EFFECTS OF SALINE COOLING TOWER DRIFT ON SEASONAL VARIATIONS OF SODIUM AND CHLORIDE CONCENTRATIONS IN NATIVE PERENNIAL VEGETATION

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ABSTRACT

The Potomac Electric Power Company (PEPCO) generating station at Chalk Point, Maryland utilizes a natural draft cooling tower in its cooling cycle. Brackish water is drawn from the Patuxent River for cooling, and consequently a saline aerosol drift is released from the tower into the atmosphere. A monitoring study was established to evaluate the effects of this saline drift on native, perennial vegetation in the vicinity of the Chalk Point power plant. Sampling from a total of 13 naturally-occurring field sites of dogwood (*Cornus florida*), black locust (*Robinia pseudo-acacia*), Virginia pine (*Pinus virginiana*), and sassafras (*Sassafras albidum*), was continued from May 1974 through September 1976. Samples were collected monthly, May through September, in any given year. Each site was comprised of ten trees of similar size and age. Samples were analyzed for sodium ion concentration by atomic absorption spectrophotometry; chloride ion concentration was determined by potentiometric titration. Samples were collected and analyzed prior to the operation of the cooling tower (1974), and also since the tower was in operation (1975-76). Statistical comparisons among the 1974, 1975, and 1976 data indicate some significant increases in ion concentration have occurred in a few sites, but these are small and are not attributable to cooling tower drift. In some instances, site post-operational ion concentrations have decreased. Aging, metabolic changes, and/or seasonal changes in rainfall are thought to contribute to the fluctuations in ion concentration.

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INTRODUCTION

Conversion of fossil fuels into electrical energy by power generating stations is an inefficient process, as much waste heat is produced. Disposing of heat into the surrounding ecosystem can have dramatic biological effects, especially if dissipated directly into a nearby waterway. Currently, the trend is toward increased usage of wet cooling towers to dissipate heat into the atmosphere, which usually has minimal environmental impact (Kolflat, 1974).

The Potomac Electric Power Company (PEPCO) located at Chalk Point, Maryland utilizes a crossflow, natural draft, hyperbolic cooling tower for their oil-fired, 632 Mw generating unit No. 3 (Holmberg, 1974). At Chalk Point, brackish water is drawn from the nearby Patuxent River for inclusion in the cooling cycle. Hence, saline aerosol drift released from the tower is a potential hazard to the ecosystem.

Manufacturer's estimates place the drift rate at .002% of the circulating water flow, or about 5.2 GPM. Obviously, the concentration of the saline drift depends upon river salinity, which ranges from 3,000 to 13,000 ppm (TDS) depending on the season (Pell, 1974). Final drift concentration will ultimately depend on evaporative losses, make-up and blowdown rates.

Compounding the problem of salt drift from the cooling tower is the unit's stack effluent which is a source of considerable saline drift, as brackish river water is used in the particulate scrubbers (Meyer and Stanbro, 1977). Also, in the near future a second cooling tower and stack will be put into operation for generating unit No. 4, with the potential of doubling drift emissions in the area and creating even greater potential for damage to surrounding vegetation.

The Chalk Point Cooling Tower Project, administered by the Maryland Power Plant Siting Program, is a multi-year study to ascertain the impact of saline drift at Chalk Point. The Botany Department at the University of Maryland has been investigating the long-term effects of saline drift on native, perennial vegetation in the vicinity of Chalk Point.

The two most abundant ions in Patuxent River water are sodium and chloride. Both ions are readily absorbed through foliar applications. Any monitoring efforts should include analysis of foliar samples for changes in concentrations of these ions. As salt deposition rates from cooling towers are minimal, probably soil salinity would be little effected, in comparison to toxicity of foliar salt depositions (Bernstein, 1975). Considerable research has been completed on sodium and/or chloride concentrations in foliage of woody plant species, much of which is concerned with foliar salt deposition as a result of highway deicing operations (Smith, 1970; Hall, et al., 1972; Lumis, et al., 1973; Sucoff, 1975).

A few investigations are concerned with saline drift from cooling towers, with respect to vegetation effects (Mulchi and Armbruster, 1974; Hindawi, 1976; McCune, et al., 1976; Curtis, et al., 1977; Francis, 1977). The importance of monitoring salt levels in foliar tissues is the potential for damage by the accumulation of salts emanating from the cooling tower

and/or stack effluents. Symptoms of foliar salt damage are well documented in the literature (Bernstein, 1964; Bernstein, et al., 1972; Shortle, et al., 1972; Lumis, et al., 1973; Bernstein, 1975; Dirr, 1976).

Approaching the study of saline aerosol drift at Chalk Point requires a two-phase investigation. The primary phase is to gather sodium and chloride concentration data for several years prior to the operation of the cooling tower (Curtis, et al., 1976). This negates the possibility of prior contamination and leads to an acquisition of base-line, or comparative reference data. Base-line data acquisition is an effort to define the natural, seasonal variations of mineral uptake by given species at specific locations. These data describe root uptake only in most cases, although this does not negate the possibility that a few sites might occasionally receive salt spray from the river.

The second phase of this investigation begins with the operation of the cooling tower. Then begins the long-term acquisition of post-operational data from the study sites. Post-operative data provide information concerning any changes in sodium and chloride levels when compared to the base-line, and lends credence to any assessment concerning the impact of salt contamination on native vegetation.

MATERIALS AND METHODS

The Chalk Point Power Plant is situated about 65 km (40 miles) southeast of Washington, D. C., just north of the confluence of the Patuxent River and Swanson Creek (Fig. 1). The area is a diversification of hardwood-pine forests and small farms where tobacco, corn, and soybeans are important crops

Forested areas on and off power plant property were surveyed to determine species diversity and distribution. Four species of native trees were determined to be widespread and in sufficient numbers to allow for site location (See Table 1).

TABLE 1

Native tree species samples for foliar Na^+ and Cl^-. The location of the tree sampling-sites is shown in Fig. 1.

Scientific name	Common name	Number of sites*
Pinus virginiana Mill.	Virginia pine	6
Robinia pseudo-acacia L.	Black locust	3
Sassafras albidum (Nutt) Nees	Sassafras	3
Cornus florida L.	Dogwood	1

*Ten trees were sampled at each site on a monthly basis.

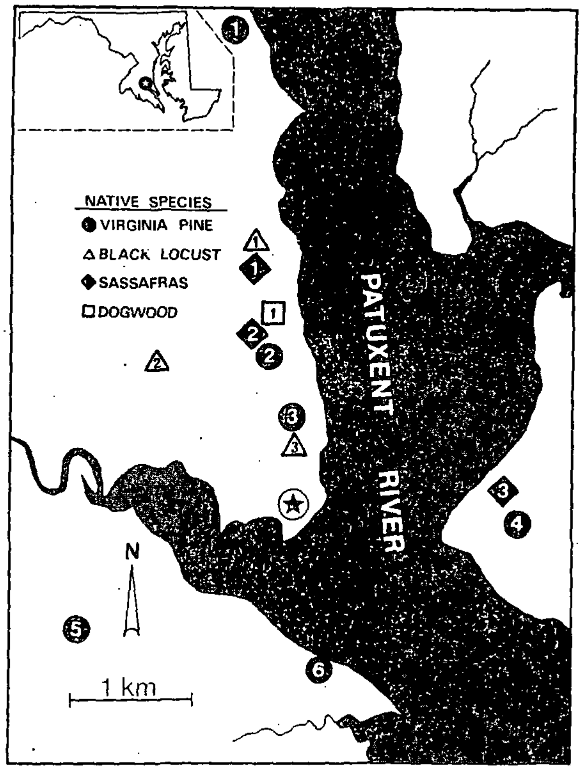


Fig. 1. Chalk Point Power Plant location in Maryland (upper inset) & location of tree sampling sites in the vicinity of the power plant.

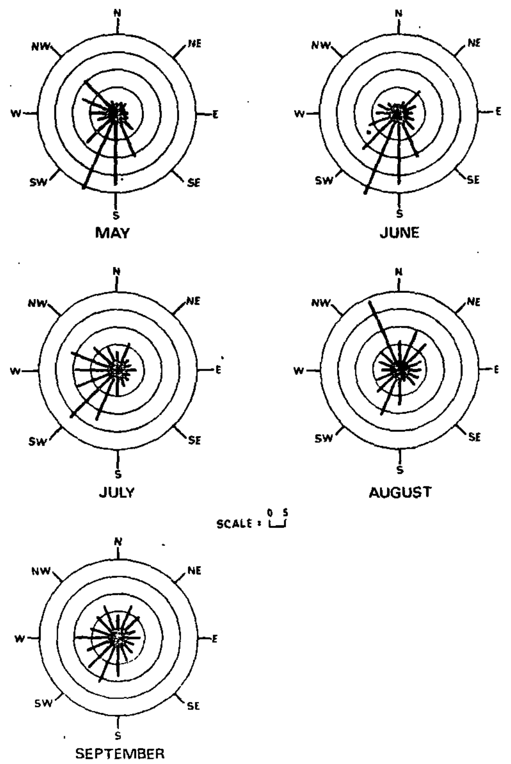


Fig. 2. Monthly (May-Sept., 1976) wind rose data taken from the 50 M level at the Chalk Point meteorological tower. Diagrams indicate the monthly wind directions and percent time spent in each direction.

Each of the 13 sites listed was comprised of 10 trees of similar size and age, and each was in close proximity to the other. Ten trees were selected for each site to provide a reliable statistical basis. Eight sample sites were situated on power plant property; the remaining five sites were located on private property (Fig. 1). All trees were marked and tagged with a species identifier and tree number. A detailed soil description was described for each site in Curtis, et al., (1977).

Each site was sampled monthly, beginning May through September. Sampling usually began near the middle of each month, completed in a 2-3 day period, and never attempted on rainy days or immediately thereafter, but rather 1 or 2 days later. Approximately 10-15 grams (dry wt.) of leaves or needles were randomly collected from the lower tree crown. Sampling was done with the collector wearing plastic surgical gloves to minimize the risk of contamination from perspiring hands. Samples were collected in labeled, brown, paper bags. Leaves were not washed, but brought to the laboratory and dried in a forced-draft oven for 48 hours at $95^{o}C$. Upon drying, samples were individually ground in a Wiley Mill to pass through a 20-mesh screen, and placed into screw-cap bottles for storage until analysis.

Chloride ion concentration was determined by a modification of a potentiometric titration method outlined by LaCroix, et al., (1970). An Orion chloride ion electrode and double junction reference electrode were used in combination with an Orion model 701 digital pH meter. A 0.5 g leaf sample was shaken in 50 ml of 0.1 N HNO_3 on a wrist-action shaker for 15 minutes. The solution was then titrated, while stirring, with 0.01 N $AgNO_3$:0.1 N HNO_3. The endpoint was determined as the millivolt reading of an aliquot of the 0.1 N HNO_3 used for chloride extraction. Standard procedures for analysis required the preparation and analysis of three replicates for each sample. Chloride standards were titrated at the beginning of each run and a standard curve determined through regression analysis.

Sodium ion concentration was determined by atomic absorption spectrophotometry. A 0.5 gram leaf sample was weighed into a 15 ml crucible and heated in a muffle furnace at $475^{o}C$ for a minimum of 12 hours. The ash was then dissolved in 5 ml of 20% (w/v) HCl and gently heated (not boiled) to insure dissolution of the ashed sample. This mixture was washed through Whatman No. 40 ashless filter paper and the filtrate diluted to 100 ml with distilled water. Three blanks were routinely run with every 24 replicates. A Perkin-Elmer model 303 atomic absorption spectrophotometer and sodium lamp were set up according to standard conditions for sodium. At the beginning and end of each run, known sodium standards were analyzed and a standard curve generated through regression analysis. Standard procedures required the analysis of three replicates for each sample.

Results of chloride and sodium analyses are reported in μg/g leaf dry wt. The term ion load adequately describes both internal and external foliar salt concentrations under natural conditions. Means, standard deviations, coefficients of variation, and standard errors of the mean are routinely determined for the three replicates of each leaf sample. Multi-year comparisons of data are made on the computer. Monthly trends, site comparisons, tree comparisons, and year comparisons are made by an analy-

sis of variance (Manova) program constructed by the University of Miami Biometrics Laboratory. Further definition of significant differences between means require Student-Newman-Keuls (SNK) test (P = .05) of significance (Sokal and Rohlf, 1969).

RESULTS

Results from sodium and chloride analyses of foliar material are summarized in a series of graphs (Figs. 3-28). Since construction of the cooling tower and stack was not complete at the time of sampling the 1974 data are considered preoperational; 1975 and 1976 data are postoperational, in that the tower was first tested in 1975 and fully operational in 1976. The graphs reveal characteristic trends that occur in each site. The following is a summary of those results:

The dogwood site (Fig. 3) exhibits an almost linear increase in chloride concentration. Sodium ion loads show no seasonal trend (Fig. 16).

Virginia pine sites (Figs. 4-9; 17-22) do not reveal any characteristic seasonal variations for chloride or sodium. However, it should be noted that Virginia pine, site 6 (Figs. 9 and 22) reflects very high levels of sodium and chloride when compared to any other pine site.

All black locust sites (Figs. 10-12) display a curious pattern for chloride, which is manifested as a slight increase or decrease in spring and early summer, followed by a dramatic increase in late summer. Sodium concentrations exhibit no seasonal trends (Figs. 23-25).

Sassafras, sites 2 and 3 (Figs. 14-15) reveal a rapid decrease in chloride in early spring and reach their lowest points in July, to be followed by a steady increase through later summer. Sassafras, site 1 (Fig. 13), clearly does not follow this same trend. Sodium ion loads have no seasonal trends at all sassafras sites (Figs. 26-28).

Considerable statistical testing was utilized as a tool to analyze the data. Table 2 is a tabular listing of site-seasonal mean comparisons for the years 1974-1976. Analysis of variance and Student-Newman-Keuls (SNK) tests (P = .05) were incorporated in the determination of these results. Non-significant means for sodium and chloride are denoted by common superscripts. Means are compared within sites, and not between sites. Results indicate there are statistically significant changes.

Dogwood, site 1, is significant for an increase of chloride in 1976, and a corresponding increase of sodium in 1976. Changes in chloride were non-significant for Virginia pine, sites 1-5, however, an analysis of the sodium data in site 2 clearly shows the 1974 seasonal mean to be significantly higher than 1975 and 1976. Virginia pine, site 6, shows significantly greater chloride ion concentrations for 1975 as compared to 1974 and 1976. Sodium for site 6 also reflects significant differences for 1974, which is considerably higher than 1975 and 1976. Seasonal means for black locust exhibit significant variations for chloride. Sites 1 and 3

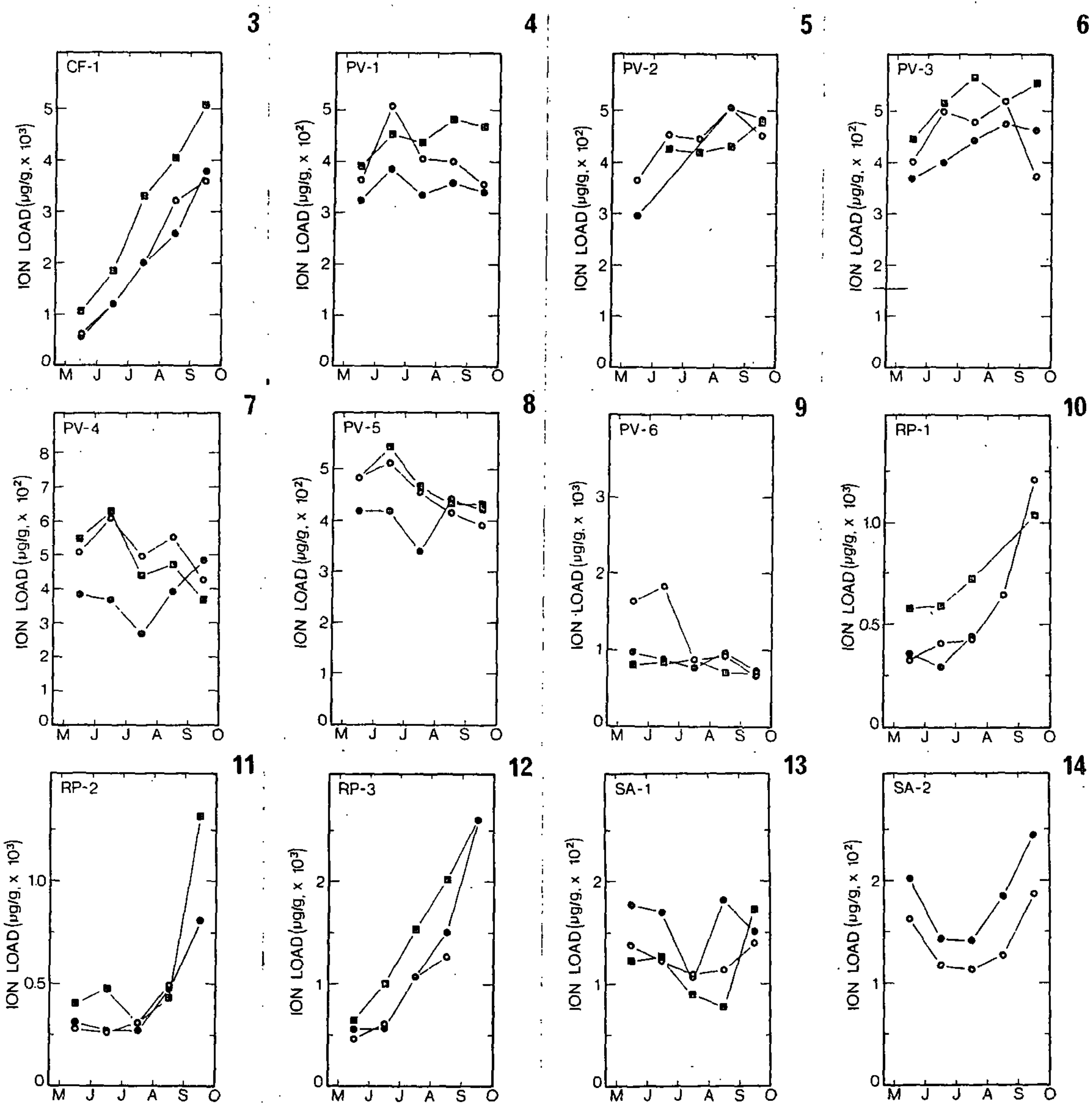
TABLE 2

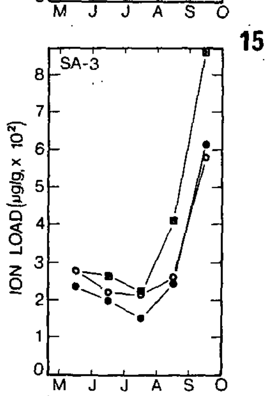
Site-Year Means for Sodium and Chloride[1]

Sites[2]	Sodium Ion Load (ppm)			Chloride Ion Load (ppm)		
	1974	1975	1976	1974	1975	1976
CF-1	53[a]	80[b]	62[a]	2045[a]	2113[a]	3060[b]
PV-1	35[a]	45[ab]	46[ab]	350[a]	405[a]	446[a]
PV-2	61[bc]	39[a]	33[a]	429[ab]	444[ab]	438[ab]
PV-3	82[ac]	93[c]	90[c]	430[a]	452[a]	519[a]
PV-4	59[ab]	73[bc]	62[abc]	380[a]	518[a]	493[a]
PV-5	61[abc]	68[bc]	62[abc]	404[a]	450[a]	481[a]
PV-6	450[b]	281[a]	345[a]	867[a]	1185[b]	792[a]
RP-1	69[a]	137[ab]	122[ab]	437[a]	405[a]	617[b]
RP-2	72[a]	114[a]	107[a]	338[a]	343[a]	408[a]
RP-3	79[a]	137[ab]	132[ab]	934[a]	837[a]	1307[b]
SA-1	87[a]	150[a]	72[a]	156[a]	125[a]	117[a]
SA-2	87[a]	133[a]	---	179[a]	142[a]	----
SA-3	76[a]	141[a]	94[a]	290[a]	313[a]	408[b]

[1]Statistical results of 1974, 1975, and 1976 site-annual mean comparisons by analysis of variance (P = .05) and Student-Newman-Keuls (SNK) test of significance. Chloride and sodium data are listed for each site. Comparisons are made within rows for each ion. Annual means with common superscripts denote those figures to be non-significant at the 5% level.

[2]CF- Cornus florida (dogwood); PV- Pinus virginiana (Virginia pine); RP- Robinia pseudo-acacia (black locust); SA- Sassafras albidum (Sassafras)





Figs. 3-15. Seasonal variations of chloride ion concentrations (ug/gdw) from tree sites shown in Fig. 1. The graph labeled CF-1 is the Cornus florida site. Graphs labeled PV-1 through PV-6 are Pinus virginiana sites; RP-1, RP-2, RP-3 represent Robinia pseudo-acacia sites; and SA-1, SA-2, SA-3 are Sassafras albidum sites. Each point represents a monthly mean for a given year.

● 1974 Seasonal Means
✪ 1975 Seasonal Means
■ 1976 Seasonal Means

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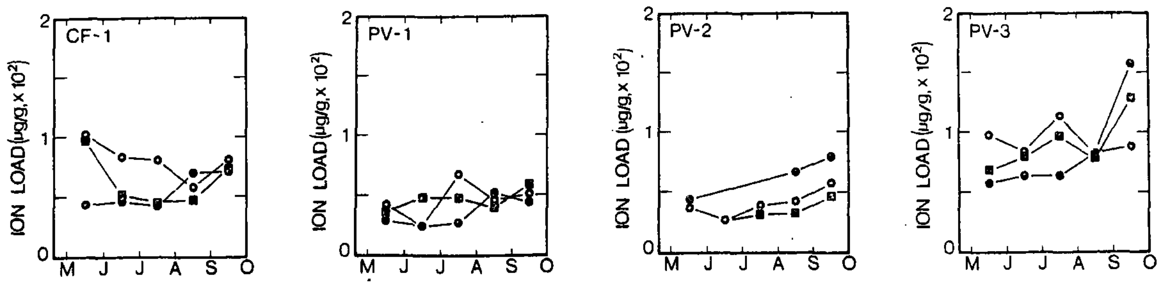

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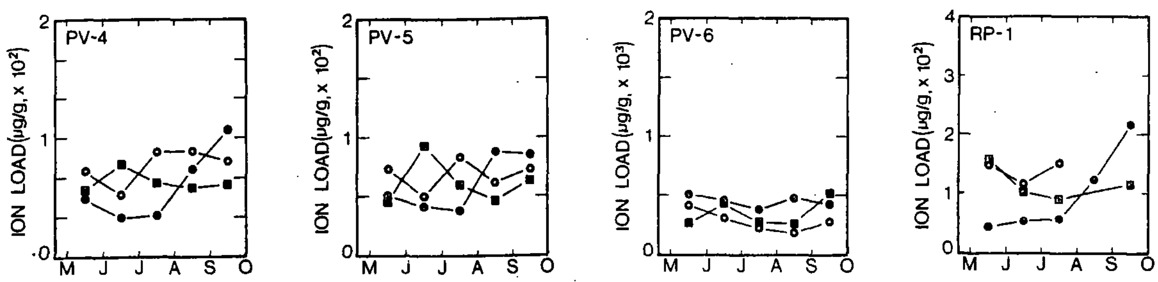

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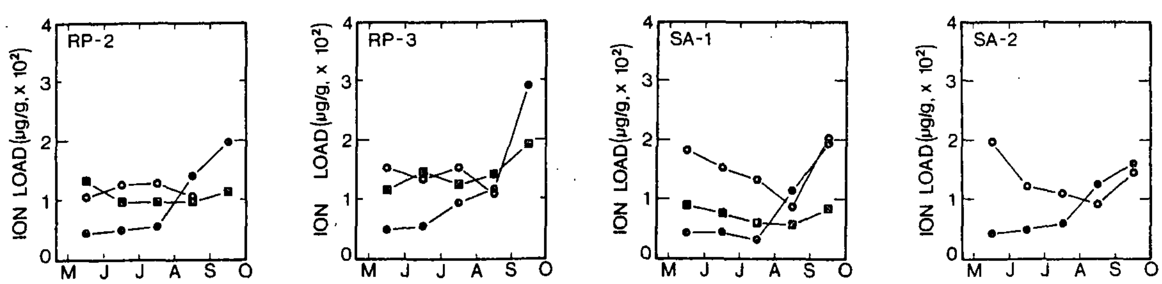

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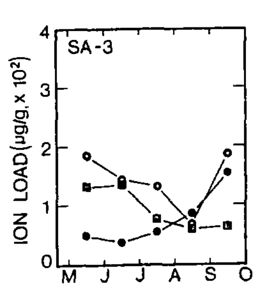

Figs. 16-28. Seasonal variations of sodium ion concentrations (ug/gdw) from tree sites shown in Fig. 1. The graph labeled CF-1 is the *Cornus florida* site. Graphs labeled PV-1 through PV-6 are *Pinus virginiana* sites; RP-1, RP-2, RP-3 represent *Robinia pseudo-acacia* sites; and SA-1, SA-2, SA-3 are *Sassafras albidum* sites. Each point represents a monthly mean for a given year.

- ● 1974 Seasonal Means
- ○ 1975 Seasonal Means
- ■ 1976 Seasonal Means

are considerably higher in 1976 over the previous two years. Sassafras, site 3, presents a similar situation to black locust.

In some instances, data are missing from graphs. In Virginia pine, site 2 (Figs. 5 and 18), there are missing points for 1974 as a result of site destruction by construction workers. All sites of black locust, sites 1-3 (Figs. 10-12; 23-25), contain missing data. Leaf miner infestations became severe in late summer and almost completely defoliated entire trees, short of killing them; hence, there was not sufficient foliage to sample. Sassafras, site 2 (Figs. 14 and 27), is complete for 1974 and 1975, but lacks data for 1976, because early in the spring of 1976 the site was destroyed by an accidental herbicide application. A suitable stand of sassafras trees could not be located nearby as a replacement.

DISCUSSION

Evaluation of the effects of saline cooling tower drift on native perennial vegetation must be based upon observations of either: (1) the existence of salt toxicity symptoms with correspondingly high ion concentrations, or (2) an increase or rapid change in salt concentration (sodium and/or chloride) since the cooling tower went into operation, as compared to seasons before tower operation.

Symptoms of salt toxicity were never observed at any sampling sites in the vicinity of Chalk Point. Literature surveys reveal that marginal or tip-burn of woody plant leaves may occur if the ion concentrations exceed .5% (5,000 ppm) for chloride or .2% (2,000 ppm) for sodium (dry wt.) (Smith, 1970; Bernstein, 1975). Inspection of the graphs results in the general conclusion that the sites manifest no excessively high ion concentrations, with the possible exception of the dogwood site. Flowering dogwood is considered to be a salt sensitive species, and foliar chloride concentrations above 5,000 μg/gdw usually result in leaf damage (Francis, 1977). Primarily, uptake of chloride ions is through root absorption at this site, rather than foliar absorption; foliar sprays were applied in Francis' research. Threshold levels may differ depending upon the site of nutrient uptake. Also, tolerance levels might be explained through genetic differences (Sucoff, 1975; Bernstein, 1975) or differences in age, as site trees are much older than the trees used in Francis' research.

Of considerable interest in the study of salt toxicities is that chloride is considered to be more important toxicologically than sodium (Boyce, 1974; Holmes and Baker, 1966; Walton, 1969; Francis, 1977). In most studies there has been a direct relation between applications of chloride and injury. Many researchers also found that woody plants are more sensitive to salt sprays than non-woody ones. Consequently, it is most probable that saline aerosols at Chalk Point will damage leaves of trees before non-woody annuals and crops.

Table 2 indicates that statistically significant differences ($P \leq .05$) in chloride and/or sodium exist at several sampling sites: CF-1 (Figs. 3 and 16), PV-2 (Fig. 18), PV-6 (Figs. 9 and 22), RP-1 and 3 (Figs. 10 and

12), and SA-3 (Fig. 15). Statistics provides an objective means of comparing postoperational data to preoperational data. The possible effects of meteorological phenomena (rainfall, wind patterns, etc.), site effects (aging, changes in metabolic uptake, etc.), or tower operating ranges are not taken into direct consideration when yearly comparisons are made. These factors must be considered individually before an accurate assessment can be made regarding drift effects on vegetation.

Significant site increases of ion loads have occurred primarily in 1976, an exception is a decreased concentration at the dogwood site. Four sites: CF-1, PV-2, RP-1, and RP-3 are situated north of the cooling tower. An examination of monthly wind rose data (Fig. 2) reveals that for the majority of the 1976 growing season, at least part of the time these sites were downwind. However, it appears that salt drift did not contribute appreciably to the salt levels on these sites.

A general survey of Table 2 reveals that a majority of the collecting sites exhibits an increase of chloride for 1976, when compared to the previous two years, but fail to show respective increases in sodium for that same year. Although most of these increases are not statistically significant, there is an obvious trend indicated. One could attribute these subtle increases to cooling tower drift. However, sodium ion concentations do not reflect these same increases in 1976, but exhibit subtle increases in a majority of sites in 1975, when compared to 1974 and 1976. Sodium is a major component of Patuxent River water (Meyer and Stanbro, 1977; Francis, 1977), and should show proportionate increases with chloride. Sites that exhibit significantly greater chloride concentrations ($P \leq .05$) in 1976 occur randomly, with no spatial relation to the cooling tower, and in most cases adjacent sites show no significant increases. Indeed, many nearby sites reflect decreases in chloride and/or sodium ion concentrations.

Significant changes of sodium and choride concentrations at PV-6 can be attributable to site location, which is directly along an embankment of the Patuxent River. The Virginia pines at this site are undergoing considerable physiological stress due to their habitat. Frequently, the river level is high enough to submerge the roots of some trees and often winds create salt aerosols.

Conclusions drawn from this three year study are generally that, thusfar, the cooling tower drift effects on native, perennial vegetation are negligible in the vicinity of Chalk Point. Seasonal wind patterns undoubtedly deposit some saline drift on several or all of the native sites in the vicinity of the cooling tower; however, shifts in sodium or chloride concentration are attributable to seasonal changes in rainfall, aging of tree sites, changes in metabolic activity, or natural, physiological stresses.

The potential for deleterious effects to vegetation by saline drift exists in the vicinity of the cooling tower. Flowering dogwood is a salt sensitive species, as was indicated by simulated drift studies by Francis, 1977. These same spray studies have indicated the possibility of accumulation of ions in the wood of dogwood. Smith (1973) suggested accumula-

tion of sodium in woody twigs of urban trees. Hence, toxic ions may accumulate in woody tissues over long periods of time to be eventually translocated to leaves with possible deleterious effects.

Expected drift rates from the cooling tower and stack effluent (Meyer and Stanbro, 1977), coupled with the future completion of unit 4, could lead to salt damage of flowering dogwoods, especially those of CF-1 which are about 1 km north of the cooling tower. On-site damage to other species is a possibility, although remote. Off-site damage of woody species cannot be ascertained at this time.

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Page Number	Nature of Correction
I-12	Figure 5: new copy enclosed: current reproduction cannot be read.
I-15	Figure 8: ordinate should be g, not mg.
I-16	Figure 9: ordinate should be g, not mg.
I-106	Table 1: a new page is enclosed with corrections in the surface texture column.
I-119	Figure 1: LSD = 20.8 instead of 5.2
I-120	Figure 2: LSD = 20.8 instead of 5.2
I-121	Figure 3: LSD - 20.0 instead of 5.0
I-122	Figure 4: LSD = 20.0 instead of 5.0
I-123	Figure 5: LSD = 37.2 instead of 9.3
I-124	Figure 6: LSD = 37.2 instead of 9.3
I-125	Figure 7: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-126	Figure 8: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-127	Figure 9: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-128	Figure 10: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-129	Figure 11: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-130	Figure 12: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
II-28	Figure 9: Dash line is for K = 3.69 instead of 2.97 and dash-dot line is for K = 2.97 instead of 3.69
II-34	Table 1: Number of afternoon visible plumes observed should be changed from 125 to 175 in "Characterization of Cooling Tower Plumes from Paradise Steam Plant"

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Errata cont.

III-3 2.1 Mathematical Modelling, 4th line:
park, $1 \leq M \leq 10$ uncoupled systems consisting...

11th line: ......the two components v_z and v_x of...

2nd equation:

$$\mu_1 = (K_1 v_z{}^2/v^2 + K_2 v_z v_x{}^2/v^3 + K_4 F)/R + K_3 \Delta\rho g/\rho v^2$$

4th line after the equations:

initially had no vertical momentum (μ)

III-4

$$\frac{da}{ds} = (0.5\ \mu_1\ a - \theta_1 + K_y/av)/(1 + \alpha/(1 - W))$$

$$\frac{da}{ds} = (0.5\ \mu_1\ b - \theta_2 + K_z/bv)/(1 + \beta/(1 - W))$$

III-5 page center:

This method delivers N_K Gaussian plumes for the N_K cooling towers which are then superposed point by point in the space downwind of the plant.

3rd line from bottom:

.....the plume of tower j and $\alpha - \beta = (1 - W \frac{dW}{ds})$. Fig. 2

III-13 2nd line:

.....due to the drift droplets but - mainly in the case of

III-119 2nd paragraph, lines 9 and 10:

"1.2×10^3 Kg/Km-Month" and "0.60×10^3 Kg/Km-Month" rather than "1.2×10^6 Kg/Km^2-Month" and "0.60×10^6 Kg/Km^2-Month".

III-122 2nd paragraph, line 11: same corrections as above.

III-123 Table 2: "total at range" values should be "10^3" not "10^6" and have units "Kg/Km-Month".

III-125 Table 3: footnote should be "*Kg/Km-Month multiplied by 10^{-3}".

III-162 Add reference:

Thompkins, D. M. (1976) Atmospheric dispersion and deposition of saline water drops, Master of Science Thesis, Graduate Program in Meteorology, University of Maryland, College Park, Md., 69 pp.

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Figure 5. Recovery of NaCl from Ropes with Known Amounts of NaCl Added

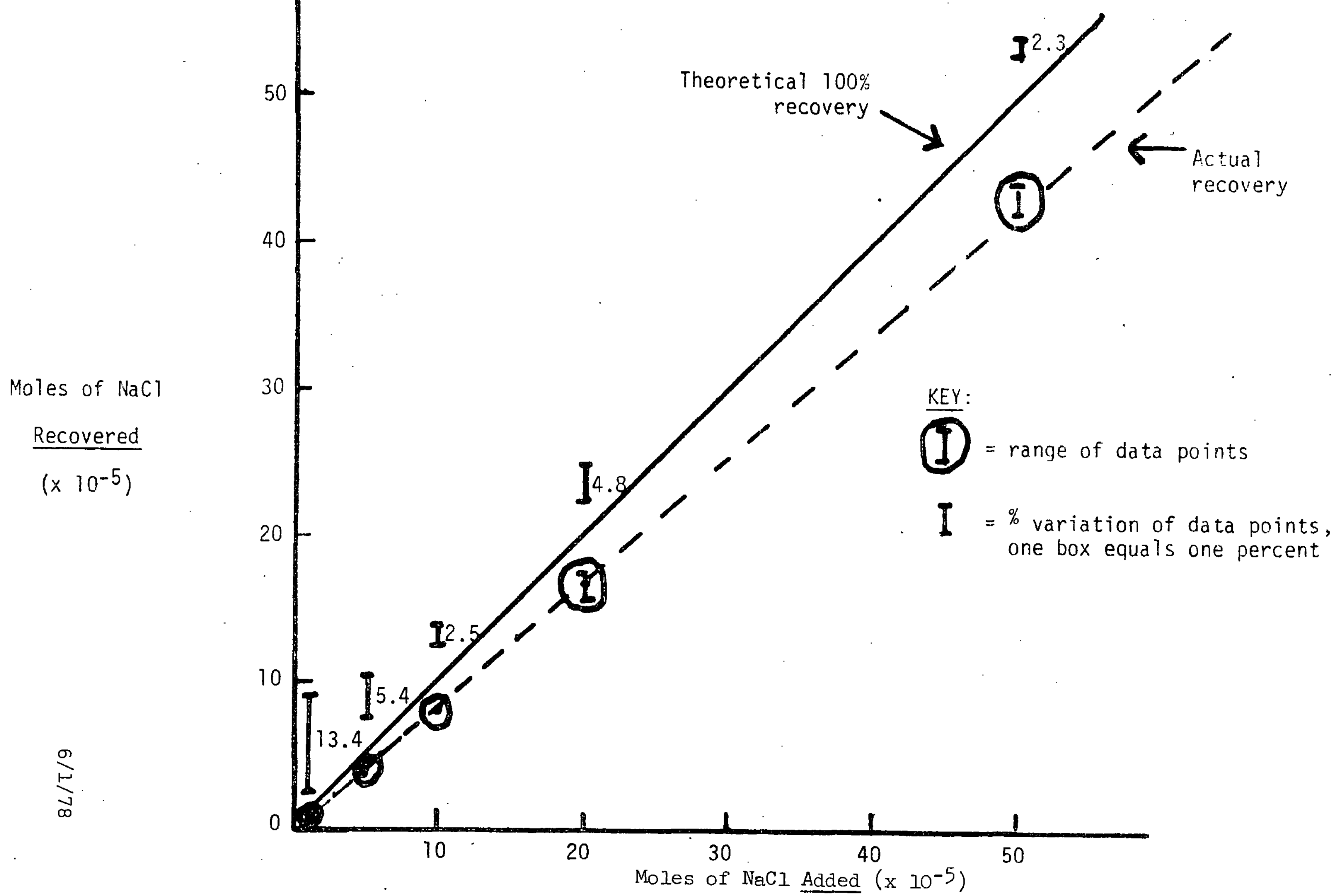

Table 1. Classification and partial chemical and physical characterization of the soils at the Chalk Point research sites.

Location with Respect to Cooling Tower: Distance	Direction	Soil Series	Surface Texture*	Physical Analysis*: Sand	Silt	Clay	Chemical Analysis*: Extractable Mg	P	K	Ca	Na	Organic Matter	pH
-- km --				------ % -------			------ μg/g -------					-- % --	
1.6	north	Lakeland	fine sand	90	3	7	67	61	22	57	17	0.9	5.1
	east	Lakeland	fine sand	90	7	3	23	51	45	236	20	0.9	6.5
	south	Mattapex	loam	45	45	10	28	19	71	50	19	1.5	5.5
	west	Sassafras	fine sandy loam	73	21	6	62	12	51	96	18	0.8	5.8
4.8	north	Sassafras	fine sandy loam	75	19	6	29	24	59	152	20	0.9	5.8
	east	Woodstown	fine sandy loam	76	15	9	64	50	83	210	22	1.9	5.4
	south	Sassafras	fine sandy loam	68	25	7	50	5	31	245	20	0.6	5.9
	west	Westphalia	loamy fine sand	83	12	5	24	65	48	24	18	1.3	6.0
9.6	north	Sassafras	sandy loam	54	34	12	67	53	70	102	22	2.3	5.6
	east	Matapeake	loam	45	45	10	73	6	31	404	22	1.1	5.9
	south	Galestown	fine sandy loam	71	24	5	37	46	93	344	17	1.1	6.1
	west	Woodstown	loamy sand	78	17	5	53	4	28	164	21	1.0	6.0

* All values are reported for samples collected at a depth of 0-15 cm.

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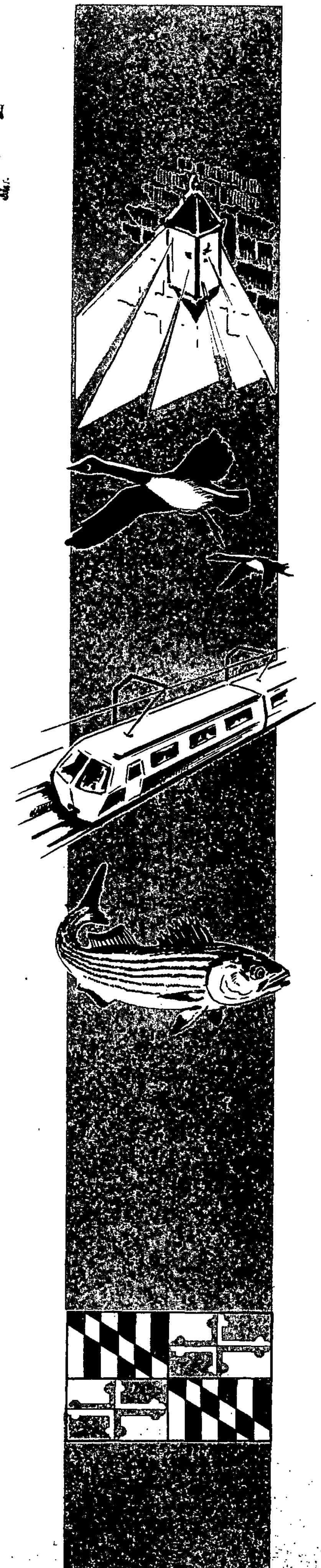
PROCEEDINGS



A SYMPOSIUM ON ENVIRONMENTAL EFFECTS OF COOLING TOWER EMISSIONS

May 2 - 4, 1978

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