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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 2 1988

OFFICE OF
RESEARCH AND DEVELOPMENT

MEMORANDUM

SUBJECT: Status Report of the Woburn Workgroup

FROM: William H. Farland, Ph.D.
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Assessment (RD-689)

TO: Vaun A. Newill, M.D.
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In April 1984, the Office of Research and Development at EPA was asked by then Administrator William Ruckelshaus for its opinion on the circumstances that were unfolding in Woburn, Massachusetts. The Administrator's request was prompted by a study on Woburn conducted by investigators from the Harvard School of Public Health and its review by a variety of individuals in the scientific community. Scientists in th Office of Research and Development examined the limited information available to them at the time and after a preliminary consultation with the authors of the Woburn drinking water study provided the Administrator with an interim opinion. At the same time, the Office of Drinking Water at EPA was considering available scientific information on volatile organic compounds for the development of drinking water standards. The circumstances at Woburn were thought to be an instructive case study that might help to guide further development of scientific information to be used in the establishment of control strategi s for volatile organic compounds. It was on this basis that an Ad Hoc workgroup of EPA scientists continued to seek and examine scientific information on Woburn. It was the Workgroup's expectation that, in looking at Woburn, a better understanding of the more general relationship between risk assessment and epidemiology at hazardous waste sites could be gained, and that meaningful research needs could be identified.

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The Workgroup was aware that a Superfund site exist d in the area and kept staff responsible for Superfund proceedings informed of its activities. The Workgroup has always considered its deliberation to be separate from the Superfund activity because its objectives were different. In this context, while the Workgroup's report may add to the overall explanation of the circumstances existing in Woburn, it is not intended to b used as a basis for the decision, expected later this year, by EPA's Region I Office concerning the Wells G and H Superfund site at Woburn.

Over the course of time, reviews of the existing and historical circumstances in Woburn have raised many questions and uncertainties. While the EPA Ad Hoc Workgroup acknowledges the existence of questions and uncertainties, it is of the opinion that there are both health effects and environmental contamination in the community, and that their nature needs to be better characterized. Furthermore, the circumstantial evidence in Woburn, evidence of leukemia in other parts of the U.S., and the notion of a broader search for volatile organic compounds as contaminants in the nation's drinking water may all suggest the need for focussed studies to see if there are causal links between drinking water contaminants and health in general. While EPA's Office of Drinking Water has promulgated standards for the volatile organic compounds most frequently detected in drinking water, enough methodological concerns have been raised in recent times to possibly warrant such studies.

A status report including observations and findings of the EPA Workgroup is attached. It is clear that the analysis of the Woburn data may be useful in planning additional studies both in the areas of cancer epidemiology and in groundwater modeling. I will keep these suggestions in mind as we plan research for FY89 and beyond and will share my thoughts on these subjects with other ORD Office Directors.

Attachment

JUN 2 1988

Status Report of the Ad Hoc "Woburn Workgroup" U.S. Environmental Protection Agency

1. Background

During April 1984, several activities converged that heightened EPA's interest in the possible association of contaminated water in the city of Woburn, Massachusetts with health effects in the area. Investigators from the Harvard School of Public Health released a draft report of its study of the area, newspaper articles appeared with increasing regularity, and EPA's Office of Drinking Water was in the process of establishing standards for volatile organic compounds (VOC's) in drinking water. All of these activities bore on the unfolding circumstances in Woburn, where it was alleged that water in wells G and H, which supplied a significant amount of drinking water to the townspeople of East Woburn from 1964 to 1979, was contaminated principally with trichloroethylene, but also with other VOC's.

The EPA established a workgroup to evaluate available data and to explore research implications and information needs concerning the potential association of contaminated well water with what were presumed to be a leukemia cluster and other adverse health effects in Woburn. The workgroup began with an information gathering activity, discussions with Dr. Steven Lagakos, principal investigator in the Woburn study, and a visit to the site of contamination. The workgroup identified areas of investigation that it wished to follow. However, its progress was halted for a year on advice of EPA General Counsel because of legal action brought by the citizens of Woburn against W.R. Grace and other parties, which had been engaged in

industrial activities in Woburn for many years. When the citizens' suit against W.R. Grace was settled, the EPA workgroup continued its deliberations.

Three objectives were identified by the workgroup as its mission:

(1) To develop a workgroup opinion on the association between contaminated drinking water in Woburn, and cancer and reproductive status in the community; and

(2) To examine the information on leukemia diagnosed in the area for any indications of an unusual distribution of subtypes, age, and prognosis; and

(3) To explore the possibility of suggesting that a search of broader national interest be conducted for the association of VOC's in drinking water with adverse health status existing in the U.S.

The following sections represent the analyses and recommendations of the workgroup on these three objectives.

2. Contamination of Drinking Water in Woburn and Health Status in the Community

A. Existence of an Increased Incidence of Leukemia in Woburn

The Massachusetts Department of Public Health identified a significant excess risk of childhood leukemia in East Woburn during the period from 1969-1979. Subsequently, Lagakos, et. al., (1986) published a series of reports that considered, among other things, a possible link between childhood leukemia and contaminated drinking water from wells G and H.

The Lagakos et al. study has been extensively reviewed (see, for example, comments to the Journal of the American Statistical Association, 1986 listed with references). Although there is little doubt that leukemia

incidence is elevated in Woburn, there is doubt about the association of an elevated risk of leukemia with the contaminated drinking water from Wells G and H based on the Lagakos et al. data. Lagakos et al., themselves, indicated that only 4-6 of the 20 cases identified in their study could be associated with the contaminated drinking water. Cluster analyses of the leukemia cases, done by Dr. Richard Clapp, Massachusetts Department of Health, found little evidence that a cancer "cluster" existed in Woburn. The lack of a positive association in such analyses does not, however, invalidate the fact that the leukemia incidence was significantly elevated. The Workgroup thought that more insight into the issue of the environmental cause that may be responsible for the increased leukemia could be gained by examining leukemia subtypes, ages, and survival of the leukemia victims. If rare subtypes or unusual distribution by age or survival could be found among the 20 cases, it could increase the strength of an association.

Greaves and Chan (1985) introduced methods for typing cell surface antigens of leukemia cells in the late 1970s. The analyses, when combined with cytogenetics, histochemical studies, and clinical information can increase the probability of correctly classifying childhood leukemia. However, the availability of these test results i.e., cytogenetics, histochemical and immunohistological and other clinical information for the cases in Woburn is incomplete, making it difficult to determine the possible existence of a unique distribution of acute lymphoblastic leukemia subgroups.

In addition, the information available to the EPA workgroup regarding the age distribution of the leukemia victims at diagnosis indicates that it is not different from that of common acute lymphoblastic

leukemia in all of the U.S., with the majority of patients younger than five years old. Furthermore, because only 20 cases were reported in Woburn, it is not possible to evaluate if a differential survival pattern among the 20 is evident. As a result, the workgroup was not able to identify an age, or survival difference with respect to the acute lymphoblastic leukemia cases in Woburn.

The Workgroup was told by the Massachusetts Tumor Registry that there may be three cases of "Philadelphia-chromosome" positive cases among the 20 in Woburn. This may be important for a more focussed assessment of the implications to Woburn because the Ph-chromosome is usually recognized as a marker for chronic myelocytic leukemia (CML) or, more recently, for the more uncommon types of acute lymphoblastic leukemias (ALL). Different chromosomal breakage and reassociation involving different oncogenes have been suggested for these two types of cancers (CML, ALL) even though cytogenetically they are called by the same name--"Philadelphia chromosome." The latter may involve different pathogenic mechanisms in comparison with all other acute lymphoblastic leukemias. An additional issue to be resolved is whether all three cases were located in East Woburn.

The Workgroup concluded that the excess leukemia incidence in Woburn may be real but that the reported association by Lagakos et al. of an association between contaminated drinking water and excess leukemia was tenuous. The Workgroup further concluded that available information on leukemia subtypes and the cluster analyses that had been conducted did not provide further insight beyond what was available from the Lagakos et al. study as to the etiology of the leukemia cases.

B. Examination of Reproductive Effects

Reproductive effects in the community were explored in the Lagakos et al., study. Several issues concerning the study's analysis of these effects impede the ability to determine the relationship between contaminated drinking water and reproductive effects in Woburn with reasonable certainty. Many issues were discussed in the commentary published with the Lagakos report (see reference list). Three additional issues of concern are described below.

The exposure profile presented in the Harvard study was inferred from individuals' residences. While a general exposure level could be assigned to homes in different sections of the community, data were absent on the proportion of an individual's daily water that was consumed in those homes, and on the amount of water consumed per day. Other sources, such as inhalation or dermal contact with VOCs during showering could also significantly increase an individual's exposure. Variations in either of these parameters could radically affect the relative exposure level of individuals in the community, even among those living in the same household.

The data requested in the questionnaire for the Lagakos et al., study on pregnancies and other health characteristics could have been reported by any adult in solicited households, rather than from the individual directly affected. While the probability of errors in reporting or biased recall were addressed by the investigators, more important problems associated with poor recall in proxy respondents were not. For example, research has shown husbands' recall of pregnancy-related data to be much less accurate and complete than their wives' recall. The Lagakos et al., analysis did not partition the data according to type of respondent,

making it impossible to examine the effects of differential recall by type of respondent. Furthermore, the design of the questionnaire did not encourage complete recall of events. Given these limitations, external verification with medical records would have given some indication of data quality. In addition, the questionnaire was administered by volunteers who may have had insufficient training, possibly reducing the consistency in data collection.

The study probably produced an underestimate of outcomes qualifying for study because it utilized unconventional definitions for these outcomes. For example, birth weights and congenital malformations were compared only in infants surviving to seven days after birth. Infants with severe malformations or very low birth weight are less likely to survive and thereby are less likely to be included in these analyses. All of the above circumstances preclude use of the study data to assign or deny reproductive risk to contaminated drinking water.

Several steps could be taken that would provide more definitive conclusions about an association of contaminated drinking water with possible reproductive effects in the community. Retrospective projects could include (1) the generation of more accurate water consumption/exposure data as an expression of exposure, relating these data to recorded data on reproductive outcomes (such as birth weight, registered fetal death, and infant mortality) from 1969 onward, or (2) repetition of the questionnaire survey with a more detailed questionnaire administered only to the women who may have been pregnant. Prospective studies could include (3) ongoing surveillance of adverse reproductive outcomes through record examination (e.g., birth certificates) plus collection of data on "well

children" in Woburn and surrounding communities, and (4) determining more empirically the reproductive toxicity of trichloroethylene and associated chemicals through animal and epidemiological investigations in other locations. Items (1) and (3) are currently being done under a cooperative agreement between the Centers for Disease Control (CDC) and the Massachusetts Department of Public Health, with the exception of data on individual water consumption.

C. Cancer Risk Assessment

During some of the Workgroup's more recent meetings, some of the members thought that it might be useful to place the contaminant concentrations detected in Wells G and H into perspective by utilizing typical EPA risk assessment methodology to characterize the carcinogenic risk of ingestion of chemicals either known or potentially present in Wells G and H. These cancer risks would then serve as an approximate indicator of the degree of contamination of Wells G and H and also identify which chemicals might present the greatest risk. Risk assessment is normally used to estimate the likelihood of future adverse health effects. In this case, however, risk assessment was used in an attempt to reconstruct what the risks might have been, assuming that the levels of contamination detected in the period 1979 to 1986 in Wells G and H in and monitoring wells surrounding G and H were representative of past contamination. It was hoped that by using quantitative risk assessment as an analytical tool in addition to previous efforts using epidemiology to estimate hazard qualitatively, the two methods might complement each other and provide additional insight. To

meet this objective two members of the Workgroup conducted a preliminary risk assessment focused on the risks of ingesting ground-water from Wells G and H.

It is important to note that the risk assessment is purposely narrowly focused only on the hypothetical risks to an adult ingesting contaminated ground water from Wells G and H during their period, which might be significant, of operation from 1964-1979. Risks from other exposure pathways such as inhalation of volatiles while showering or ingestion of contaminated soil were not evaluated. These pathways are, however, being evaluated in the Endangerment Assessment currently being prepared by EPA Region I (Boston). The Endangerment Assessment is much more comprehensive and will include the results of more extensive and recent sampling and analysis. The purpose of the Region I Endangerment Assessment is to define the risks to public health and the environment presented by current and future site conditions and may be used to support enforcement actions. It does not attempt to reconstruct what the risks might have been during the period in which Wells G and H were operating. Such risk assessment tools are normally used at Superfund sites to predict prospectively the likelihood of adverse health effects. In the workgroup analysis, however, these tools are used in an attempt to reconstruct what the risks might have been recognizing that the estimated cancer risks represent the upper-bound estimate of additional incidences of cancer due to the levels of exposures of the carcinogens that may have been present in Wells G and H. These estimates are not predictions of incidence nor do they represent the actual risk of developing leukemia or other specific types of cancer.

Exposure in the Workgroup's analysis was estimated for a "typical" adult resident of East Woburn who might have received an average of 30% of his drinking water from Wells G and H for the entire 15 years that Wells G and H were operating (1964-1979). The typical adult was assumed to weigh 70 kg, ingest 2 liters of water per day and live for 70 years. Contaminant concentrations in Wells G and H were assumed to be constant during the 15 years of the well's operation at levels corresponding to the arithmetic mean of the analytical results taken in 1979 by the Massachusetts DEQE and in 1986 by the U.S. Geological Survey. Exposure was expressed as a chronic daily intake in units of milligrams of contaminant per kilogram body weight per day (mg/kg-day). Because there is considerable uncertainty in estimates of contaminant concentrations in Wells G and H since they were only sampled twice and the quality assurance/quality control for the 1979 data is unknown, the degree of contamination in monitoring wells surrounding Wells G and H was also used to derive risk estimates. These monitoring wells, which were installed and sampled as part of the Superfund Remedial Investigation, are located at distances varying from about 600 to 2,000 feet from Wells G and H. It should be noted that distance alone is not a reliable indicator of the likelihood of contaminants migrating to Wells G and H. In general, the surrounding monitoring wells were significantly more contaminated than Wells G and H. For example, TCE and chloroform were measured in surrounding monitoring wells at concentrations up to about 1,000 times higher than that found in Wells G and H. It must be realized that since monitoring wells are not a source of drinking water, any estimates of exposure using those results represent only potential exposure levels which might possibly have been achieved if the concentration of contaminants measured at the

surrounding monitoring wells were 1) present in similar concentrations during the potential period of exposure and 2) were to migrate undiluted or unattenuated to Wells G and H. Data on the likelihood of these two conditions are not currently available to the Workgroup.

Risk was characterized by combining exposure levels with available cancer potency factors derived by EPA's Carcinogen Assessment Group to calculate an upper-bound estimate to excess cancer risk. As was previously mentioned, these estimates are upper-bounds on the risk and the "true" risk from ingesting contaminated well water is probably less and may be as low as zero. These estimates are not to be construed as an estimate of actual incidence of likely specific responses such as leukemia.

Risk estimates for both Wells G and H, and surrounding monitoring wells at five sampling locations are shown in Table 1. The total upper-bound carcinogenic risk based on analytical data from Wells G and H is $7x10^{-6}[B_2]$ (See Table 1 for explanation of this number and letter designation). In contrast, the cancer risk associated with exposure calculated from concentration of contaminants measured in monitoring wells surrounding Wells G and H shows risks as high as 10^{-3} for Group B_2 Probabl Human Carcinogens and 10^{-3} for Group A Human Carcinogens. Of additional significance is that some of the highest risks are due to contaminants which were not detected in Wells G and H (e.g., vinyl chloride and benzene). Both of these contaminants are proven human carcinogens and furthermore exposure to benzene is known to cause leukemia in adults. Again, it should be emphasized that risk estimates derived from monitoring well data are basedon potential exposure since the monitoring wells are not a source of drinking

TABLE 1 - ESTIMATES OF LIFETIME UPPER-BOUND CANCER RISK FOR INGESTING WATER FROM WELLS G AND H AND SURROUNDING MONITORING WELLS[1,2]

CONTAMINANT[3]	EPA WEIGHT OF EVIDENCE[4]	DRINKING WATER WELLS G&H[5]	SURROUNDING MONITORING WELLS[6,7] (APPROXIMATE DISTANCE FROM WELLS G AND H) W.R. GRACE (2000 FT.)	OLYMPIA (600 FT.)	WILDWOOD (600 FT.)	UNFIRST (1700 FT.)	WEYERHAUSER (1800 FT.)
Trichloroethylene	B2	3×10^{-6}	3×10^{-5}	4×10^{-7}	8×10^{-4}	8×10^{-8}	
Tetrachloroethylene	B2	3×10^{-6}	5×10^{-5}	3×10^{-7}	4×10^{-7}	1×10^{-4}	
Chloroform	B2	1×10^{-6}			3×10^{-4}		
Benzene	A			3×10^{-7}			9×10^{-5}
Vinyl chloride	A		1×10^{-3}		9×10^{-5}		
Totals[8]	A		1×10^{-3}[A]	3×10^{-7}[A]	9×10^{-5}[A]		9×10^{-5}[A]
	B2	7×10^{-6}[B2]	8×10^{-5}[B2]	7×10^{-7}[B2]	1×10^{-3}[B2]	1×10^{-4}[B2]	

NOTES:

1. Risks have been estimated under the following exposure assumptions and conditions:

   a. They assume that a typical adult might have received 30% of his drinking water from Wells G and H for a period of 15 years.

   b. A typical adult would have ingested 2 liters of water each day for 15 years.

   c. A typical adult weighs 70 kilograms and has a life expectancy of 70 years.

2. Cancer risk values are estimates of the lifetime upper-bound risk of excess incidences of cancer which might be attributed to ingestion of the specific chemicals list for a period of 15 years. They are not not a prediction of actual incidence of cancers in an exposed population, nor do they address specific carcinogenic responses such as leukemia.

NOTES (Con't):

3. The contaminants shown below represent only a partial listing of contaminants found in Wells G and H, and surrounding monitoring wells. They were selected as indicators because their cancer potency factors were available and concentrations tended to dominate risk estimates. It should be noted that other contaminants have been detected in the ground water and may contribute to the overal toxicity of the complex mixture of chemicals found in the wells.

4. EPA classifies chemicals for carcinogenicity as follows: Group A - Human Carcinogen; Group B - Probable Human Carcinogen, based on either limited human evidence of carcinogenicity [B1] or sufficient evidence in animals in the absence of either sufficient or limited human evidence [B2] as defined in the EPA Carcinogenic Risk Assessment Guidelines; Group C - Possible Human Carcinogen; Group D - Not classifiable as to human carcinogenicity; Group E Evidence of non-carcinogenicity for humans.

5. Risk were estimated assuming contaminants were present at the arithmetic mean of analytical results measured in 1979 by Massachusetts DEQE and in 1986 by U.S. Geological Survey.

6. Risks were estimated assuming ingestion of water from the monitoring wells using the arithmetic means of sampling results reported in the Superfund Remedial Investigation. As recommended by EPA Region I Quality Assurance Staff, "outlier values" were not included. The results of more recent ground water sampling were not available for inclusion in this analysis. They will be included in the Endangerment Assessment currently being prepared in Region I.

7. Since these risk estimates are derived from contamination concentrations measured in monitoring wells not used for domestic supply, they should be considered potential exposure conditions. Distance alone is not a reliable indicator of the likelihood of contaminants migrating to Wells G and H. There is no data available that indicates these higher levels of contaminants were present in Wells G and H.

8. Total risks are calculated assuming additivity per EPA risk assessment guidelines. Estimates of risk for known human carcinogens [A] are presented separately from those associated with probable human carcinogens [B2].

water and there is no direct evidence available to indicate that these more recently identified contaminants (e.g., benzene, vinyl chloride) or higher concentrations of previously detected contaminants (e.g., trichloroethylene, tetrachloroethylene, chloroform) were present during the period of exposure (1964-1979) in either surrounding ground water or in Wells G and H. They do, however, indicate there is a potential for the cancer risk to have been much higher than that estimated by the contamination data for Wells G and H alone.

3. RESEARCH DIRECTIONS:

The third objective of the Workgroup effort was to determine the guidance that the Woburn situation could offer for future environmental research. Two areas of possible research from a national perspective were identified:

(1) The evidence in Woburn was considered by the Workgroup inadequate to establish or refute a causal relationship between the contaminated drinking water and an excess risk of leukemia. Reports of other apparent clusters of leukemia in the United States with suspected environmental causes raise concern that such associations should be investigated in some systematic manner, however. In this regard the Workgroup thought it best to test hypotheses developed from Woburn in areas of the United States where the information is sufficient for such hypothesis testing but where clusters have not been reported. In this way one avoids the problem of having an effect in search of a cause where several causes might reasonably be associated (See the analysis by Swan and Robins in the Journal of the American of the American Statistical Association, Vol 81:395, 1986 for a further discussion on this point).

To test an hypothesis of an increased risk of leukemia being caused by the drinking water contaminants that were found in Wells G and H, one would likely want to conduct the study in an area where there was good information on drinking water contamination and where a good tumor registry existed. Such hypothesis testing would of necessity assume that it was one or more of the contaminants that were identified in Wells G and H that is associated with the increased leukemia risk.

Many factors would need to be considered in the feasibility of doing such a study. Drinking water contamination for any particular system may vary with time. Furthermore, information on the types of contaminants found in Woburn for most drinking water systems is limited. Also, information on contamination for a wellwater system may be limited to certain wells. As in Woburn, it may be difficult to relate contamination of wells that are part of a larger system to the leukemia cases that may be identified. One would also have to consider migration into and out of the area under study. One may also want to consider particular types and possibly subtypes of leukemia, ages at diagnosis, and survival of cases in evaluation of hypotheses. Such considerations would obviously depend on the quality and quantity of data provided by a tumor registry.

The study could be designed in several ways depending on the availability of the data. The Workgroup decided that investigation of areas of the United States where such a study could be conducted as well as design considerations were beyond the scope of the Workgroup's objectives. Discussion of such points would best be addressed by a feasibility analysis.

(2) Thorough review of the literature for embryo/fetotoxicity data on the contaminants that may have been present in Wells G and H. Based on the

results, evaluate the reasonableness of doing embryo/fetotoxicity animal studies on these chemicals. Consider the possibility of doing a comprehensive study of reproductive agents in another community where the water supply is contaminated with contaminants similar to those in Wells G and H.

In addition to these research areas of national interest, the Workgroup offers the following suggestions for site-specific research which might provide a better understanding of the relationship between adverse health effects and environmental contamination in Woburn.

(1) Conduct a carbon chloroform extract (CCE) test identical to the one conducted in 1978 by Dufresne-Henry consultants for the town of Woburn on a water sample from Wells G and H. The CCE tests could be performed on ground water samples from both Wells G and H (if possible), and surrounding monitoring wells. The results of the CCE tests could then be compared to the 1978 result of 2.79 mg/L and might yield valuable information on the uncertain relationship between current contamination levels and those during periods in which Wells G and H were operational.

(2) Because benzene is the only chemical detected in either Wells G and H or surrounding monitoring wells that has been definitely associated with leukemia, possible sources including underground gasoline storage tanks could be targeted for investigation. Such an investigation should identify possible sources in existence from 1964-1979, the likelihood and extent of any release of hazardous substances from such sources, and the likely transport and fate of any contaminant plumes.

(3) Since the two sets of analytical data (Wells G & H and the monitoring wells) suggest somewhat different conclusions about the

likelihood of adverse effects from ingestion of contaminated well water from Wells G and H, further research could be conducted to determine whether the higher concentrations of contaminants detected in the surrounding monitoring wells after closure of Wells G and H were likely to have been present during the period Wells G and H were operational and could have migrated to Wells G and H in similar concentrations. Ground water contaminant fate and transport models and tracer tests could be employed to predict plume migration and attenuation.

(4) A possible explanation for the relatively lower contaminant concentrations measured in Wells G and H versus those of the monitoring wells is that during operation, these wells may draw significant quantities of surface water from the Aberjona River thereby diluting the more highly contaminated surrounding ground water. Since the hydraulic relationship between Wells G and H and the Aberjona River probably varies depending on seasonal hydrologic conditions, monthly sampling of Wells G and H conducted over a full year's hydrologic cycle might be useful.

(5) Given the history of dumping of chemical wastes in Woburn and the obvious limitations of visually identifying contaminated media, further environmental sampling and analysis should be conducted beginning in likely play areas in the vicinity of the Pine Street neighborhood. During a site visit to the area by some of the members of the Workgroup in October 1987, a small swamp area containing several old drums were noticed just west of Pine Street adjacent to the Boston and Maine Railroad tracks.

Conclusions

The EPA Workgroup is of the opinion that (1) there is an increased incidence of childhood leukemia in Woburn and (2) it cannot be determined if

leukemia and drinking water in the community are causally associated.

Reproductive risk associated with contaminants in the drinking water of Woburn can be neither assigned nor denied based on available evidence. This is because of uncertainties associated with exposure estimation, procedural concerns about the questionnaire used to generate data, and the terms of definition for reproductive outcomes.

Although the cancer risks estimated using the contaminant concentrations measured in Wells G and H in 1979 and 1986 do not indicate an unusually high risk, given the limitations of the analysis and the very large range of uncertainty in both the identity and concentration of contaminants present during the period of exposure (1964-1979), these risk estimates should not be interpreted as adequate evidence to eliminate any likelihood of elevated incidences of cancer or other adverse health effects among consumers of drinking water from Wells G and H. In attempting to reconstruct and assess the level of contamination in Wells G and H, it is important to keep in mind the environmental setting of the wells. The surface water and land surrounding Wells G and H have reportedly been used as an uncontrolled waste disposal area. As indicated by the chemical analysis of monitoring wells, ground water surrounding Wells G and H is clearly extensively contaminated with potentially and proven cancer-causing chemicals.

For the contaminants detected in both Wells G and H and surrounding monitoring wells, the data collected from monitoring Wells show concentrations much higher (e.g., up to about 1,000 times for TCE and chloroform) than in Wells G and H. Since these concentrations are found in surrounding ground water they suggest a possibility that concentrations of

contaminants in Wells G and H could have been significantly higher than indicated by analytical results only from Wells G and H.

The results of the risk assessment also indicates that the Wells G and H contamination should be viewed more broadly than one of TCE in the drinking water. The risk assessment suggests that chemicals other than those detected in Wells G and H (e.g., benzene and vinyl chloride) might have played a significant role endangering public health.

Therefore, it is the opinion of the Workgroup that since the sets of data from drinking water wells and monitoring wells suggest somewhat different conclusions about the likelihood of adverse health effects, the key issue becomes: What is the likelihood that the concentrations of contaminants recently reported in monitoring wells surrounding Wells G and H could have been present in Wells G and H during the period of exposure from 1964-1979?

Areas of research of both national and local interest have been described above. All of the suggested areas of further research would of course have to compete for resources with other proposed environmental research projects identified in the Agency. Further discussion of the merit of additional research regarding some of the issues raised by Woburn would occur at that time.

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