0	46.6	High and
		"	3.3	149.2	low fire.
OMNI, 1981	Douglas Fir	19.4	9.9	62.2	
		17.1	9.9	40.0	Includes
		16.3	5.6	42.8	start up.
		17.6	4.1	58.6	low fire.
EPA	--	25.0	--	4-30	
Church, 1981	--	25.0	--	25.0	
WMSCPI, 1981	--	25.0	Medium	50.0	
			Smolder	100.0	

DeAngelis et al., tested both very dry and "green" pine by adding a fuel charge to established coals in a hot stove, and then burning at high fire with sufficient air to prevent any smoldering. Consequently, the results do not reflect the emissions from either cold start up or from an air starved fire, and are probably not representative of common burning practices. But what are common burning practices?

In 1979-80 Church found some information in this regard that about 39% of Missoula's wood burners used wood for auxiliary heating. This probably entails starting a fire at least once a day, which means: cold start up. In addition, Church found that at least 30% of the wood stoves in use at that time were air-tights with thermostatically controlled air inlets. Such stoves control heat output by regulating the air flow to the fire. If properly sized for heating needs, and used in a reasonably well insulted room, such stoves will starve the fire for air about half the time.[11]

The WMSCPI study gives additional information as to common burning practices. It revealed that at least 41% of the wood stove burners in four cities in Montana (other than Missoula) regularly smolder burn by closing the air draft on their stoves.[12] From these findings, it is obvious that EF's such as DeAngelis', that do not reflect even low fire burning, much less smoldering, are inappropriate for use in Missoula, where such activity is almost certainly practiced extensively.

Applicable studies

The results, shown in Table B-2 (above), of both the Rossman and Odell (1980) and the OMNI (1981) studies are more generally applicable to the Missoula situation. Both sampled the emissions from Douglas Fir during the full fire cycle. In addition, although neither tested smoldering conditions, both did monitor emissions during low firing. Notice that their results are all higher than those of DeAngelis, some substantially higher. This is a reflection of the Rossman finding that over 90% of particulate emisions occur during the first half of each burn[13], (especially during cold start up), and the finding by others that the emission rate varies inversely with the amount of available air.[14] This last point would suggest that an even higher EF should be used to represent smolder burning, a fact not taken into account in the next two entries in Table B-2.

The EPA range for emission factors of 4-30 lbs/ton is based primarily on the work of Butcher and Buckley, 1977. This specific paper was not available for review, but the work of Butcher and Sorenson, 1979 was. In this later study, a stove was tested using a high volume sampler to collect the emissions from the stack at a point 18 feet above the stove. Temperatures at the collection point were not monitored but were estimated to be about 100°C. If this is accurate (it may be low), at least some of the condensible organics in the effluent would still have been gaseous and therefore not collected by the hi-vol filter. Since later tests have shown that at least 40% of wood stove emissions are condensibles,[15] it is appropriate to conclude that Butcher's results and therefore EPA's emission factors are too low. It follows then that Church's choice of EF, which was based on the EPA accepted range, must also be too low to represent the situation in Missoula.

The final entries in Table B-2 show the burning conditions assumed and the emission factors used to estimate particulate emissions from wood stoves by the 1981 WMSCPI study. Two EF's were used to represent pollutant outputs for medium fire and smolder burning. These were felt to be more representative of common burning practices. The medium fire EF of 50 lbs/ton is about the mean of the values found by OMNI for low fire, optimal burning. It is somewhat higher than than the mean of the two Rossman tests (47 lbs/ton). The choice of 50 lbs/ton then, is about the rate found for high to medium firing with constant tending to prevent smoldering. This figure was used in this work to represent the practically achievable particulate output from common residential stoves.

The EF chosen to represent smolder burning (100 lbs/ton) is about 32% higher than the mean of the results of low fire testing by both Rossman and OMNI (76 lbs/ton).[16] However, these studies did not test smoldering fires. Additionally, the burn rates of the OMNI "low fire" tests are probably higher than the rates for either low fire or smolder operation of most common stoves (e.g., Butcher was able to operate his test stove as low as 2.2 lbs/hr.). Therefore, a low fire or smolder burn rate that was half that of the OMNI rate would produce greater emissions.[17] Consequently, an EF of 100 lbs/ton for a smoldering stove is more representative than the EF used by Church, and may even prove to be conservative.

As with the EF's for fireplaces, the WMSCPI EF's for stoves were approved for use by the Montana Department of Health's Air Quality Bureau. Therefore, the EF's for stoves of 50 and 100 lbs/ton are used for calculations in this work.

Footnotes

1. Western Montana Scientists' Committee for Public Information, 1981, Survey of Residential Wood Use in Helena, Bozeman, Great Falls and Kalispell, Montana," A Report to the Air Quality Bureau, Department of Health and Environmental Sciences, Cogswell Building, Helena, MT. 59601; page 2

2. W.T.Greene and B.J.Tombleson, n.d., 1981?, "Institutional and Regulatory Approaches to Control Residential Wood Burning Emissions," Oregon Department of Environmental Quality, Portland, OR 97207

3. David R Rossman and F. Glenn Odell, 1980, "Evaluation of Wood Stove Emissions," Prepared for Oregon DEQ and USEPA, page 3

4. These include the works: John M. Allen, 1981, "Control of Emissions from Residental Wood Burning by Combustion Modification," in Wood Heating Seminar 1980/1981, Wood Heating Alliance; This study tested only cured oak and is not comparable to the other studies.

   A.C.S.Hayden and R.W.Braaten, 1980, "Performance of Domestic Wood-Fired Appliances," Canadian Combustion Research Laboratory, Ottawa, Ontario; This study used the "indirect method" of measuring stove efficiency, which measures energy loss up the stack.

   James E Short, 1974, "Particulate, Carbon Monoxide, and Hydrocarbon Emissions From Residential Fireplaces," Air Quality Source Testing Report #74-1, Albuquerque Department of Environmental Health; This study tested an assortment of woods that are not strictly comparable with woods available in Montana.

5. J.W.Shelton et al., N.D., "Wood Stove Testing Methods and Some Preliminary Experimental Results," in ASHRAE Transactions Vol. 48, Part 1 1178; This study found that optimal moisture content of about 22% produced lowest emissions and highest efficiencies. By interpolating EF's upward or downward to correct for differences in moisture content, I determined that that particular variable in the source test studies probably did not affect emission outputs to any great degree.

6. J.A.Peters, T.W.Hughes, and D.G.DeAngelis, 1981, "Wood Combustion Emissions at Elevated Altitudes," Monsanto Research Corporation, in Wood Heating Seminar 1980/1981, Wood Heating Alliance

7. Hayden and Braaten loc. cit.; and Short, loc. cit.

8. Scott Church, 1981, "Residential Wood Burning and Its Impacts on Particulate and Carbon Monoxide Emissions in Urban Missoula," Air Quality Unit, Missoula City-County Health Department, Missoula, MT 59801

9. WMSCPI, 1981, 23

10. John Kowalczyk, 8/18/81, personal communication

11. Jim Carlson, 8/81, personal communication

12. Author's calculation using raw data from WMSCPI, 1981

13. Rossman and Odell, 1980, 3

14. Samuel Butcher and Edmond M.Sorenson, 1919 "A Study of Wood Stove Particulate Emissions," JAPCA Vol.29, No.7: 724-728, July, 1979

15. Rossman and Odell, 1980

16. The emission factors chosen to represent emissions from smoldering stoves were selected in the absence of hard data as to this condition. To date, no studies have examined this aspect of RWB, apparently because investigation of this particular condition has never been specifically requested by the contracting agencies. This fact remains a serious deficiency in extant source test data.

16. This is the logical conclusion based on the findings of Rossman and Odell loc. cit., that show the difference in emissons between high and low fire stove operation; and those of Butcher and Sorenson loc. cit., that emission output is inversely proportional to combustion rate.

Appendix C

Form Work Sheet

The form on the following page illustrates the work sheet that was used to calculate the projections of future particulate outputs in Missoula. Once the sheet was filled in, the rows were simply multiplied across, and then summed for a total. The following key defines the categories on the sheet other than the obvious.

%ATS w/ts = percent of the total stove population that was comprised of air-tight stoves with thermostats, under this category, 50% of the total were placed in the next two lines and considered to be burning at either medium or smolder fire

Other = the rest of the stove population besides the above group. Under this category, stoves were divided into either medium or smolder burning. This is where the effects of the education changed the number of units in each category, depending on which scenario was being used.

New = the portion of the population subject to the NSPS limitation being investigated.

$\overline{X}$ Cds = the average number of cords considered used by each type RWD, this amount was 1.5 cords/fireplace and 3.5 cords/stove

Mass = the average mass of a cord of wood in Missoula = 1.64 tons

Burning Season NSPS Alternative

WBD	#	$\bar{X}$ Cds	Mass	BR	EF	Tons Partic.	Comments/Totals
Fireplaces							Best Possible Case
" (new)							
Stoves							
%ATS w/ts							
" med.							
" smd.							
Other med.							
" smd.							
New Stoves							TOTAL
Fireplaces							Best Realistic Case
" (new)							
Stoves							
%ATS w/ts							
" med.							
" smd.							
Other med.							
" smd.							
New Stoves							TOTAL
Fireplaces							Midrange Case
" (new)							
Stoves							
%ATS w/ts							
" med.							
" smd.							
Other med.							
" smd.							
New Stoves							TOTAL
Fireplaces							Worst Case
" (new)							
Stoves							
%ATS w/ts							
" med.							
" smd.							

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