Quality, Quantity, and Availability of West Virginia Oil and Gas Well Brines for Highway Deicing Purposes

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Research findings over the last decade have indicated that use of natural brines as highway deicing agents was technically feasible and cost-effective in a variety of situations. The principal remaining concern related to brine availability. An in-depth evaluation of oil and gas field brines on a statewide basis was undertaken. Published information was limited, so a survey was conducted of oil and gas producers in the state to obtain information on the quantity and quality of brine produced. Data collected were compiled as a microcomputer data base to be used by the West Virginia Division of Highways. Selecting brine parameters for analysis and acceptable concentration levels for those parameters was somewhat difficult, since there are no generally accepted guidelines for oil and gas brines. The two most important issues involving a brine's suitability for highway deicing are melting effectiveness and the level of potentially harmful constituents. The data base was implemented to determine brine quantity estimates on a statewide basis. Almost 2.2 million L/year were identified. All counties producing suitable brines were clustered in the west-central and north-central portions of the state. On the basis of current brine availability, the most promising applications are as an additive to abrasives rather than application of straight brine directly to the pavement.

Brines (either prepared or natural) have received considerable attention as a snow and ice control material since they act fast and do not blow off the road. A number of state and local highway agencies use natural brines from geologic formations beneath the earth's surface. Since West Virginia is a significant producer of oil and gas and associated brines, it was appropriate to examine the use of brines on West Virginia highways.

The significant quantities of brines produced in West Virginia are difficult to dispose of in an environmentally acceptable manner since the brines are much more concentrated than seawater. The currently preferred method of brine disposal is via injection wells; however, this is often a very expensive method in the Appalachian region. Since there is, at present, no completely satisfactory and cost-effective method of disposing of waste brine, brine is often disposed of directly into ground or surface waters with potential water quality deterioration.

During the past decade, several research projects have been undertaken in West Virginia to address questions associated with the use of natural brine as a deicing agent. Both laboratory and field testing programs have been conducted on brines alone and on brine as an additive to abrasive materials and deicing salts. Findings indicated that use of natural brines as a highway deicing agent was technically feasible and appeared cost-effective in a variety of situations (*1*). On the basis of the research, the West Virginia Division of Highways (WVDOH) had enough information to begin acquiring equipment and building facilities to implement a brine usage program. The principal concern remaining related to the availability of brine. Thus, an in-depth evaluation of oil and gas field brines on a statewide basis was undertaken.

The overall goal of this research was to evaluate the quality and quantity of oil and gas field brines across the state in anticipation of a larger-scale use of brines. Specific objectives established to meet this goal are

1. To expand the necessarily limited brine quality information collected in Phase I to include brine availability information statewide,
2. To work with oil and gas producers to determine current brine production and brine quality from major fields and to estimate the production life of these fields, and
3. To develop, from existing information and analyses conducted as part of this research, a microcomputer-based brine availability (quantity and quality) data base.

BRINE AVAILABILITY INFORMATION

To obtain data on the quality and quantity of brine, several federal and state agencies and trade associations were contacted, including the Environmental Protection Agency (EPA), the West Virginia Department of Natural Resources, the West Virginia Department of Energy, the West Virginia Geologic and Economic Survey, the West Virginia Oil and Natural Gas Association, and the Independent Oil and Gas Association of West Virginia. However, only the West Virginia Geologic and Economic Survey was able to provide much useful data on brine quality.

The quantity of brine produced from a given well depends on a variety of factors, including the geological formation tapped and its depth, and the well's location, construction, age, and operation (*2*). Many wells produce little brine when first put into production but then produce more with time; others yield large quantities of brine initially. Brine produced per well is extremely variable.

Clearly, the best source of hard data on brine production is the oil and gas industry. The investigators were able t

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obtain estimates of brine available for deicing from 13 companies, as will be discussed, but a comprehensive listing of brine produced statewide was not available. A 1987 survey of actual brine production included approximately 15 percent of the gas wells and 10 percent of the oil wells in the state (*3*). Assuming that the amount of brine produced in the wells reported is representative of produced water from all active wells in the state gives an estimate of 844 million L of brine.

Even if the figure of 844 million L of brine production per year is a reliable estimate, only part of the brine would be available or suitable for use on roadways. Brines unsuitable for use include those that are too weak or that contain undesirable levels of contaminants. It is also likely that brines from a number of wells would not be cost-effective for use because of their remote location or low production, resulting in unacceptably high transportation costs.

As a result of discussions with various state agencies and trade associations, it was found that there are an estimated 1,800 producer-operators in West Virginia with between 30,000 to 45,000 wells. However, most of the wells may be classified as stripper wells that produce only small amounts of oil or gas, and some are inactive. In addition, most of the operators are relatively small companies with fewer than 25 wells.

Discussions with representatives from the oil and gas industry were carried out to ascertain what type of information on brine quantity, well location, and brine quality they would be willing and able to provide. We found, with few exceptions, that most companies did not have significant information on brine quality. In addition, most companies were unwilling to provide information on quantity or quality for individual wells. Most were, however, willing to report the quantity of brine available from a group of wells in a given geographic area.

A brine survey form was prepared to gather data from each company for the data base. The information requested for each brine source included county, formation or zone, quantity of brine available from October to April, estimated production life, well group location, and distance that the company was willing to haul the brine to a WVDOH maintenance station.

Initial contacts with each oil and gas producer were made by phone. During the initial call, the purpose of the project was explained and a request for participation was made. If the company representative agreed to cooperate, a brine survey form and accompanying explanation was sent along with a request for the form to be filled out and returned to the investigators as soon as possible. Samples were also requested.

Of the 71 telephone contacts made during the study, 18 companies completed the brine survey form. Of the remaining 53 companies, 4 had been sold or were no longer in business. Thus, 49 companies rejected participation in the project either explicitly (stated a reason) or implicitly (did not respond). The most common reason given for rejection was production of only a small quantity of brine. Of the 18 companies that returned the survey forms, only 14 actually provided samples of brine for analysis.

CHOICE OF CONSTITUENTS AND FORMULATION OF BRINE RANKING SYSTEM

One of the early project tasks was choosing which constituents would be determined for each brine. A closely allied task was choosing acceptable concentration levels for some of the parameters. The two most important issues regarding a brine's suitability for highway deicing are melting effectiveness and the level of potentially harmful constituents.

Discussions were held with state regulatory personnel in West Virginia and Pennsylvania to aid in choosing constituents. Consideration was also given to the EPA Drinking Water Standards and to typical levels of various constituents normally found in brines. The final choice of acceptable levels was based on the judgment of the researchers. It was decided to limit the list of constituents to 10 because of time and resource constraints.

Table 1 presents the 10 constituents chosen for analysis and provides a rationale for the choice in each case. Also included are the acceptable levels where pertinent. It may be noted that different acceptable levels have been specified for use in road spreading and for addition to abrasives. This is because brine application rates for road spreading are based on 142 kg total dissolved solids (TDS) per two-lane kilometer, whereas brine application rates for use with abrasives are expected to range from about 3 to 9 kg TDS/two-lane-km (*4*). Since the brine application rate for abrasives is only about 5 percent of that for road spreading, higher acceptable levels of iron, sulfate, barium, lead, and oil and grease are shown for brine added to abrasives.

In areas where a variety of brine sources are available for use, it appears prudent to use the brines with the best melting effectiveness and lowest concentrations of undesirable constituents. Hence, a ranking system was devised for both brine spreading and brine addition to abrasives applications. The system was based on concentrations of total dissolved solids, barium and lead. A point system was used that allows a maximum value of 7 (most desirable) and minimum value of 1 (least desirable). Thus, a brine with high TDS (above 250,000 mg/L) and low lead and barium levels would earn a high rank of 7 points. But a brine with relatively low TDS (less than 200,000 mg/L) and high lead and barium levels would receive a low rank of 1 point. The system is clearly arbitrary in nature, but it is simple, easy to use, and can be readily applied to new brines.

BRINES ANALYSIS AND RANKING

As noted earlier, brine samples were obtained from 14 oil and gas producers. Seventy samples were analyzed from 23 counties and 25 different formations or zones. On the basis of meeting the acceptable criteria chosen (Table 1) for TDS, barium, lead, and oil and grease, 32 of the 70 brines sampled were found to be suitable. Of the 32 brines, 19 were acceptable for both spreading and adding to abrasives, whereas the other 13 could be used only as abrasive additives. Detailed data on the composition of each brine are presented in the project final report (*5*).

Range and mean constituent values were determined for the suitable project brines. TDS levels varied from 150,000 to 311,200 mg/L. In general, the stronger brines originated from deeper formations. As would be expected, the major elements determined (chloride, sodium, and calcium) increased as the TDS increased.

TABLE 1 Brine Constituents Analyzed and Acceptable Levels Chosen

Parameter	Rationale	Acceptable Road Spreading	Level[a] Added to Abrasives
Total Dissolved Solids	A high TDS improves melting efficiency and reduces volume of brine required	150,000 (min)	150,000 (min)
Chloride	Same as TDS	NLS[b]	NLS
Sodium	Same as TDS	NLS	NLS
Calcium	Improves melting at lower temperatures	NLS	NLS
pH	Low pH may accelerate corrosion of equipment and impact surface runoff	NLS	NLS
Iron	May cause staining of concrete roadways	For values >500, restrict to use on asphalt	NLS
Sulfate	High sulfate levels attack concrete	For values >400, restrict to use on asphalt	NLS
Barium	Health effects	30 (max)	100 (max)
Lead	Health effects	6 (max)	7 (max)
Oil and Grease	Potential for slippery conditions and environmental impact	35 (max)	160 (max)

a all values in mg/l except pH
b NLS - no limit specified

Calcium levels varied from 13,440 to 35,630 mg/L and averaged 23,910 mg/L. The presence of calcium is desirable in that calcium salts lower the freezing point more than sodium salts, allowing the use of a calcium-based deicing agent at a relatively lower temperature. Iron ranged from 22 to 1010 mg/L, with an average value of 319 mg/L. The high variability in iron is probably due to sample handling during collection and analysis. On exposure to air, ferrous iron will slowly oxidize to ferric iron and precipitate. When used for road spreading, brines with iron concentrations of greater than 500 mg/L are restricted to use on asphalt to avoid staining of concrete.

Sulfate levels, which varied from 20 to 1080 mg/L (average 361 mg/L), are of interest because of potential attack of concrete. It is recommended that brines with sulfate levels above 400 mg/L be restricted to use on asphalt when brine is used for road spreading. Because of dilution with meltwater, actual runoff sulfate levels are not expected to cause concrete to deteriorate.

Lead in project brines varied from 2.7 to 6.4 mg/L, with an average of 4.3 mg/L. It is thought that these levels are environmentally acceptable for a variety of reasons. First, there is a large amount of dilution by meltwater available. For example, assume the average brine containing 212 560 mg/L TDS and 4.3 mg/L lead was applied at a loading rate of 142 kg TDS/two-lane-km in a road spreading application. Also assume that there was 3.2 mm of precipitation on the highway for dilution. It can be shown that the runoff lead concentration at the edge of the roadway would be approximately 0.16 mg/L. In addition, as the runoff moves toward a water course, significantly greater dilution would occur as meltwater from the surrounding terrain mixes with runoff from the roadway. The preceding discussion assumed a road spreading application rate of 142 kg TDS/two-lane-km. For an application in which brine is added to abrasives, it was noted earlier that the application rate would be extremely small (5 percent of that used for spreading) and hence lead levels would be insignificant.

Barium in project brines varied from 0.2 to 98.5 mg/L, with a mean of 20.5 mg/L. As noted in Table 1, acceptable brines for road spreading and for use as abrasives additives should have barium levels of less than 30 and 100 mg/L, respectively, for health considerations.

It should be noted that dry deicing agents also contain trace constituents such as lead and barium. A variety of dry sodium and calcium chloride deicing agents were analyzed during Phase I (*6*) for comparison with trace elements in natural brines. Results were expressed as milligram of constituent per kilogram of TDS. The lead in the dry agents averaged 6.7 mg/kg in sodium chloride and 500 mg/kg in calcium chloride samples tested, whereas barium averaged 114 mg/kg in two sodium chloride samples tested. Using the average values for project brines gives 20.2 and 96.4 mg/kg of lead and barium, respectively, in the dry deicing agents. Hence, trace elements in dry deicing agents used may actually exceed those in natural brines in some cases.

Oil and grease concentrations ranged from 2 to 160 mg/L, averaging of 41 mg/L. Brine used for spreading will be restricted to an oil and grease level of less than 35 mg/L to avoid slippery pavement conditions.

DEVELOPMENT OF BRINE DATA BASE

Information Requirements and Report Capabilities

To evaluate the potential for brine usage in a given part of the state, information is required about brine quality, brine quantity, location, and estimated production life of the field. In addition, a list of oil and gas companies in an area willing to provide brines would be required. Storage and handling costs must also be carefully considered. It was anticipated that the oil and gas companies would deliver brine to most WVDOH maintenance stations at no cost, but it is clear that the distance between the brine source and the nearest maintenance station is an important consideration in selecting a particular brine.

To use this brine information, certain data are also needed from the user. User inputs would include the location of the maintenance station at which brine is desired, the quantity required (based on past history of rock salt usage), and the method of brine application desired (e.g., road spreading, salt prewetting, stockpile freezeproofing, or adding to abrasive mixtures). Although not part of the information requirements per se, any system for accessing and manipulating brine data must incorporate such user inputs.

It was initially anticipated that brine quantity and quality information could be acquired on a well-by-well basis. Discussions with oil and gas producers indicated that because of the sensitive nature of the data, producers will not usually provide data on individual wells but would be willing to provide data on groups of wells producing from a particular formation. Thus, the data base described herein is based on well groupings. Given the potentially large volume of data to be handled, the need for frequent updating, and the need to serve different users, a computerized data base was created.

Two types of reports were envisioned. The first report, which would identify brine producers, is intended for use at the managerial level, either at the WVDOH main office in Charleston or at the district headquarters. For each WVDOH district, the report would list the brine producers in each county making up that district. An address and telephone number would be provided for each producer along with an estimate of the quantity of brine available in gallons per year.

The second report, which would identify specific brine sources, is intended for use by county maintenance personnel in making arrangements for acquiring brine. The oil and gas producers in each county who have agreed to cooperate would be listed with an address and telephone number. The location of the haul point and the zone or formation from which the well group produces should be indicated along with the quantity, quality, and transportation information.

PC-FILE+, a general-purpose data base manager, was selected as the most appropriate for project purposes. The software runs on all of the IBM series of personal computers, as well as all compatible and most "nearly compatible" computers. It is designed to work with any printer. PC-FILE+ requires a 384K or larger MS-DOS computer with two double-sided disk drives or one double-sided disk drive and a hard disk, an 80-column display, and MS-DOS or PC-DOS Version 2.0 or later.

The main data base, which contains the information items discussed earlier, was designated as BRINE. Table 2 provides a list of the fields that make up the BRINE data base. To ensure that any particular brine is acceptable for use on highways, BRINE includes only those brines that have been found to be acceptable.

Several reports were developed that would be useful to WVDOH users. The PRODUCER list includes, for each WVDOH district, the brine producers in each county making up that district. An address and telephone number are provided for each producer along with a cooperation code and the quantity of brine available in gallons per year. The cooperation code is designated as either "P" or "H." A "P" indicates that the company is willing to provide brine but that WVDOH must make arrangements for transportation. An "H" indicates that the company is willing to haul brine (at no cost) a reasonable distance to WVDOH maintenance facilities.

The SOURCE list is typical of the report that might be requested by county maintenance personnel in making arrangements for acquiring brine. The oil and gas producers in each county who have agreed to cooperate are listed with an address and telephone number. The location of the haul point for a well group is given in a form that would be identifiable to the system user, such as a town or a highway intersection. The zone or formation from which the well group produces is also indicated along with the quantity of brine produced in gallons per year and estimated production life. The haul that a producer is willing to make at no charge to WVDOH is presented in terms of either a distance or a haul time, as provided by the producer in response to the questionnaire. Finally, an analysis of the brines is presented in terms of the 10 parameters selected as being useful in identifying suitable brines for highway purposes.

Identification and Ranking of Suitable Brines

Haul distance is obviously a factor to be included in any ranking system for selecting brine sources. However, as the

TABLE 2 Fields Making Up Brine Data Base

Field Name	BRIEF EXPLANATION
Sample Number	ID Number assigned by researchers
Company	Oil/Gas producer
Contact	Individual providing data
Address	Street address
P.O. Box	Post office box number
City	City
State	State
Zip Code	Zip code of city
Area Code	Telephone area code
Phone Number	Telephone number
Formation	Geologic formation from which produced
Location	Geographic location of well grouping
District	WVDOH District number
County	County
Quantity	Quantity of brine available
Estimated Life	Estimated life of well grouping
Cooperation Code	Producer willingness to haul brine
Storage	Producer willingness to store brine
Haul Distance	Distance producer willing to haul
Haul Time	Trip length producer willing to haul
pH	pH of brine
TDS	Total dissolved solids of brine
Chloride	Chloride content of brine
Sodium	Sodium content of brine
Calcium	Calcium content of brine
Iron	Iron content of brine
Barium	Barium content of brine
Lead	Lead content of brine
Sulfate	Sulfate content of brine
Oil & Grease	Oil & grease content of brine
Station	WVDOH maintenance stations within haul distance
Comments	Remarks

project progressed, it became apparent that haul distance did not affect the brine selection decision in the way the researchers had envisioned at the proposal stage. Thus, as will be described, inclusion of haul distance in the ranking system is implicit as opposed to explicit.

Currently, a number of oil and gas producers are hauling (or paying to have hauled) brines considerable distances to dispose of them. Review of questionnaire responses tended to support this statement, with companies indicating haul radii of 2 or even 3 to 6 hr. The radius of haul would vary depending on the type of highway over which the haul is made. For example, a truck can travel significantly farther in 2 hr over an Interstate highway than it can over a two-lane, two-way highway with sharp curves and steep grades.

Because of the considerable haul distances involved and the wide range in these distances, a traditional economic analysis of hauling cost versus distance does not apply. Hauling brine to a particular maintenance station is an either-or situation. This complicates any attempt to incorporate hauling considerations as part of the ranking system for a specific brine.

The ranking system developed can be considered as a two-step process. First, suitable brines for which the distance from the well group to a WVDOH maintenance station is less than or equal to the haul distance indicated by the producer are identified. That is, the data base includes a list of the brine sources within a reasonable haul distance of each maintenance station. Second, the quality ranking system is then applied to each of the brines feasible for a given maintenance station. As with the quality ranking system, haul considerations have been incorporated into the ranking system by the researchers and do not need to be considered by data base users.

Identifying feasible brines for particular maintenance stations was essentially a manual process. Existing WVDOH salt stockpile locations were plotted on a state highway map. The centroid of each well grouping was also plotted on the basis of the location indicated on the producer's questionnaire response. For each centroid, a circle was plotted with radius equal to the indicated haul distance. Where producers indicated a haul time instead, the time was converted to a distance using the following factors:

- Interstate highways: average speed = 72 km/hr
- Two-lane highways: average speed = 40 km/hr

From this plot, it was a straightforward process to identify the maintenance stations within the economic haul circle for each well grouping. The list of these maintenance stations, for each brine source, was then incorporated into the BRINE data base.

DATA BASE IMPLEMENTATION

The brine analysis information, for those producer-furnished samples that were deemed appropriate on basis of the criteria presented earlier, was input to the data base. In addition, those maintenance stations within the economic transportation distance, as determined by the haul distance analysis, were entered appropriately. The data base was then implemented to determine brine quantity estimates statewide.

Brine Quantity Estimates

To determine the availability of brine statewide, a printout was generated from the data base showing the quantity of suitable brines in each of the producing counties. These results are shown in Table 3. The 32 samples, each representing a different well group, came from 14 of the 55 counties in the state.

The quantities were plotted on a state map in order to visualize the geographic distribution of suitable brines. Except for Raleigh County in the southern part of the state and Nicholas County in the center of the state, all of the brine-producing counties are clustered in the west-central and north-central portions of the state, that is, between the Ohio River and the Clarksburg-Buckhannon area. Previous work, both by this research team and others, has shown that there are other significant brine-producing areas in the state, for example, Monongahela-Preston counties, Randolph-Tucker counties, and Kanawha-Clay counties. Brines from these areas were not included on the map because either the brines are not suitable for highway purposes or producers from those locations did not respond to the survey.

As provided in Table 3, this study identified slightly more than 2.1 million L of suitable brines available statewide each year. This quantity can be considered as the minimum amount of brine available. Other producers of suitable brines will certainly come forward once the WVDOH begins using brines for highway purposes. However, even if additional brine becomes available, it is fair to say that certain parts of the state will not be candidates for implementing a brine usage program. These areas include the northern panhandle, the eastern panhandle, and the southeastern and the southwestern parts of the state.

Brine Feasibility at Selected Locations

Information from the data base was used to evaluate the feasibility of brine usage at selected maintenance stations in brine-producing areas of the state. In consultation with WVDOH maintenance personnel, several scenarios for using brine were developed and evaluated. The scenarios were:

- Application to Interstate 79 in central West Virginia
- Application in urban areas
- Application in vicinity of brine sources
- Application of brine-treated abrasives

All scenarios assumed an average West Virginia winter: 18 storms a year with three salt applications per storm. In addition, it was assumed that the brine strength was 200 000 mg/L TDS requiring an application rate of 85 kg/two-lane-km to apply 142 kg TDS/two-lane-km. Obviously, brine strength will vary depending on the source. Survey results indicated that most suitable West Virginia brines are in the range of 160 000 to 250 000 mg/L.

It was determined that, given the haul distances involved, the Interstate system is not an attractive setting for using brines. A special truck would be needed to carry the large quantities of brine involved.

The second scenario involved straight brine application in densely populated areas, where distances are not great but the need to act quickly is important. Results indicated that there is almost enough brine within a reasonable haul distance of Charleston, Clarksburg, and Parkersburg to handle two of the three urban ares. Although the scenario appears feasible for the two urban areas that might be chosen, negligible brine would be left statewide for other highway applications.

In the third scenario, a county having well groupings where sufficient quantities of brine are available would become a candidate for application of straight brine on paved roadways. There are only five areas in the state where such a large quantity of brine exists in a relatively concentrated area. In the five counties (or groups of counties) that have brine sources close enough to make this approach practicable, conversion

TABLE 3 Quantities of Suitable Brines Available in Each Producing County

County	Well Groups	Liters per year
Doddridge	1	55,640
Gilmer	3	151,000
Harrison	5	224,150
Jackson	1	31,800
Lewis	4	334,000
Mason	1	31,800
Nicholas	3	111,280
Raleigh	2	22,260
Ritchie	1	158,970
Roane	5	395,200
Tyler	2	152,900
Upshur	2	26,390
Wirt	1	318,000
Wood	1	98,560
TOTAL	32	2,112,000

to brine would save only 5 to 10 percent of a candidate county's salt usage.

The final scenario involved treating a standard abrasive hopper spreader with brine as a substitute for conventional rock salt. Assuming that 6.7 kg TDS/two-lane-km would be added to the abrasive material, a 3.8-m^3 (5-yd^3) truck would be treated with 568 L of brine each time it left the maintenance yard. Analysis indicated that nine counties have sufficient brine within a reasonable haul distance.

The most promising of the four scenarios is its addition to abrasives for enhanced melting action. Nine counties were identified with sufficient brine for abrasive treating needs, and a one-winter pilot study or field trial in one or two of these counties was recommended. To implement this recommendation, a sample agreement between the WVDOH and CNG Development, a local producer, to conduct a field trial was developed. The agreement is written so that CNG Development will provide brine and storage tanks to the WVDOH Weston Maintenance Station in Lewis County. Although the sample agreement is written for a specific company and location, it can be readily modified for use with other companies and locations. The agreement is written so as to be a companion document to a set of pollution prevention guidelines and conditions; both documents are contained in the project final report (*5*).

Pollution prevention guidelines and conditions were prepared for submission to the West Virginia Department of Natural Resources and are designed for use during brine application to cinder abrasives to enhance melting action during a field trial at the Weston Maintenance Station in Lewis County. The rate of brine application with the cinder abrasives will be quite low (approximately 7 kg TDS/two-lane-km), so the potential for any environmental problems is extremely limited.

CONCLUSIONS

Data on the quality of brines in West Virginia were not readily available. Useful historical data were obtained but suffered from limitations such as the date of the data, limited geographic coverage, or the exclusion of important constituents. It was concluded that there was a need for systematic collection of brine quality data from each oil and gas producer. The West Virginia Department of Energy is planning to collect such data within the next few years.

Similarly, no comprehensive data are available on the quantity of brine produced in West Virginia. The best source of such data is the oil and gas industry. Until a government agency such as the West Virginia Department of Energy specifies a mandatory data collection program, producers will most likely be unable or reluctant to provide brine production data. However, the brine availability data base compiled as part of this research will be of use to the West Virginia Division of Highways in the near term.

Choosing brine parameters for analysis and acceptable concentration levels for these parameters was somewhat difficult since there are no generally accepted guidelines relative to oil and gas brines. In the researchers' opinions, the two most important issues regarding a brine's suitability for highway deicing are melting effectiveness and the level of potentially harmful constituents. The parameters evaluated in this study were total dissolved solids, chloride, sodium, calcium, pH, iron, sulfate, barium, lead, and oil and grease. Since the brine application rate required for abrasives is only about 5 percent of that for road spreading, higher acceptable levels of iron, sulfate, barium, lead, and oil and grease were indicated for brine added to abrasives.

Traditional economic analyses of hauling cost versus distance do not apply to the transportation of brines. The transportation of brine from the wellhead to a particular WVDOH maintenance station is an either-or situation. Thus, inclusion of haul distance in the brine ranking system is implicit (i.e., invisible to the user) as opposed to explicit.

The data base was implemented to determine brine quantity estimates on a statewide basis. Almost 2.2 million L per year of suitable brines were identified. In general, all of the counties producing suitable brines in this study are clustered in the west-central and north-central portions of the state.

Perhaps the major overall conclusion drawn from this research is that based on current brine availability, the promising applications are as an additive to abrasives rather than an application of straight brine directly to the pavement. Previous studies (*4*) on West Virginia brines have shown that they are also suitable for prewetting of rock salt and stockpile freezeproofing.

The quantity of available brine identified should be considered as a minimum. Once the beneficial use of brines for highway purposes is demonstrated, other producers of suitable brines will certainly come forward. However, even under these circumstances, the northern panhandle, the eastern panhandle, and the southeastern and southwestern parts of the state are unlikely candidates for implementing a brine usage program.

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