

Abstract: Craters of the Moon has participated in air quality monitoring projects for the National Park Service and other agencies for over a decade. Until recently, managers assumed a pristine airshed existed at Craters of the Moon, with the only pollution occurring in the summer in the form of windblown dust and smoke. Recent events such as possible pollutant-caused foliar damage and increased industry in southern Idaho raised questions about the current status and developing trends of air quality. This paper examines visibility, total suspended particulates (TSP), fine particulates, and pH levels. Over the past five years, visual range has shown a significant steady decline ($p < 0.01$); TSP have generally decreased; and pH has remained approximately the same. Results of the fine particulate study suggest that sulfates and windblown smoke are important contributors to the particulate make-up of the CRMO airshed.

some statement as to inability to conclude or define cause of visibility decline

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INTRODUCTION

Approximately 80% of the total land mass at Craters of the Moon National Monument (17,513 ha) was classified as wilderness in 1970 under the national wilderness system. The airshed in wilderness areas greater than 5000 acres (2025 ha), officially designated as Class I air, has been afforded strict protection according to the Clean Air Act amendments of 1977. These amendments not only established as a national goal protection of visibility in Class I Federal areas, but also provided national ambient air quality standards (NAAQS) for six (now seven) criteria pollutants deemed to be harmful to human health. A "standard" is the maximum permittable pollutant level in the ambient air, while "criteria" is a term used to define a pollutant which may be anticipated to endanger public health and welfare.

~~Personnel~~ at Craters of the Moon have participated in air monitoring projects for over a decade. Since 1974, the park has operated a high volume sampler for the state of Idaho. This sampler monitors Total Suspended Particulates (TSP), recognized as one of the criteria pollutants. According to Idaho's Department of Health and Welfare, Craters of the Moon exhibits the lowest TSP loading across the contiguous 48 states. Data from Craters of the Moon are utilized by the EPA as background levels representing clean air (Robert Wilkosz, pers. comm.).

In 1982 Craters of the Moon became one of several units participating in an NPS-^{supported}~~sanctioned~~ visibility monitoring program, originally implemented in 1980. Visibility is a key resource to many NPS units. Enabling legislation for many areas recognizes specific scenic vistas as deserving special protection for the enjoyment of future generations. To complement the visibility study, a fine particulate monitoring network was established to help the NPS determine the cause of visibility reduction. Particles less than 2.5 μ (microns) in diameter (generally, between 0.1 and 1.0 μ) are extremely efficient at scattering light, thus they play a major role in decreasing visual range (EPA 1979, Malm 1983, Id. Dept. of Health and Welfare 1984). Fine particulates cause special concern because they are generally thought to be anthropogenic in nature. From 1982 through spring 1986 Craters of the Moon operated a series filtration sampler which sampled both coarse and fine particles.

In addition to particulate monitoring, Craters of the Moon is participating in a nationwide survey of acidic/^{fallout}deposition. Weekly precipitation samples have been collected at the park since 1980 and sent to an analytical laboratory in Illinois. There, pH and conductivity and levels of several ionic constituents of the sample are determined. (what acid? specifically, /analysis on specific elements)

The programs in which Craters of the Moon (CRMO) have participated have been of a regional or national interest. It became apparent that although the park was receiving overall project summaries from

cooperators, management personnel really did not have an understanding of interrelated air quality trends at the park-specific level. In the fall of 1985, Dr. James Bennett of the NPS Air Quality Division (AQD), noted several types of foliar anomalies which he attributed to possible damage by fluoride and ozone. This, accompanied by a lack of knowledge at the park level, helped spark an interest by management personnel to determine what, if any, changes were occurring to the CRMO airshed, based on several years of data collected.

The objectives of this study were to establish trends and correlations in the data thus far collected. Due to a time constraint, statistical correlations were not drawn between data sets.

*a note for the
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STUDY AREA

Craters of the Moon National Monument lies on the northern edge of the Snake River Plain, 30 km southwest of Arco, ID. The monument contains the majority of cinder cones and volcanic fissures of the 85 km long Great Rift, extending southeastward from the base of the Pioneer Mountains towards American Falls, ID. Elevations at Craters of the Moon range from 1627 m to 2343 m. The adjacent portion of the Snake River Plain slopes downward towards the southeast from 1767 m to 1615 m.

Average annual precipitation from 1957 - 1987 is 43.2 cm with a winter peak in January and a larger spring peak in May. A wind rose generated from hourly data taken from November 1984 - May 1987 shows a mild northerly component occurring in the winter and spring and a strong southwesterly component the entire year. Southwest winds generally occur in the 16 - 32 km/h range, while northerly winds generally encompass the 6.4 - 9.6 km/h range.

The monument was established by presidential proclamation in 1924 and enlarged to its present size of 215 km² in 1926. The 175 km² Class I air wilderness portion of the monument lies 41.8 km northwest of the Idaho National Engineering Laboratory's (INEL) coal-fired Chemical Processing Plant (CPP). The potash fertilizer plant in Pocatello, a major producer of SO₂ in southern Idaho, lies 80 km to the southeast.

METHODS AND MATERIALS

A. Data Collection

A1. Total Suspended Particulates

The high volume sampler is the EPA-designated instrument used to sample TSP. The sampler draws in a specified volume of air over a 24-hour period, depositing particles less than 100μ in diameter on an 8" x 10" (20 x 25 cm) quartz filter. Prior to September 1987, matted glass fiber filters were used. Standard procedures for operating a high volume sampler are identified in Appendix B of 40 CFR 50. Samples are taken every sixth day as specified by the EPA to coincide with a national sampling scheme.

TSP filters are pre-weighed by state laboratory personnel and conditioned to less than 50% relative humidity to eliminate interference by water-attracting properties of the filter. A packet of pre-weighed filters is sent to the monument to be run on the approved sampling scheme. Exposed filters are stored at the park until the end of the current monitoring month and sent to the Pocatello Division of Air Quality where laboratory analysis occurs. Total suspended particulate matter concentration is determined by comparing the exact sample weight with the volume of air sampled, and calculated as $\mu\text{g}/\text{m}^3$.

Annual geometric means are determined to monitor compliance with national standards (NAAQS) as set forth in the Clean Air Act amendments. Primary standards for TSP are $75 \mu\text{g}/\text{m}^3$ annual geometric mean, and $260 \mu\text{g}/\text{m}^3$ 24-hour maximum. Secondary standards are $60 \mu\text{g}/\text{m}^3$ and $150 \mu\text{g}/\text{m}^3$. Primary standards protect human health and secondary standards protect public welfare by protecting plants, vegetation and soil.

A2. Fine Particulates

The SFS-500 series filtration sampler captured coarse and fine particulates on the following two stages:

coarse particles ($15 - 2.5 \mu$ in diameter) on stage 1; and
fine particles (less than 2.5μ in diameter) on stage 2.

The NPS AQD contracted with the University of California-Davis to run the fine particulate study in conjunction with its visibility study. From June 1982 - March 1985, the network consisted of 31 sites. Craters of the Moon participated in the study from June 1982 - May 1986.

Blank filters in sealed cassettes were sent to the monument for operation and returned to the Crocker Nuclear Lab in Davis, CA for final analysis. Every week, two samples of three days' duration each were run by park personnel.

At the laboratory, each filter was weighed and mounted in a 35-mm slide frame, then subjected to proton beams from a cyclotron. The particulate makeup of the filters was determined by energy emitted from x-rays formed during proton bombardment. Concentrations of all elements heavier than fluorine were calculated with the x-ray technique.

Generally, soil-derived elements dominated the coarse filters, while the fine particulate make-up consisted of industrial-type particles.

A3. Visibility Monitoring

From June 1982 - June 1985, visibility instrumentation at Craters of the Moon consisted of a manually-operated teleradiometer and a 35-mm camera. The teleradiometer is a sort of telescope with an electronic photosensor which measures contrast between the sky and a dark distant object. Simplistically, contrast would be a maximum with no interference from light-scattering particulates.

Seasonal ranger personnel took contrast readings three times each day at 0900, 1200, and 1500 and photographs twice daily at 0900 and 1500 to correspond with a nationally-approved monitoring scheme. Big Southern Butte and the Caribou Mountains were the two mandatory monitoring targets, while the optional targets were Moore, Crescent Butte, and the Teton.

The teleradiometer had four filters corresponding to the green, red, blue, and ultraviolet wavelengths, though the green wavelength corresponds most to the human view. Weekly contrast measurements and exposed slide film were sent to the Air Resource Specialists (ARS) group in Ft. Collins, CO for analysis. The ratio of sky and target light intensities were combined with the target's inherent contrast in a series of equations which yielded visual range (NPS 1983). Minimum visual range was the target distance and maximum theoretical visual range was 391 km (ARS, pers. comm.). In addition to the calculated visual range, a perceived visual air quality (PVAQ) was recorded. A linear relationship between PVAQ and teleradiometer contrast readings exists (Malm 1983).

Monitoring activities occurred primarily in the summer months (June, July, and August) when personnel were available and weather conditions made monitoring equipment accessible.

In summer 1985, manually-operated equipment was replaced with an automatic camera-teleradiometer system. The automatic teleradiometer took measurements in the green wavelength only, continually sending information to Ft. Collins via satellite. Park personnel changed camera film and checked the teleradiometer weekly, recording all activities in a log book. The automatic photographic system consisted of a 35-mm camera body, 135 mm lens, databack which would imprint the day of month and time on each slide, and a three-alarm clock which operated the camera. Big Southern Butte was the only target utilized, and photos were taken

three times per day at 0900, 1200 and 1500. Standard operating procedures specified manually photographing a color documentation chart with each roll of film.

In May 1986, the teleradiometer at Craters of the Moon was returned to Air Resource Specialists, but the photographic system remained. Visual range and PVAQ data are now calculated directly from daily slides, and more reliable information can be obtained for a longer period throughout the year. All supplies are sent to the park from Air Resource Specialists. Any changes in film quality are detected by ARS through the use of unexposed "seasonal control" rolls stored on-site and returned to ARS each season.

All data are analyzed by ARS. After each individual observation is considered, the Standard Visual Range (SVR) data set is analyzed as a rank-order cumulative frequency distribution. All values for a particular season are sorted from low to high. Daily SVR data are plotted for each season and returned to the individual park. Each season is a three-month interval beginning with winter represented as December, January, and February.

A4. NADP sampler

The National Atmospheric Deposition Program (NADP) was created by the Association of State Agricultural Experiment Stations to conduct research on atmospheric deposition and its effects on surface waters and lands (NADP 1982). The sampling network

consists of over 100 sites, of which 22 are within the national park domain. Craters of the Moon's involvement in the NADP began in 1980.

Instrumentation consists of an Aerochem Metrics Wet/Dry collector and a Belfort universal recording rain gage. The collector has a sensor unit which signals the movement of a collector lid to swing over a "dry" bucket, thus exposing the "wet" bucket to periods of precipitation. Thus, the wet bucket collects wet deposition only, while the dry bucket collects dry deposition. The rain gage records all periods and amounts of precipitation for one-week intervals.

Specific standard operating procedures have been prepared by the NADP to ensure a uniformity of sampling protocol and analytical techniques. Each week, park personnel change the wet bucket according to detailed instructions, taking care not to contaminate the sample in any manner. Rain gage recorder paper is also changed weekly. Every eighth week, the dry bucket is replaced and stored at monument headquarters. At headquarters, the wet bucket is weighed and its contents analyzed for pH and conductivity. All wet buckets, whether they contain precipitation or not, are collected weekly and sent to the Central Analytical Laboratory in Champaign, IL. to be analyzed for pH, conductivity and the following ionic constituents: sulfate, nitrate, ammonium, chloride, orthophosphate, sodium, potassium, calcium, and magnesium. Results are in turn sent to individual parks.

B. Park-level data analysis

The statistical software package, "Number Cruncher Statistical Systems" (Hintze 1985) was utilized for computerized data analysis. Visibility, TSP, and NADP data were analyzed at the park level; however, the fine particulate data were not. A detailed account of fine particulate data for all participants was prepared at UC Davis (Air Quality Group 1985). Synopses of the report are included in this document where applicable.

Two-way Analysis of Variance (ANOVA) was utilized to assess differences in mean annual and/or seasonal data. ANOVA is an appropriate statistical technique to utilize for trends analysis because it offers flexibility. The user can introduce year, season, or month terms into the model for multiple effects comparisons (EPA 1981). Introducing seasonal data helps increase the chance of finding the correct annual mean (EPA 1981). TSP data were not normally distributed, but because of a large sample size ($n=167$), this ANOVA assumption was relaxed.

All data were analyzed utilizing arithmetic means. However, NAAQS for TSP are specified in terms of geometric means. The purpose of this report was not to determine whether the park exceeded specific standards; rather to assess the amount and direction of a change. It was felt that an arithmetic mean would suffice. Data from July

1983 through August 1987 were utilized for TSP calculations. Since an imbalance existed, these data may be skewed toward the summer.

Visibility data were sent to Craters of the Moon from ARS through the NPS Seattle regional office. The data consisted of seasonal graphs representing visual range (km) and perceived visual air quality. Visual range data from 1982 - 1986 were sorted as a rank-order frequency distribution, in much the same manner as seasonal data were analyzed at ARS.

NADP data, though chemically analyzed for several constituents, were statistically analyzed for changes in pH only. Time did not permit detailed correlation analyses to be run between pH and ionic constituents. However, a linear regression was run between pH and sulfate concentration, since sulfates play a major role in visibility reduction (Air Quality Group 1985). All identifiable non-standard samples were omitted from park analyses (i.e. bulk samples where the collector lid did not operate properly; and samples longer than one week in duration). Hicks (1984) determined that bulk samples allowed time for reactions to occur between precipitation and dry atmospheric fallout, thus causing higher pH values and ionic concentrations.

RESULTS AND DISCUSSION

For the period 1982 - 1986 there were 369 summer visual range observations and 166 fall observations. Generally, fall months exhibited higher visibility than summer. On the average, seventy-five percent of the time we were able to see 135 and 140 km during summer and fall, respectively. For the entire data set, average July visibility was lowest (171 ± 55 km); however, each July did not have the lowest summer visibility. Two low years pulled down the average (1984 = 138.5 ± 40 km; 1985 = 124.0 ± 27 km). The lowest mean monthly visibility occurred in August 1986 (108.9 ± 31.5 km), while the highest occurred in July 1983 when visual range was calculated as 209.7 ± 78 km.

There was a significant decrease in mean summer visual range from 1982 - 1986 ($p < 0.01$). Figure 1 graphically depicts mean annual SVR's, where each year is represented by summer months only. Mean standard visual ranges at Craters of the Moon were higher than nationally-calculated median summertime visibility ranges for this area (72 km, EPA 1979). Generally, the mountainous southwest is considered as having the highest visual ranges across the coterminous United States (EPA 1979, NPS 1983), with visual ranges near 113 km. According to a 1984 Idaho Department of the Environment report, data from Craters of the Moon were utilized by the EPA as background visibility levels (Robert Wilkosz, pers. comm.).

According to the EPA, Craters of the Moon exhibits the lowest TSP loading across the contiguous 48 states (Robert Wilkosz pers. comm.). Mean annual TSP values are represented in Figure 2. For the period July 1983 - December 1986, overall mean TSP loading at Craters of the Moon was $13.3 \pm 8.7 \mu\text{g}/\text{m}^3$. The extremely high standard deviation can be attributed to a maximum value of $76 \mu\text{g}/\text{m}^3$ occurring in early July 1983, with many lower values also present. TSP levels were less than $29 \mu\text{g}/\text{m}^3$ 90% of the time. The national 24-hour standard for TSP is $260 \mu\text{g}/\text{m}^3$.

Craters of the Moon N.M.

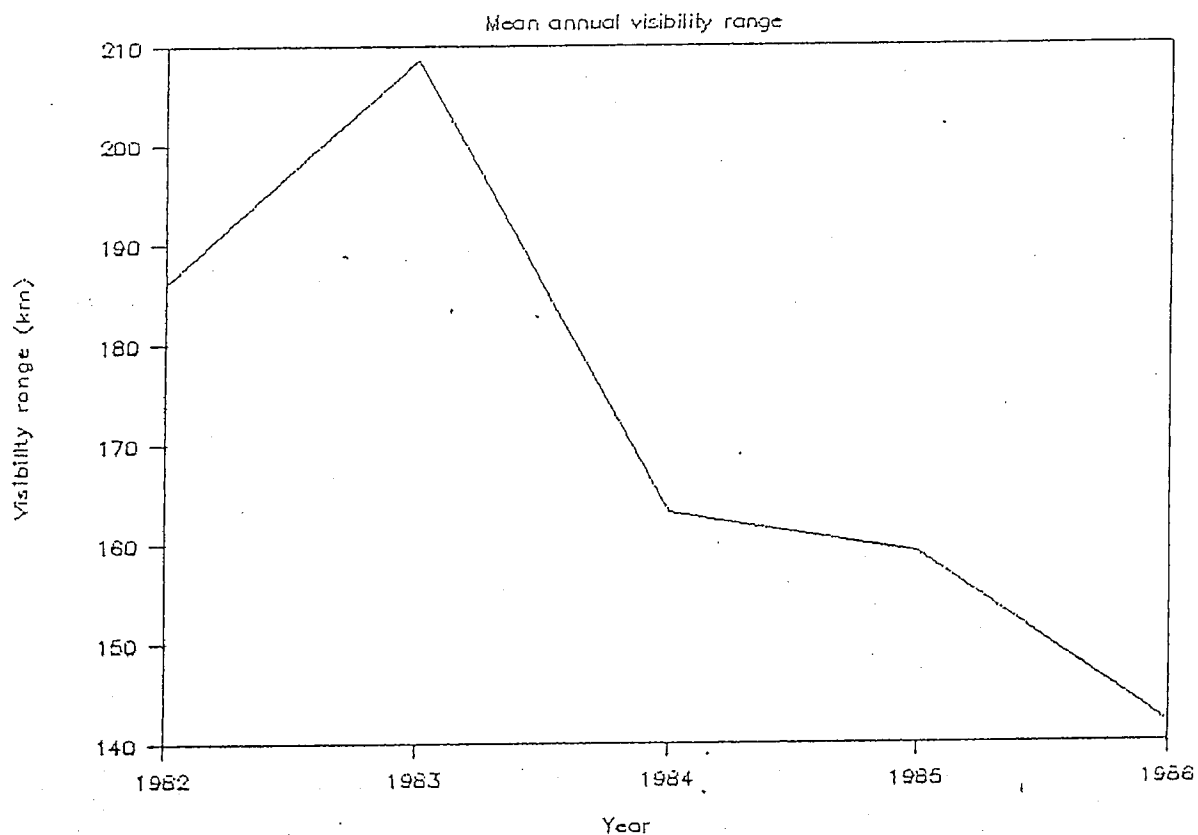


Figure 1. Mean annual visual range (km). Summers, 1982 - 1986.

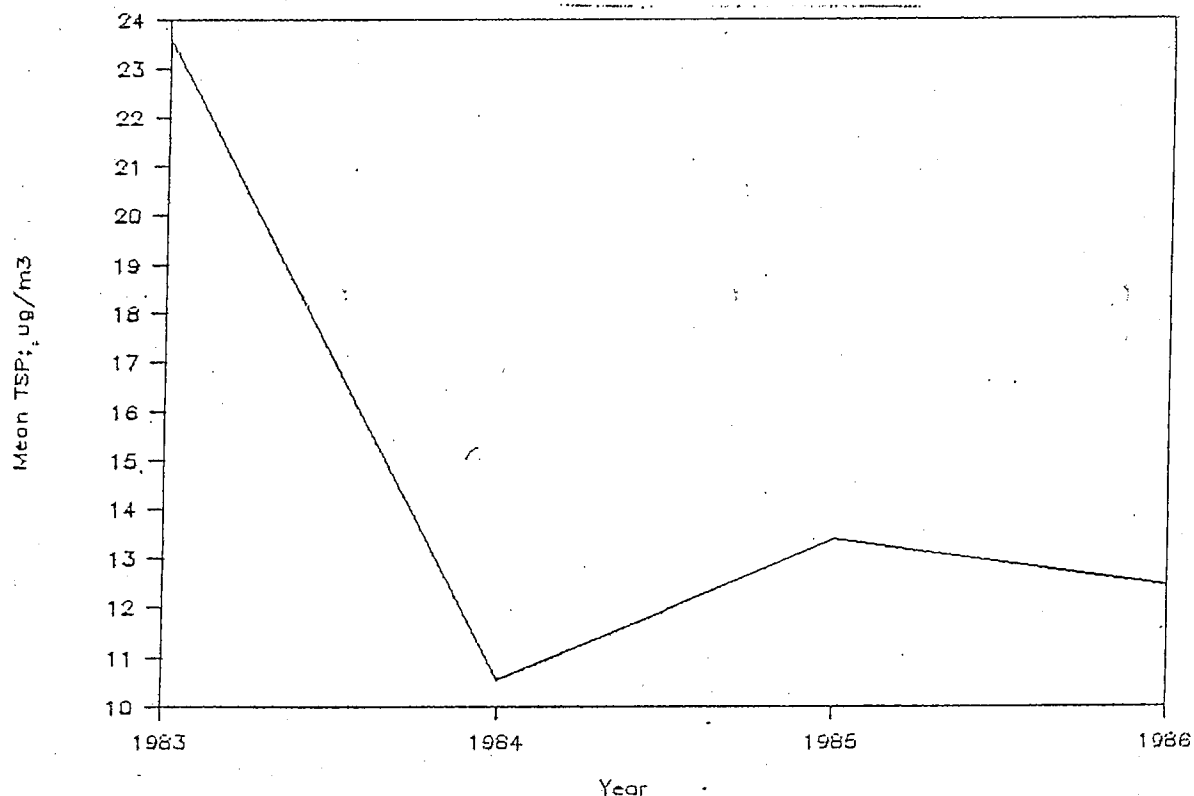


Figure 2. Mean annual TSP ($\mu\text{g}/\text{m}^3$). July 1983 - December 1986.

TSP values from 1983 were significantly higher than the other three years ($p < 0.01$). Contrast values testing the period 1984 - 1986 reveal no significant differences between years ($p = 0.26$ and 0.51). Mean TSP values are as follows:

Table 1. Mean annual and seasonal TSP values ($\mu\text{g}/\text{m}^3$). (Standard error values are represented parenthetically)

Year	Value (SE)	Season	Value (SE)
1983	23.6 (3.3)	Spring	10.2 (1.4)
1984	10.7 (1.4)	Summer	21.9 (1.6)
1985	13.7 (1.2)	Fall	11.5 (1.1)
1986	12.1 (0.9)	Winter	7.9 (1.1)

Summer TSP values were significantly higher than all other seasons ($p < 0.01$), again due to the outlying value occurring in July 1983.

Levels of total suspended particulates for July 1983 were high ($\bar{U} = 48.7 \mu\text{g}/\text{m}^3$), while average visibility for this same month was also a maximum ($\bar{U} = 20.6 \text{ km}$). This may not make sense at first glance, but when considering the nature of meteorological events at Craters of the Moon, the possible reasoning becomes intuitive.

During summer extremely high afternoon winds can push particulate matter into and out of the region in a matter of hours, so that one day visibility may be poor while the next day it may be excellent. No wind data are available for 1983, but 32% of all summer 1985 winds were greater than 16 km/h.

On July 7, 1983 visibility was a low 60 km, while one week earlier visual ranges were at a maximum at 390 km. Data from Pacific Northwest studies indicate that vegetative burning and windblown dust are important sources of light-scattering particulates (EPA 1979). Approximately 80% of the mass of smoke particles from forest fires is in the size range $<1.0\mu$, making them effective visibility-reducers (NPS 1983). Wildfires burn approximately 1.8 million acres per year and emit an estimated 2 million tons of particulate matter annually, causing general haze over broad regions. Although I have not collected western fire frequency data, particulate matter from forest and range fires could account for considerable visibility degradation in southeast Idaho during the summers.

One method of "tracking" wildfires is to measure fine nonsoil potassium (K), the best indicator of the presence of smoke (EPA 1979, Air Quality Group 1985). Fine K has both a soil and a non-soil component. Sources of nonsoil K are vegetative burning and potash industries. Craters of the Moon exhibited several peaks in fine nonsoil K levels during the fine particulate study. The largest peak occurred in early July 1983, followed by smaller peaks

in September 1983 and another large peak in August 1984. These peaks all correspond to periods of elevated total suspended particulate concentration, making it appear that vegetative burning plays an important role in TSP concentration at Craters of the Moon.

The association of TSP and fine nonsoil potassium with visibility is not as apparent. In scanning raw data, periods of high TSP seem to correlate with periods of lowered visibility during the summer 1983 potassium peaks. During August 1984, such a correlation is not as recognizable. No statistical correlations were drawn between TSP, fine K, and visibility for several reasons. Visibility measurements were made daily and TSP measurements were taken every sixth day. Operator inexperience may have generated noncorresponding, questionable data bases. Other investigators have attempted to use multiple regression analysis to relate several variables to visibility reduction (EPA 1979), utilizing techniques that were beyond the scope of this study. Lags could exist between the time when TSP samples were taken and when visibility towards Big Southern Butte may have been affected. It is difficult to determine, by simply scanning raw data, to what degree visibility might be affected by particulates. Some particles are more effective at scattering light than others, making their effect on visual range not easily recognizable. Also, there are inherent problems with the TSP system. Filters are exposed to much handling, possibly causing over-inflation of particulate matter.

Figures 3 and 4 depict mean monthly TSP and standard visual range data, showing no apparent positive or negative correlation.

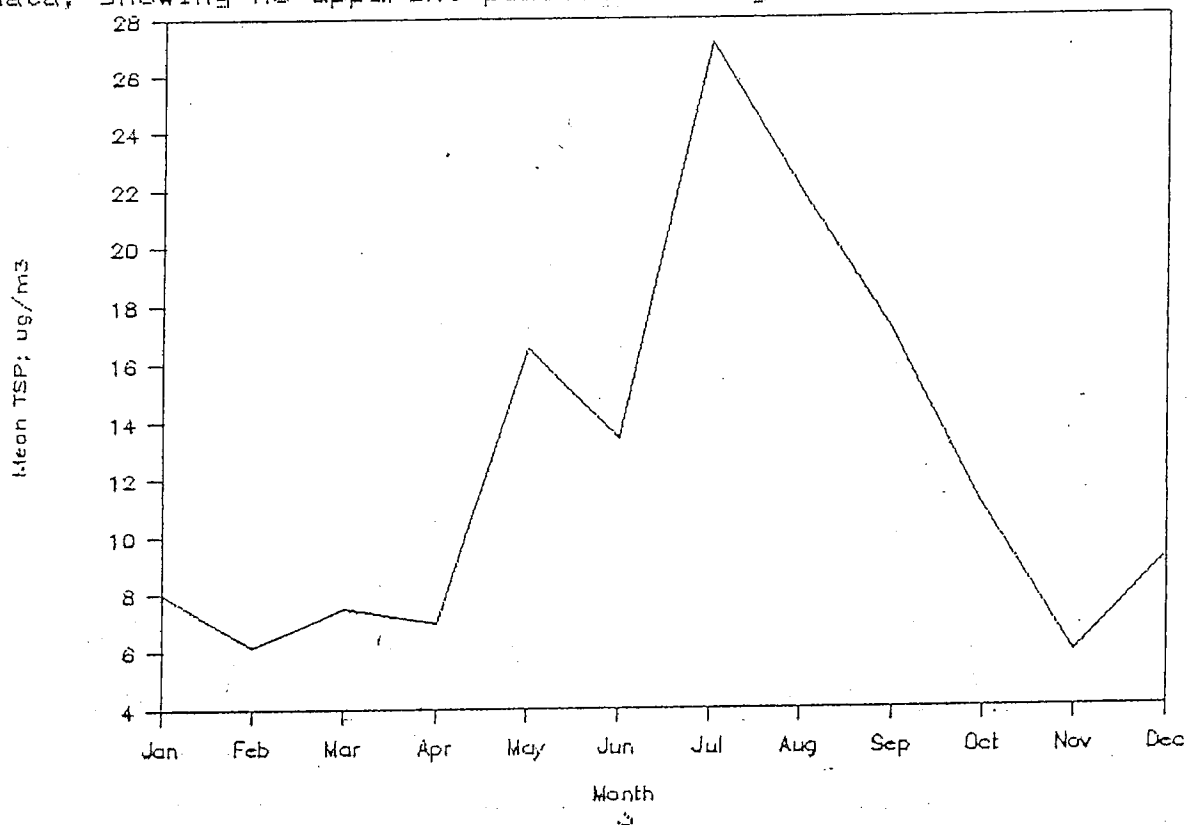


Figure 3. Mean monthly TSP ($\mu\text{g}/\text{m}^3$). July 1983 - December 1986.

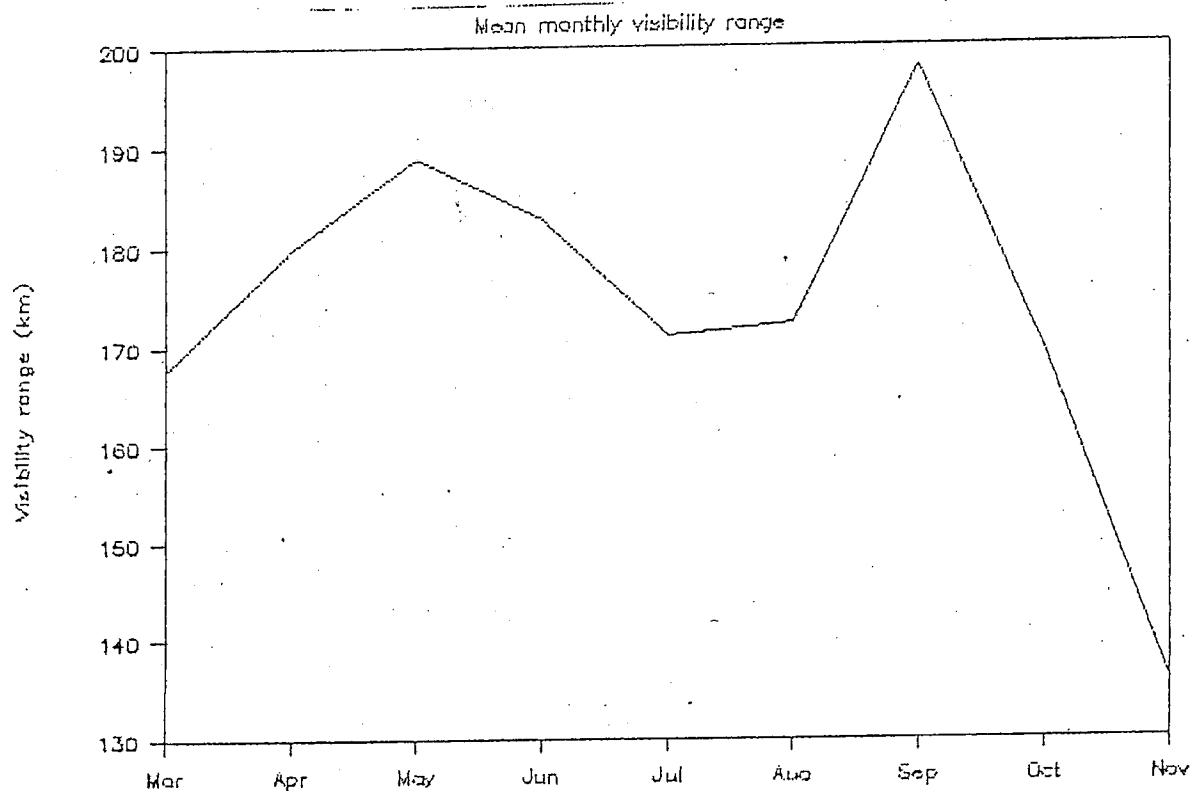


Figure 4. Mean monthly visual range (km). 1982 - 1986.

It is interesting to note that mean annual visual range and TSP concentration (summers only) both exhibited a decline during the study period (Table 2). Possible explanations for this are:

- 1) improved TSP filter handling techniques by park personnel has led to less contamination and unreliaibly high filter weights;
- 2) more accurate visibility measurements with automatic equipment;
- 3) visibility degradation could be caused by particles not captured on TSP filter;
- 4) visibility measurements are taken in the direction of Big Southern Butte, away from the site of the TSP and fine particulate filters. Perhaps degradation was accomplished by particulate matter which extended to Big Southern Butte, but due to prevailing winds, did not reach CRMO.

Table 2. Mean summer visual ranges (~~km~~) and TSP concentration

Year	Visual range (km)	TSP ($\mu\text{g}/\text{m}^3$)
1983	208.5	48.7
1984	163.1	16.9
1985	159.1	22.5
1986	141.9	19.9

The purpose of the fine particulate study was to determine the particulate make-up of the air and thus answer questions regarding visibility degradation. The series filtration sampler was a stacked unit which separated coarse and fine particles.

The coarse mass at CRMO was dominated by silicon, a typical soil-derived element. Coarse mass concentrations were highest in summer, when wind would be an important factor in spreading soil particles.

Four major components of fine mass were 25% sulfate compounds, 14% soil, 12% soot, and the remaining 49% "other" mass included nitrates, hydrocarbons, and organic matter. Fine mass concentrations were highest in winter. Overall, CRMO exhibited high concentrations of fine sulfur, which correlated highly with both fine mass and hydrogen. This is not surprising, considering the roles of sulfur and hydrogen to the particulate make-up of fine mass. Levels of fine lead were low and did not correlate with fine sulfur, suggesting a sulfur source other than automobiles. The stacked filter was situated approximately 25 m from the Visitor Center, where oil was utilized as a winter heat source and diesel-powered maintenance equipment was allowed lengthy warm-up periods. These may be likely sources for high sulfur levels in winter and spring. It is possible that fine particulates from coal-burning or an increase in potash fertilizer production during the cold months would have been transported to CRMO. The oil burner was removed

from the Visitor Center in late 1986. It would be interesting to note any changes in fine sulfur and hydrogen since that time. Unfortunately, the series filtration sampler is no longer in operation.

A simple linear regression run between pH and sulfate (represented in wet samples as SO_4^{2-}) revealed no correlation ($R^2 = 0.049$). This

suggests that sulfur compounds, though present, had no effect on the pH at CRMO. Generally, pH of "normal" rainwater is postulated as occurring between 5.6 and 5.7 (EPA 1981), although new data from more recent studies suggest that due to natural factors, the unpolluted pH of precipitation is closer to 5.0 (NAPAP 1983). Mean annual pH at CRMO has shown no significant changes between 1982 and 1987 ($p=0.75$), ranging from 5.6 in 1987 to 5.8 in 1984. For the entire six-year period, average pH was 5.7.

Arid western regions of the United States are often "protected" from acid deposition through high concentrations of neutralizing atoms, such as Ca and NH_4^+ . It is possible, therefore, for pH to exceed 5.5 yet contain significant concentrations of sulfates and nitrates. As seen in the fine particulate study, coarse and fine concentrations of Ca were not high (3.6% and 0.9% of coarse and fine mass, respectively), suggesting little importance as a Hydrogen ion neutralizer in CRMO precipitation. This preliminary correlation suggests that the atmospheric pH at Craters of the Moon has been relatively untouched by acidic deposition.

Average seasonal pH ranged from 5.60 in summer to 5.93 in spring.

Figures 5 and 6 depict mean annual and seasonal changes in pH.

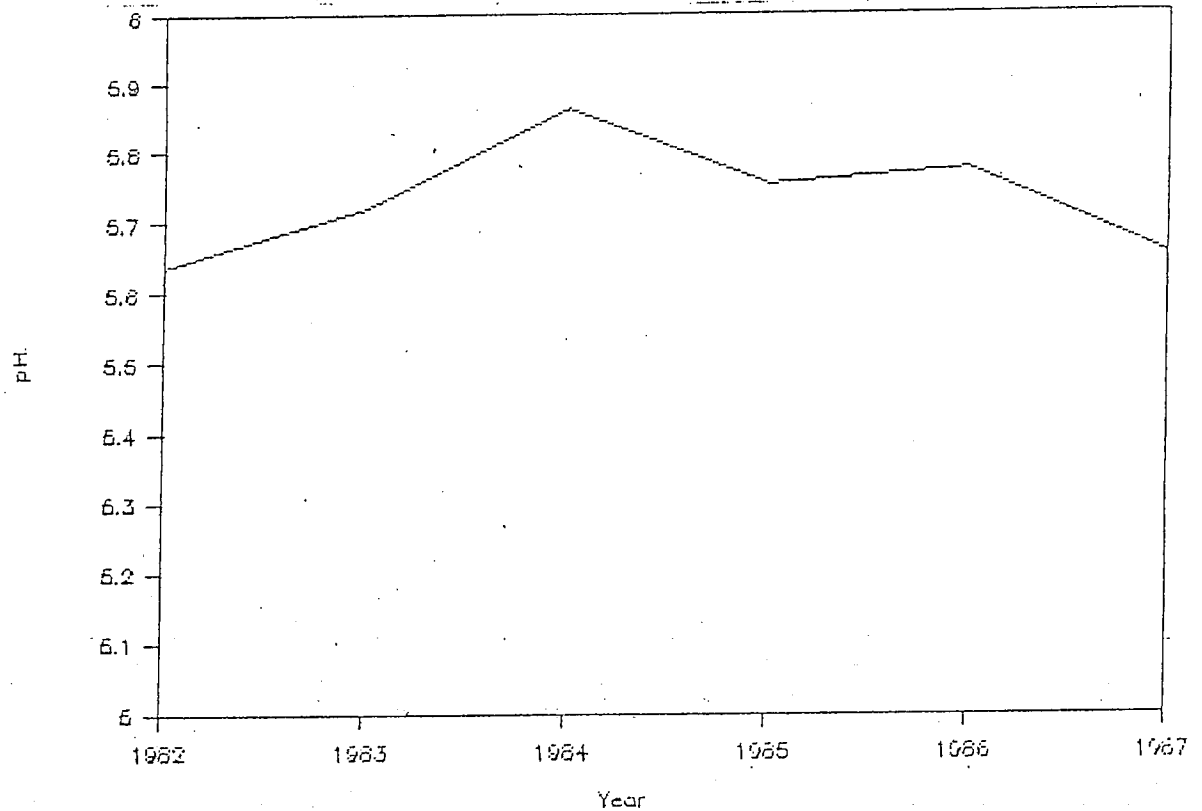


Figure 5. Mean annual pH levels. January 1982 - July 1987.

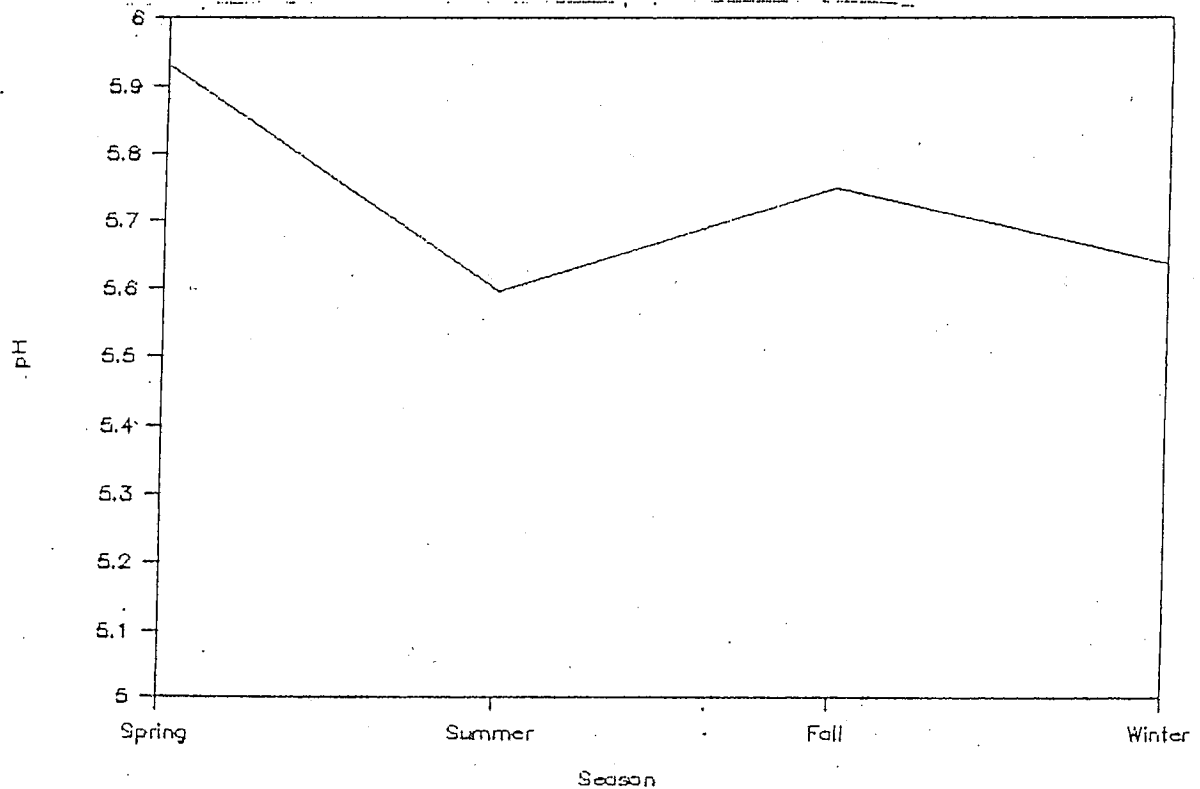


Figure 6. Mean seasonal pH levels. January 1982 - July 1987.

CONCLUSIONS AND RECOMMENDATIONS

Over the entire study period, visual range exhibited a significant decrease. Total suspended particulates during the same period also generally declined, invalidating assumptions that visibility degradation at Craters of the Moon could be solely reliant upon windblown dust and vegetative burning. Total suspended particulates do not appear to correlate with visibility degradation, though no specific conclusions can be drawn because of insufficient statistical information.

Vegetative burning appears to be an important source of particulate matter, as fine potassium (K) appears to correlate with TSP. Fine potassium is indicative of wildfires. Incidents of high potassium levels do not seem to correlate with a resultant decrease in visual range, making conclusions about visibility, TSP, and fine potassium difficult to achieve.

Perhaps fine potassium itself was too small to be captured on a TSP filter, while associated particles were not. It has been suggested that the potassium in smoke is accompanied by larger elements such as hydrocarbons which could be responsible for producing visibility impairment (Air Quality Group 1985). This could help explain why fine K itself is not associated with visibility reduction, but is associated with increased TSP.

The TSP and fine particulate filters were located at the CRMO Visitor Center, approximately 40 km north of the visibility target, Big Southern Butte. It is possible that winds from the south could push particulate matter in the direction of Big Southern Butte and affect visual range without depositing the particles on CRMO's air filters. Climatological data from not only CRMO, but surrounding areas in southeast Idaho should be investigated and correlated with particulate data. Two important areas for obtaining such data are the INEL and Pocatello, the sites of a chemical processing plant and potash plant, respectively. Wind/particulate roses could be generated to use as indices of visibility degradation associated with particulate matter. This may help determine the role and origin of specific particulates to visibility degradation.

Conclusions regarding sulfates and visibility cannot be drawn. Sulfur contents were highest in winter and early spring when visibility measurements are lacking. Increased coal use for heating purposes during these months could account for an increase in sulfur, as perhaps could the use of heating oil at CRMO headquarters. Snow removal diesel equipment, left to warm up in the maintenance area could also be a source of sulfur.

Mean values from 1982 - 1987 reveal no significant changes in pH. Highest pH levels occur in spring; lowest in summer. Many Western areas exhibit buffering capabilities, producing unrealistically high pH values due to acid neutralizers present in the air. This does not seem to be the case with CRMO; however, more work should be done to correlate the total ionic constituents of NADP water samples to resultant pH levels.

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