THE DISPERSAL AND IMPACT OF SALT FROM SURFACE STORAGE PILES AT THE WASTE ISOLATION PILOT PLANT

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ABSTRACT

A comprehensive program of ecological studies occurs at the Waste Isolation Pilot Plant (WIPP) in an effort to detect and quantify impacts of excavated salt which is stored on the surface in two piles: one having originated in 1980, the other in 1984. Both piles are surrounded by berms which channel runoff to holding ponds, so nearly all dispersal is due to the resuspension, transport, and deposition of salt particles by wind.

Ecological parameters which have been monitored since 1984 include: visual evidence (via photography), soil properties, microbial activity, leaf-litter decomposition, seedling emergence, plant foliar cover, and plant species diversity. These are periodically assessed at experimental plots near the salt piles, and at control plots several kilometers away.

Concentrations of soluble ions, particularly sodium and chloride, in surficial soil samples have been most affected by salt impacts. These parameters have been significantly higher at experimental plots than at control plots, with differences being greatest in spring. Seasonal patterns suggest that salts are dispersed and transported mostly during spring, when winds are strongest, but are leached downward through the sandy soil during summer, which is the local wet season. In no case do salt levels in the soil approach published threshholds for potential plant inhibition. Other ecological parameters reveal no consistent evidence of salt impacts. Microbial activity and leaf-litter decomposition are the same between experimental and control plots. The same is true for vegetation parameters, except for foliar cover, which is slightly reduced in plots adjacent to the salt piles. Sustained monitoring will be necessary to identify subtle or cumulative impacts of salt on the local ecosystem.

INTRODUCTION

Bedded salt (NaCl) is an attractive medium for the deep geologic disposal of radioactive waste, with the result that a number of salt-based repository sites have been proposed. The development of these sites will require the excavation and temporary storage of salt somewhere on the surface. A number of options exist for this storage phase, each with a different degree of containment, expense, and practicality. Whatever the containment option, it is important to monitor around the storage facility for evidence of the dispersal and impact of salt on the local ecosystem. For instance, high concentrations of soluble ions can inhibit the growth of plants and microbes by osmotically retaining soil water[1]. Sodium can also be toxic to plants under certain circumstances[2].

The Waste Isolation Pilot Plant (WIPP) is a research and development facility to demonstrate the safe disposal of of radioactive wastes generated by the defense activities of the U.S. Government. Transuranic (TRU) waste will be emplaced in bedded salt 655 m below the surface at a remote location in southeastern New Mexico known as Los Medanos. The facility and its operation is described in the Final Environmental Impact Statement[3] and Safety Analysis Report[4].

Approximately 850,000 m^3 of salt will be excavated and temporarily stored on the surface over the life of the WIPP project. Excavation began in 1981, and salt was transported to a 3.0 hectare stockpile immediately southeast of the facility; in 1984, salt storage was shifted to a 6.5 hectare stockpile just north of the construction and salt-handling shaft. Both stockpiles stand about 12 meters at the tallest, although the pile is projected to reach as high as 20 meters. The two stockpiles and their locations are illustrated in Figs. 1 and 2.

Both stockpiles are enclosed by berms ranging from 1 to 3 m high, which prevent runoff from entering adjacent soil. Thus, the principal mode of dispersal, if any, is via wind erosion that resuspends and disperses salt particles. Fugitive salt dust may also be generated by any phase of the salt-handling cycle on the surface at WIPP, including the dumping of salt from a skip atop the headframe into a truck, the transport of salt to the stockpile, the dumping of salt at the storage location, and the occasional grading of the salt pile to a flat surface (upon which trucks can deposit subsequent loads). Also, caliche (principally calcium carbonate) is used as a paving material at the WIPP site, meaning that traffic generates calcic dust under certain circumstances.

Fig. 1. An aerial view from the NW of the WIPP facilities and salt stockpiles.

The natural environment of the WIPP site is a Chihuahuan desert/grassland vegetation community. Shinnery oak, mesquite, and perennial grasses are dominants on the sandy dune-and-swale soils which encompass the site. The region generally receives between 30 and 50 cm of rain each year, with most coming in summer. Temperatures dip near freezing in winter and regularly surpass 100°F in summer. The area tends to be windy, especially in spring, when high winds carry large dust loads. Local environmental conditions are detailed in the Final Environmental Impact Statement[3] and in recent Ecological Monitoring Reports[5,6].

Salt Studies at the WIPP Project.

Salt studies have been performed at WIPP since the site was designated in 1975. Initial studies were conducted as part of the WIPP Biology Program, examining impacts of salt which had been experimentally applied[7], or which had been stockpiled as part of existing local operations, for instance, potash mines[8] or the Gnome nuclear test site[9].

Potential salt effects at WIPP are currently studied as part of the Ecological Monitoring Program, which has the goal of detecting and quantifying non-radiological impacts of construction and *eventually operations* of the facility on the local ecosystem[5]. The program, which began in 1984, tracks many environmental parameters which are potential indicators of salt impacts. The purpose of this paper is to describe those parameters, including the methods whereby they are measured and the salt-related results which have been observed to date.

METHODS

Six long-term monitoring plots were established in 1984 as part of the Ecological Monitoring Program. As Fig. 2 indicates, two plots are downwind from the large stockpile according to the prevailing southeasterly wind, two are upwind from the small stockpile, and two control plots are several kilometers from the site, although in similar soil and vegetation types. Each plot is designated with a central marker, around which samples are collected over an area of approximately 4 ha using random radial coordinates. Detailed rationale behind plot selection are in the first semi-annual Ecological Monitoring Report[5].

Table 1 lists the parameters being measured at each plot as possible indicators of the dispersal and ecological effects of salt. Also listed are comments on the predicted sensitivity of each parameter to salt impacts. Methods are briefly described below.

Aerial Photography is shot twice annually over the entire vicinity of WIPP, including a 1:25000 color image taken directly over the facility, stockpiles, and surrounding terrain.

Surface Photography is also shot twice annually using a 35-mm SLR camera with color film. The photographer stands with his/her back to the central marker at each monitoring plot and shoots in eight directions using standardized exposure settings. A color chart is placed in the mid-ground.

Soil Chemical Properties are measured quarterly in random surface samples (and less frequent deep samples) at each plot. Each surface sample is a composite of ten subsamples which are 10 cm on a side and 2 cm deep. Concentrations of soluble ions, electrical conductivity (EC), sodium adsorption ratio (SAR), and pH are determined using standard EPA analytical procedures.

Microbial Assays are performed quarterly using fluorescein diacetate (FDA) hydrolysis[10], which quantifies total microbial activity in leaf litter at the six plots.

Leaf-litter Decomposition Rates are tracked on a quarterly schedule in mesh bags of pre-weighed leaf litter from shinnery oak, the local dominant.

Plant Seedling Emergence is quantified every spring by counting the number of seedlings (mostly annuals) in 20 randomly placed 1-m^2 quadrats at each monitoring plot.

Plant Species Richness is quantified every fall by counting the number of species in each of 20 randomly placed 1-m^2 quadrats at each plot.

Plant Foliar Cover is quantified every fall using ocular estimation in 20 randomly placed 1-m^2 quadrats at each plot.

RESULTS AND DISCUSSION

Ecological studies at the WIPP project have generated an enormous amount of data, much of which pertain to the issue of salt dispersal and effect. Detailed findings appear every half year in Ecological Monitoring Reports[5,6]; a cumulative overview of the salt-related ecological research at WIPP is in preparation[11].

Table 1 summarizes salt effects observed over the 1.5 years during which the salt stockpiles have been monitored. A few salt impacts are evident, although changes tend to be subtle. In no cases are there severe or far-reaching changes in the conditions of the environment around the WIPP site.

Results for each parameter are briefly discussed below.

Aerial and Surface Photography

The photographic record has revealed no evidence of salt dispersal in the form of discoloration of plants or soils around the stockpiles. Environmental photography has also shown no evidence of conspicuous

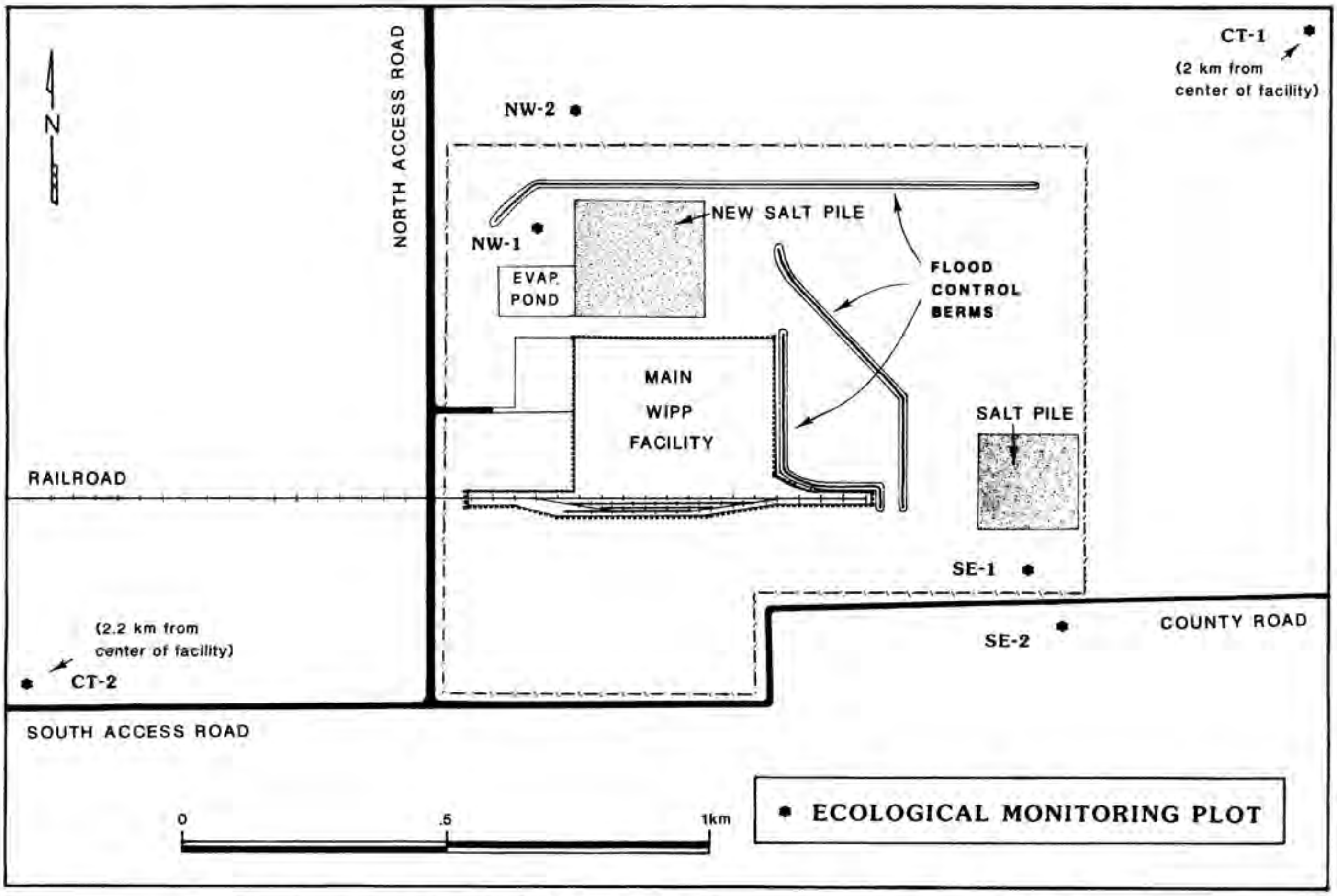

Fig. 2. Layout of ecological monitoring plots relative to the salt piles.

TABLE I
Parameters being monitored at the WIPP project for possible evidence of salt impacts.

Parameter	Freq	Anticipated Sensitivity	General Observations	Salt-Related Observations
Aerial photography	2/year	Very Slight	Documents expansion of project facilities	No detectible impacts on such as discoloration of soil or vegetation
Surface photography	2/year	Very Slight	No conspicuous seasonal or spatial patterns	No conspicuous impacts such as discoloration or plant mortality
Soil sodium	4/year	High	Highly variable and dynamic	Significantly elevated at near-field plots before, but not after, wet season
Soil chloride	4/year	High	Relatively less variable	Non-significant tendencies for levels to be elevated downwind from stockpile
Soil EC	4/year	High	Seasonally regular variation	Positively correlated with distance from saltpile, declining during wet season
Soil SAR	4/year	High	Highly variable, both spatially and seasonally	The most sensitive indicator of salt deposition on the soil
Other properties	4/year	Mixed	Relatively less variable	Occasionally elevated levels of Ca, K and Mg at near-field plots.
Microbial (FDA) assay	4/year	Moderate	Responds to rainfall patterns	No apparent salt-related differences
Leaf decomposition	4/year	Slight	Progresses linearly and in parallel at all plots	No apparent salt-related differences
Plant seedling emergence	1/year	Moderate	Significantly higher in 1985 than 1984	Slightly depressed in 1985 at plots near older salt stockpile
Plant species richness	1/year	Slight	Relatively constant between years	Slightly depressed in 1985 at plot adjacent to older stockpile
Plant foliar cover	1/year	Slight	Significantly higher in 1985 than 1984	Slightly depressed in 1985 at plot adjacent to both stockpiles

degradation in the local flora, for instance, increased mortality or reduced vigor among plants in the ecological monitoring plots. It is expected that photography would detect only the most dramatic impacts.

Soil Chemical Properties

Soil chemical properties have provided the most significant and readily interpretable evidence of salt dispersal from the storage piles. All salt-related soil parameters have been seasonally dynamic, and have differed between experimental and control plots in such a way as to indicate short-range dispersal of small quantities of wind-blown salt. The soil parameter which best summarizes salt-effects is electrical conductivity (EC), which relects the overall abundance and availability of soluble ions in the soil.

Figure 3 indicates that ECs tended to be highest at NW1 and SE1, the closest plots to the two salt piles. Intermediate levels occurred at NW2 and SE2, plots further from the salt piles, whereas the lowest values were at CT1 and CT2, the two control plots. Differences between near-field plots (NW1 and SE1), far-field plots (NW2 and SE2) and control plots tended to be statistically significant using Analysis of Variance and Student-Newman-Keuls tests[12]. Statistical results are detailed in the Ecological *Monitoring Reports*[5,6] and cumulative overview[11]; however, a good rule-of-thumb is that differences are significant if the standard error bars do not overlap.

Another consistent pattern is the fact that ECs and SARs tend to be highest in March, which is the middle of the windy season and the end of the relatively dry period in the annual climatic cycle. Salt concentrations should be highest in spring if wind is the primary cause of dispersal. Values for these parameters decline through summer, suggesting that summer rains leach soluble salts beneath the surface horizon. Subsequent monitoring should clarify interpretations of seasonal variation in soil salt levels.

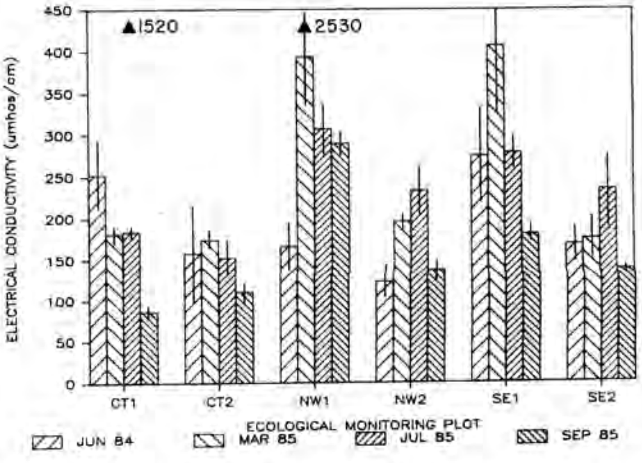

Fig. 3. Soil EC values at six ecological monitoring plots. Triangles indicate outlier values deleted from statistical consideration.

Dispersal from the salt piles was quantified by plotting the EC values of random samples as a function of distance from the edge of the nearest stockpile. Figure 4 illustrates that ECs tended to decline with distance from salt piles in both March and September of 1985. Values near the stockpiles tended to be much higher in March, resulting in a steeper rate of decline (negative slope) in the March regression line than the September regression line. This supports the interpretation that relatively high salt levels in spring are reduced by summer rains. There is a tendency in Fig. 4 for NW data points to be higher than SE data points, which is consistent with the fact the NW plots are downwind from the saltpiles according to the prevailing winds.

The effect of vegetation on soil salt data was quantified on two occasions by collecting samples from beneath mesquite and oak plants, as well as from bare areas, which is the usual practice. This comparison was performed at NW1 and CT1. In both cases, cations such as calcium, magnesium, and potassium were higher under plants than between them. These are plant nutrients, which are "pumped" from deep soils and deposited via litter (hence concentrated) on the surface beneath plant crowns. Neither sodium nor chloride at NW1 were higher under shrubs than between them, suggesting that plants are not intercepting substantial quantities of windblown salt for deposition on the surface below.

Finally, it must be emphasized that in no cases have soil salt concentrations even approached levels at which plant damage and inhibition is expected to occur. For instance, EC values never exceed 700 umhos, whereas the threshhold for trouble to agricultural species is generally considered 4000 umhos[1]. The fact that values remain low reflects the rock-hard consistency of stored salt, which is probably liberated only by the scouring action of strong winds with high particulate loads, and the permeability of the sandy soils around the site, through which soluble ions are readily leached by summer rain. Continued monitoring, and careful examination of patterns among deep soil samples, will be necessary to determine if salt is accumulating at any point in the soil profile.

Microbial Activity

Microbes are expected to be the most sensitive organisms to change in the chemical nature of the environment. Like plants, bacteria and fungi are relatively immobile, hence unable to move away from environmental stress. Furthermore, these organisms are relatively short-lived, so population changes are quickly evident. FDA hydrolysis provides a momentary index of microbial presence in the leaf litter (including both active and dormant organisms), whereas decomposition rates provide a long-term cumulative index of microbial action (the metabolic transformation of leaf tissue to carbon dioxide).

Neither microbial parameter reveals salt effects. The FDA bioassay varies dramatically, with values twice as high in December 1984 and August 1985, than in June 1984 and May 1985. Microbial activity is higher when leaf litter is cool and damp. Even though most rain falls in summer, high temperatures apparently desiccate litter to the point of restricting microbial action. The seasonal variation described above has occurred in parallel at all six ecological monitoring plots, with no apparent salt-related differences among the plots.

Decomposition rates have also been parallel among the six plots, with no apparent salt-related interplot differences. Samples emplaced in February 1985 decomposed steadily throughout the summer, retaining between 70% and 80% of their original weight as of November 1985. It remains to be seen if decomposition rates increase, or if interplot differences emerge, during the winter when the FDA bioassay indicates that microbial activity is highest.

Vegetation Parameters

Like microbes, plants seemed largely unaffected by salt dispersal. Seedlings are more sensitive to osmotic inhibition (for instance, by soluble salts in soil water) than adult plants. Densities of germinating seedlings, measured in spring of 1984 and 1985, did not differ in a consistent way between experimental and control plots. The possible

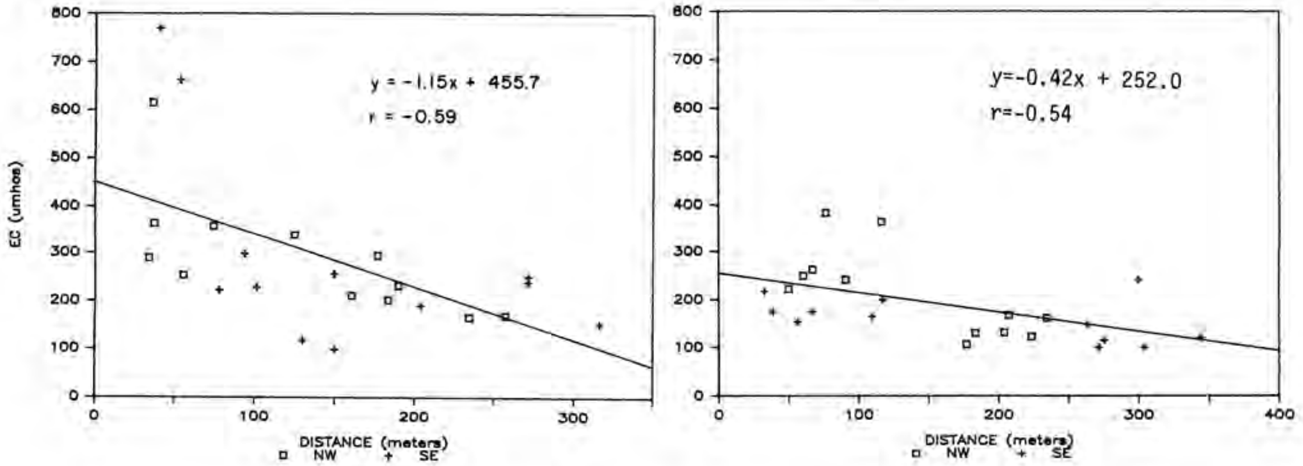

Fig. 4. Scattergrams of EC versus distance in March (left) and September (right) of 1985.

exception is at SE1, adjacent to the older salt pile, where densities were significantly lower in 1985 than at all other plots. Continued observation will indicate whether long-term inhibition of germination occurs there.

Species richness, represented by the mean number of species per quadrat among the 20 random quadrats at each plot, did not differ between the plots in fall of 1984 or 1985. However, richness is the crudest measure of species diversity, responding only to a dramatic reduction in the presence of a species at a plot. More sensitive indices of species diversity, which reflect more subtle characteristics in the composition of a plant community, will be applied when more data are available.

Foliar cover was the only vegetation parameter showing any kind of a possible response to salt effects. Figure 5 indicates that percent foliar cover was less in 1985 at the two plots closest to the stockpiles (NW1 and SE1) than at the other plots. Coverages tended to be higher in 1985 due to substantially more rainfall than in 1984. This response may reflect salt effects, although we consider it equally likely that reduced coverages are a reponse to general destabilization of the soil immediately around the salt piles and other site facilities. Portions of these plots, especially where they abut the salt piles, have sand piled on top of old litter or vegetation. Sand liberated from disturbed areas nearby seems to be forming small dune-like deposits in response to alterations in the immediate topography. For this reason, foliar cover will be monitored in conjunction with other ecological parameters in order to resolve possible salt effects from other facility impacts.

SUMMARY AND CONCLUSIONS

Measurements of soil properties indicate that some saline material is being deposited in the local ecosystem, although the amount of material is small and the biotic impacts are negligable. Regression analysis reveals that material is not transported far, because salt concentrations decline rapidly over a few hundred meters. It is not clear whether saline dust originates principally from the storage piles of salt, from the handling and transport of salt on the surface, or from the caliche stirred up by traffic in the construction area.

Salt levels in the soil are highest in spring, during the windy season, and lowest in fall, after summer rains have leached soluble ions deep in the soil. Studies of soil profiles will be necessary to identify the extent and nature of salt accumulation at depth.

Biological parameters showed no consistent response to the increased presence of salt in the soil around the WIPP site. This is because salt levels, even where elevated, remained well below published threshholds for biological damage or *inhibition*. Sustained monitoring of these biological parameters will detect possible cumulative effects of salt on microbes or vegetation.

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