

EQUITY IN ENVIRONMENTAL HEALTH: DATA COLLECTION AND INTERPRETATION ISSUES

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In order to assess the issue of inequity in exposure to environmental hazards, researchers must identify subgroups whose exposure is disproportionately greater than the average exposure experienced by the remainder of the population. The general population is a complex mixture of subgroups, each consisting of individuals who experience a wide range of exposures and whose ability to cope with the consequences of those exposures is equally varied. Therefore, large efforts are needed to collect data that will enable researchers to determine comprehensively which subgroups are highly exposed and which subgroups have disproportionately greater health effects as a result of exposures to environmental hazards. The interpretation of findings is more of an art than a science, especially when two population subgroups are being contrasted. Addressing environmental equity requires explicit comparisons between groups, and racial and ethnic contrasts will be prominent. It is often difficult to identify the underlying mechanisms that produce particular patterns of results. However, researchers and policy makers

1. This manuscript has not been subjected to review by the authors' agencies and institutions. The views expressed are solely those of the authors and do not necessarily represent the policies of their respective organizations.

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3. Key Words: environment, exposure, health, race.

4. Abbreviations: DHHS, Department of Health and Human Services; DOA, Department of Agriculture; EPA, Environmental Protection Agency; HIV, human immunodeficiency virus; PCRs, polymerase chain reactions; SES, socioeconomic status; VNTRs, variable number of tandem repeats.

must understand the dynamics that may have produced a particular pattern of results so they can separate those factors that are amenable to change from those that are not.

INTRODUCTION

The evaluation of environmental equity includes the assessment of both inequities in environmental exposure and differences in the hosts' capacity to cope with health effects of exposures. In fact, for both of these constructs, there is a full range of experiences among individuals in the population. That is, the population is not a simple mixture of subgroups, each consisting of individuals with the same experience. Therefore, the evaluation of inequities among subgroups, such as racial or ethnic subgroups, is complex. Hence, the data collection needs are immense to conduct a comprehensive examination of the magnitude and importance of environmentally-induced health inequities.

Some evidence is available (discussed by the various working groups of this conference), suggesting racial and ethnic health inequities resulting from specific exposure(s) to environmental and occupational insults. However, less is documented regarding the distribution of health outcomes as a result of exposures. Placing emphasis on the exposure distribution would conform more closely with the research paradigm which the Environmental Protection Agency (EPA) uses for risk assessment evaluations. This presumes environmental inequity is sufficiently demonstrated by inequitable exposures. Rarely included in this paradigm is a thorough evaluation of the host's capacity to deal with the health effects of exposure, either in terms of host biological susceptibility or the social context within which the individual seeks or receives care for health effects of exposure.

A systematic evaluation of environmental inequity requires:

- characterization of the population at risk—that is, demographic, socioeconomic, and occupational information with enough detail to distinguish a high risk subpopulation relative to the remainder of the population;
- characterization of the distribution of the toxicant—that is, geographic, socioeconomic, and physical features with enough detail to distinguish between potential exposures of the subpopulation and of the remainder of the population; and
- characterization of the host, including: susceptibility—that is, pre-existing conditions and physiologic assessments; health status—that is, the frequency of suspected health effects with sufficient detail to distinguish both clinical and preclinical effects in the subpopulation relative to the remainder of the population; and the social structure of the host population—that is, access to care, health practices, and psychosocial stress and resources.

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The interpretation of many and varied data brought together from each of these dimensions has the potential problem of being done in simplistic fashion, leading to both false positive and false negative conclusions.

The next section describes data collection problems for each dimension noted above. (This paper places emphasis on demographic and health descriptors; specific media, substances, and host biological susceptibilities are dealt with in other reports in this volume.) The second section discusses problems with interpretation of the complex array of variables and associations. The paper emphasizes the evaluation of racial and ethnic contrasts because, at the conference, these were the central issues of environmental health assessment and policies addressed.

PROBLEMS WITH DATA COLLECTION

The above list of data needs, although short, places an extraordinary burden on data collection activities if: the subpopulation that is to be identified is less than, say, 10% of the population; the exposures of interest involve multiple chemicals or multiple media; or the health effects being evaluated are infrequent in the general population or have long latent periods. In the following discussion, issues and problems are organized in terms of data collection issues and assessment issues. Features of data collection that are of particular importance to the user include generalizability and size. Features of assessment that are of particular importance to the user include validity and reliability, data quality, and continuity. Other features of importance, not discussed in detail below, are accessibility and timeliness.

Defining the High Risk Groups (Table 1)

Data Collection Methods. A variety of methods are available for collection of data relevant to human risk assessment, each having some limitation on the quality and quantity of collectible information. Experimental studies or in-depth studies of small populations identified either by exposures or health effects involve extensive evaluation of a few individuals. At the other extreme, probability surveys, which can be used as reference surveys, determine distributional characteristics of a large population, such as a nationally representative survey. These surveys necessarily involve collection of limited amounts of data on a large number of individuals or geographic sites, usually selected to be representative of a larger universe. Between these extremes are registries (focusing on a large group of individuals selected because they are representative of certain populations) and targeted epidemiologic studies (that employ case-control or cohort designs to focus on hypothesis testing). In the evaluation of environmental equity, all of the above methods are potentially relevant, depending on the objective.

The most complete study would be the comprehensive, enumeration of a population. The best examples of this data collection method are the birth and death records. Such a comprehensive collection is usually only feasible for one-time events that do not require follow-up. Complete enumeration, nevertheless, has limited utility to detect high risk groups. Even a completely

TABLE 1. Data Collection Problems: Defining High Risk Populations

Data Collection Methods (Features of importance: generalizability and size)
Choice of method <ul style="list-style-type: none"> • Experimental study • Applied, or response, epidemiology • Targeted case-control or cohort studies • Registries • Reference population surveys • Complete enumeration
Sampling design <ul style="list-style-type: none"> • Representative • Convenient
Detecting small populations or rare events
Assessment Issues: Defining Relevant subgroups (Features of importance: validity and reliability, data quality, continuity)
Culturally determined characteristics <ul style="list-style-type: none"> • Evolution of cultural identity • Heterogeneity within categories • Asking sensitive information • Choosing appropriate indicator
Populations in transition <ul style="list-style-type: none"> • Movement from place to place • Estimation of local population size • Intermarriage • Assimilation • Changing daily living activities

enumerated population is finite in size, and the high risk subpopulation may be small (or the event may be infrequent). The ability to detect a "meaningful" doubling in the event frequency (Wagener, 1990) or to detect a "meaningful" subgroup with an increased health effect (Rothman, 1990) is fraught with difficulties, not the least of which is the great number of false positive findings.

Short of complete enumeration, the selection of sampled populations is required. It is unfortunate that a great many studies involve samples of convenience, that is, the study of a group of individuals readily available to the investigator. Without knowing how the subjects became involved in the study, the generalizability of conclusions reached from the analyses of these data will always remain speculative. While useful for the generation of hypotheses or

evaluation of specific al., 1981)] do not yield Probability-based surveillance health information data

There is a vast array requires knowledge of weighted estimates can be used only to a limited extent. The relative standard error quadratically as the 10% of the entire subpopulation will population.¹ In this case, the error is more than double that in the general population means that making a survey of the risk subgroup, the standard error of the survey. Put another way,

Reference surveys information on specific subject) might provide a more accurate estimate of the true prevalence of the disease.

¹For instance, if the condition, based on frequency of the condition, is shown below.

Because RSE equals 1 divided by the square root of a population of 1,000, the RSE is 0.0316.

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that is, the RSE based on a population of 10,000 is 0.01.

evaluation of specific hypotheses, these studies [e.g., the Harvard study of six cities (Ware et al., 1981)] do not yield information on the distribution of exposures in the larger population. Probability-based sampling, e.g., representative sampling, contributes to the environmental health information data base in a non-biased way.

There is a vast array of probability sampling designs. The selection of a representative sample requires knowledge of the entire population, and then the identification of samples for which weighted estimates are representative of the larger population. But representative surveys can be used only to a limited extent to identify high risk groups that are rare in the population. The relative standard error of the estimates generated from surveys increases essentially quadratically as the subpopulation size decreases. If the high risk subpopulation is less than 10% of the entire population, estimates of exposure or of health effects among that subpopulation will have relative standard errors more than double that of the entire population.¹ In this situation, if the true condition frequency in the subpopulation were less than double that in the general population, significant conclusions might not be reached. This means that making definitive statements about small subgroups usually requires an *a priori* oversampling of that subgroup. Hence, without *a priori* identification of a potentially high-risk subgroup, the subgroup would be unlikely to be identified as high risk in the reference survey. Put another way, we see things in the light under the lamppost.

Reference surveys can be augmented in a number of ways to increase the amount of information on special, rare subgroups. Network sampling (or the sampling of friends of the subject) might provide an alternative method for improving the numbers of subjects included

¹For instance, if the relative standard error (RSE) of an estimate of the frequency of a chronic condition, based on a sample of 10,000 people, is 8%, then the relative standard error of the frequency of the chronic condition among a subpopulation of 1,000 people might be 25%, as shown below.

Because RSE equals the standard error (SE) divided by the estimate (Y), the ratio of the RSE based on a population of 1,000 (RSE_{1,000}) to the RSE based on a population of 10,000 (RSE_{10,000}) is

$$\begin{aligned} \frac{RSE_{1,000}}{RSE_{10,000}} &= \frac{SE_{1,000}}{Y} \times \frac{1}{\frac{SE_{10,000}}{Y}} \\ &= \frac{SE_{1,000}}{SE_{10,000}} \\ &= \frac{\sqrt{1,000}}{\sqrt{10,000}} \\ &= 3.16; \end{aligned}$$

that is, the RSE based on a population of 1,000 is 3.16 times greater than the RSE based on a population of 10,000.

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from an undercovered subpopulation. Nested designs can be used to obtain detailed information on special subgroups included in the larger reference survey. Followback studies can be performed subsequently to likewise obtain additional information. Follow-up studies allow for enrichment of the data set to be able to better characterize less common events or health outcomes.

Assessment Issues: Defining Subgroups. All data collection methods are predicated on being able to obtain valid information on relevant, defining characteristics of the subpopulation. Relevant subpopulation categories important in environmental equity considerations include race and ethnicity, as well as other sociodemographic subgroups. Some environmental equity issues involve the assessment of culturally-defined characteristics. Asking culturally-defining information is not a static research issue. Social perceptions and, hence, self-definition of cultural identity change. For instance, the question on race in the decennial Censuses have asked the respondent to classify themselves as "Negro" (in 1960), then "Negro or Black," then "Black or Negro," and, most recently, "Black" (in 1990). Now, the term "African-American" is beginning to replace what had been categorized as "Black."

In the past decade, there has been increased usage of questions about ethnicity, with categories largely restricted to Hispanic and non-Hispanic. This classification is primarily cultural, and to some extent political, rather than biological. Depending on the social context, individuals who have both Hispanic and non-Hispanic ancestors may categorize themselves as either Hispanic or non-Hispanic. The same is true of individuals with both Black and non-Black ancestors. Consequently, using a simple categorization to evaluate differential environmental impact on a disease with known biologic susceptibilities might generate a great deal of misclassification. There is a need to have a better understanding of the conceptual definitions for race and ethnicity. The extent of heterogeneity within categories will affect conclusions regarding the health-effects assessment.

Income and poverty are also culturally-sensitive variables. The wording of questions related to income has a big impact on whether and how the individual answers the question. For instance, although more than 80% of respondents answer income questions, a few respondents will only answer whether or not they received income above a certain level, say \$20,000, being reluctant to classify themselves into more specific categories. Some respondents include only earned income in their calculations, others include unearned income. Total household income is not a good indicator of the resources available to individuals. Per capita income is an alternative. Also, poverty indicators take into account the number of people dependent on that income, not just the amount. Poverty level is typically determined from the household size and income. This calculation, however, ignores the impact of persons outside of the household who are dependent on its economic resources, such as children living elsewhere to attend schools or adults living in health care institutions.

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² Such as using the preschool exposure

There are a variety of socioeconomic and demographic variables available to investigators. The selection of a social-class indicator for a particular evaluation should carefully consider the conceptual relevance, the role of social class for the outcome of interest, applicability of the classification to all members of the population, time relevance of the indicator to the exposure or outcome,² reliability and validity, multiple versus single indicators, simplicity, and comparability to other studies (Liberatos et al., 1988; see also other discussions in this volume). In some cases, existing social-class indicators are not appropriate. New indicators may be needed, such as ancestral background, language spoken at home, or mixed race/ethnic classifications. These characteristics are measures of assimilation and biological background of individuals.

Populations change in ways other than evolving cultural definition. For instance, populations grow (or decrease) in number and move. Only during the census years, once a decade, is there an enumeration of the population in every location. Therefore, to monitor the population during the intercensal periods, estimates of the demographics of the local population are needed. Models that produce these estimates use census data, data on births and deaths in the local population in previous years, census-derived information on in- and out-migration of households, and national adjustments. Due primarily to sampling variation, these regression models tend to produce unstable estimates of small minority populations. For any given year and age-sex-race group, the estimates when summed over all local populations tend to be closer to the national total for the White population than for the Black or other populations, because the latter populations are very small in many local areas and adjustment of these local minority population estimates has little effect on the total sum. Further, because the estimation must necessarily depend on prior data to estimate current and future populations, changes in the migration patterns are missed. If a local area experiences the influx of certain population segments because, for instance, a large manufacturing plant is located in that area, the estimation model would not incorporate this locally-specific information and thereby underestimate the influx of that segment of the population. Therefore, intercensal population estimates in a local area, potentially exposed to a certain pollutant, could be very much in error when certain subgroups of the population (e.g., pregnant women, children, or minority populations) are the basis for concern.

Subgroups of the population might also be in transition because exposure patterns are changing. One such subgroup is the elderly. As the cultural expectations of the elderly change, the activities of the elderly change. Hence, the possibilities for various exposures, including work- or hobby-related exposures, and the potential for health effects among the elderly, have changed remarkably in the past 20 years. This means that it might not be sufficient to collect information only on the age of the individual. It is also important to know whether the

² Such as using the inappropriate assumption that not completing high school was indicative of preschool exposure to lead paint.

individual is currently working and what productive activities, including hobbies, that person regularly pursues.

Characterizing Exposures (Table 2)

In the course of normal, day-to-day activities, most individuals come in contact with environmental pollutants. The potential for exposure exists in the air we breathe, the water we drink, the food we consume, and the soil and dust we contact. The exposure differs day-to-day and hour-to-hour. Further, the magnitude of the exposure varies between individuals, either because of different activities, different exposure frequency, or different proximity to pollutants. In sum, the exposure experiences of a population form a distribution. In any population, for a given chemical, most individuals may be exposed to some extent and some individuals will be exposed to a greater extent than others. Therefore, the objective of environmental equity studies is to identify the potential for high exposures for the purpose of subsequently preventing unacceptably high exposures to any person. All agencies involved in the improvement of environmental health share this objective. The additional purpose for focusing on environmental equity is to determine whether the individuals at the high end of the exposure spectrum largely can be defined by one or two characteristics. When such a situation occurs, several opportunities exist to address the situation. First, the exposure can be ameliorated. Second, the population can be targeted for health promotion activities. Third, the cause for the high exposure can be evaluated and prevented in the future. And fourth, the characteristics can be used to identify additional subpopulations at risk for high exposures.

TABLE 2. Data Collection Problems: Characterizing Exposures

Data Collection Methods (Features of importance: generalizability and size)
Choice of method <ul style="list-style-type: none"> • Area vs. individual • Multi-media • Multi-mixture • Multichemical • Complete characterization
Sampling design <ul style="list-style-type: none"> • Representative (of what?) • Convenient
Assessment Issues: What is Relevant for Environmental Health? (Features of importance: validity and reliability, data quality, continuity)
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Data Collection Methods. The problem, then, is to be able to adequately characterize the exposure distribution, and, by inference, the dosage distribution. Data systems that provide data which might be used to characterize human exposure include data systems of sources of the pollutant (e.g., production volumes, emission inventories, or compliance inventories), concentrations of the pollutant in the environment (e.g., monitoring systems, epidemiologic studies in response to public concerns, or microenvironment studies), and probabilities and characteristics of human exposure (e.g., registries, personal monitoring, or interviews).

In general, however, the first two classes of data systems have not been established for the purposes of characterizing human exposures of the general population. Inventories, collected primarily for regulatory purposes, characterize releases at one end of the pollutant source spectrum, either the violators or the (likely) heavy polluters. Individuals, however, may have greater total exposures to pollution from other (non-extreme) sources. Data from source of pollutant data systems, which do not include fate and transport information, may not be useful for the characterization of the exposure distribution of individuals.

Data systems that assess concentrations are generally established for the purpose of evaluating pollution in a given geographical area, not for the purpose of establishing the exposures to individuals in a population. This introduces uncertainty when trying to make conclusions regarding the exposures experienced by individuals in the population. Not only will the exposures vary between individuals living in the geographical area, but also the exposure is imperfectly correlated with the actual dose received by individuals. However, to some extent, the variation in pollutant concentrations between one area and another will correlate with the variation in the *mean* exposures between one population and another. That is to say, ecologic comparisons can be useful to determine geographically-defined populations with higher exposures. However, to identify subgroups within those populations, area monitoring is largely uninformative.

Data systems that compile information on pollutant concentrations in the environment are generally focused on single, or simple, forms of pollutants; complex mixtures are not assessed due to limitation of cost and proper procedures. Further, the different monitoring systems are not coordinated, so that it is difficult to evaluate simultaneous exposures from several media.

The site selection for these monitoring data systems is largely independent of the population exposed. Apart from the urban focus of many monitoring systems, the selection of monitoring station location is not characteristic of the population's activity patterns (e.g., placed near recreational facilities or near highways) nor representative of the population exposed (e.g., placed near schools or distributed to neighborhoods with different socio-demographic characteristics). Indeed, many monitors are placed in locations of convenience, rather than placed according to a specified, rigorous sampling scheme.

Elsewhere in this volume, the media-oriented workgroups discuss the problems specific to their purview.

Assessment Issues: What Measurements are Relevant for Environmental Health? The above discussion focused on problems with characterizing the pollutant distribution in areas. Extrapolation from the distribution of pollutant concentrations in areas to the distribution of doses in people is fraught with problems: the fraction of the external toxicant that gets into the body (through ingestion, respiration, etc.), the inability to adjust for individual characteristics and activities that affect exposure (frequency of hand-to-mouth movements, job characteristics, etc.), inability to adjust for ambient characteristics that affect delivery (adherence to particles, etc.), inability to characterize all media, and extrapolation to ambient microenvironment. However, assessing the distribution of doses received by individuals in a population (using, for instance, biomarkers) is not simple. Assessments require detailed exposure information (perhaps obtained through interviews) in addition to tissue samples obtained from the subjects. The subject selection must be representative of something to make meaningful conclusions regarding the findings. The subject selection need not be representative of the entire population; for instance, it may be representative of a subpopulation.

Characterizing human exposure patterns is a complex objective. The few systems that have attempted to characterize these patterns either focus on a few human activities, such as work or risk behaviors, or focus on a few individuals selected because of their residence, rather than the extent to which they represent a larger population. Extrapolation of the latter to larger populations is difficult, and extrapolation of the former to total exposures is not possible.

Missing from this list of exposure data are microenvironmental exposures resulting from personal activities, such as hobbies or gardening, and the range of exposures resulting from cultural patterns. The information on the distribution of doses received from exposures is even more limited. Experimental studies characterize the dose received from controlled exposures. However, information on actual doses experienced by population groups is available for very few chemicals.

A basic problem with using data from the systems available to characterize the distributions of exposures experienced by humans is heterogeneity. There is tremendous heterogeneity in sources for a particular chemical, in activities leading to potential exposures, and in the chemical mixtures to which people are exposed. Yet this very heterogeneity is itself the source of the environmental equity concern.

Characterizing Health Effects (Table 3)

The Scientific Advisory Board of the Environmental Protection Agency (EPA) encouraged EPA to "target the most promising opportunities for reducing the most serious risks to human health and the environment" (Reilly, 1992). Apart from experimental studies or "natural" experiments (including work-related exposures), what is the possibility of

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characterizing health effects and, hence, identifying the most promising opportunities for reducing the most serious risks to human health posed by the environment?

TABLE 3. Data Collection Problems: Characterizing Health Effects

Data Collection Methods (Features of importance: generalizability and size)
Assessing health status <ul style="list-style-type: none"> • Self-report • Administrative records • Examination
Selecting samples <ul style="list-style-type: none"> • Representative (of what?) • Convenience • Clustered
Obtaining detailed information <ul style="list-style-type: none"> • Nested designs • Follow-up • Follow-back
Characterizing small populations <ul style="list-style-type: none"> • Combining studies • Multivariate analyses
Assessment Issues: What are the Relevant Health Effects? (Features of importance: validity and reliability, data quality, continuity)
Disease vs. Symptoms Indicators, indexes, profiles, or batteries
Intervening variables <ul style="list-style-type: none"> • Personal health practices (smoking, diet, etc.) • Activities • Histories (occupational, residential, medical) • Host susceptibility • Psychosocial stressors, resources • Access to medical care

Data Collection Methods. Data on the health of the population come from several possible sources: interviews with the public, administrative records (including death certificates, insurance records such as Medicare, and hospital discharge records), and examinations of the public. Each source has strengths and limitations that influence our ability fully to characterize the health status distribution among the population and, hence, to identify subgroups of the population at risk for adverse health effects of exposure. Each source also has strengths and limitations regarding the validity and reliability of the data collected.

Self-report of disorders is a complex process involving the subject's understanding of the question, understanding of his or her own health status, utilization of medical facilities to determine the nature of the disease, knowledge of the name of any diagnosed disorders, and willingness to share those problems with the interviewer. Hence, a great deal of time is spent by survey managers in training interviewers to be culturally sensitive and knowledgeable about answers to commonly asked questions. Further, in some populations there is a language barrier when only English is used.

On the other hand, administrative records are either brief (as, for instance, the death certificate) or affected by the purpose of the record (as, for instance, the effect of insurance diagnostic-related group definitions on the diagnoses listed on the hospital discharges). Further, these records are always affected by the accuracy and completeness of information available to the person filing the report.

Examination surveys, which might seem superior to the other methods because physiological determinations can be made in addition to interview information, are severely handicapped by resources, in terms of both personnel and time. There is always give and take between the amount of time that can be spent with any particular subject and the number and breadth of examination assessments that can be conducted. Collecting a great deal of information on each subject requires interviewers, examiners, technicians, data processors, administrative assistants, etc. This data collection method, therefore, tends to be conducted either on targeted populations or on small samples of the population. Hence, the accurate estimation of frequencies of rare health outcomes or full characterization of population subgroups is difficult, unless the study is designed to oversample for specific groups. (See discussion above regarding small and rare subgroups.)

Apart from the vital registration system, all data on health status are derived from surveys. Hence, the identification and adequate characterization of a small group of individuals is problematic. It is unlikely that a substantial number of individuals with a specific exposure pattern will be included in any survey. Hence, the determination of the rate for particular health effects among these individuals is not possible for other than very common health endpoints. Instead, sophisticated statistical techniques are required to combine the information obtained on many individuals, each of whom experiences various aspects of the specific exposure pattern being considered. Under certain conditions, data may have to be combined across several data sources to obtain sufficient data to estimate effects with some reasonable precision. Further, multivariate techniques are often necessary to evaluate confounders. Finally, carefully designed studies that integrate collection methods (such as nested designs, followback, or follow-up) enhance the amount of information without losing the ability to generalize the findings to the larger population.

Assessment Issues: What are the Relevant Health Effects? Disease is a process, evolving from a healthy individual to tissue (or cellular) changes to preclinical changes in organ systems to

symptoms to diagnosis. The probability of identifying a disease progresses along this case for many chronic diseases. (That is, the probability of identifying a healthy, normal state in a population may be in the range of 10% to 20% of the number of expected cases. The more closely aligned the frequency estimates are to the actual frequency, the more changes or subclinical disease. This means that the classification of disease is particularly difficult. The classification of disease from the subject. For judgement that is of descriptors are difficult.

Symptoms often occur. An individual's health status or quality of life might be a measure of single or multiple concepts or more than one dimension and of health status.

The health effects of host susceptibility. coordinated Federal (1989)) is improving are other non-Federal methods of assessment.

The evaluation of subject to ethical considerations (develop data that reaction) or VNTR must be a concern unrelated to the presence of foreign Virus (HIV)). The

symptoms to diagnosable disease. Because the process is reversible to some extent, the probability of identifying individuals in any one state becomes increasingly smaller as one progresses along this continuum. If the disease state is irreversible and long lived (as is the case for many chronic diseases), the probability of identifying individuals with this disease is improved. (That is, the diseased individuals don't die immediately or rapidly revert to the healthy, normal state.) The estimated frequency of *diagnosable* disease in moderately sized populations may be imprecise because either the disease is rare or the exposure rare so that the number of expected cases would be small. This means that assessment of health endpoints more closely aligned to the normal end of the continuum is likely to yield more accurate frequency estimates. For instance, symptoms or biomarkers of tissue damage (pathological changes or subclinical symptoms) may occur more frequently in the population than diagnosed disease. This means, however, that the complex examination studies may be required. A particularly difficult problem for the assessment of symptoms is the evaluation of severity. The classification of headaches as "frequent," "often," "seldom," or "rare" requires a judgement from the subject. Further, "bad," "severe," and "debilitating" headaches requires another judgement that is often culturally affected. Culturally unbiased definitions of these severity descriptors are difficult to develop.

Symptoms often occur in combination, especially those leading to disease. Similarly, an individual's health status can be characterized by more than a single dimension. Health status or quality of life might be characterized by indicators, indexes, profiles, or batteries. *Indicators* are measures of single concepts. *Indexes* measure multiple concepts on a single scale. *Profiles* measure multiple concepts on multiple scores based on the same scale. *Batteries* measure multiple concepts on multiple scales. The impact of exposure on health can be determined in more than one dimension. Research is needed to evaluate various measurements of symptoms and of health status and their utility for evaluating environmental health issues.

The health effects in some individuals may be more severe than in others, due to differences in host susceptibility. Nutritional factors affecting host susceptibility are difficult to assess. A coordinated Federal Program [the National Nutrition Monitoring Program (DHHS & DOA, 1989)] is improving the assessment methods (largely interview information). Although there are other non-Federal research initiatives, more research is needed to develop information methods of assessing nutrition.

The evaluation of genetic factors, although they are more easily assessed than nutrition, is subject to ethical concerns. Whenever cells are cultured, or DNA stored, there is potential to develop data that uniquely identify the subject [through repeated PCR (polymerase chain reaction) or VNTR (variable number of tandem repeats) techniques]. Subject confidentiality must be a concern. Also, there is the potential to identify disease-susceptibility genes unrelated to the diseases being evaluated from the environmental health perspective or the presence of foreign DNA inserted into the genome [for instance, Human Immunodeficiency Virus (HIV)]. These determinations generate increased concern for the confidentiality of

subjects [who might be unfairly prejudiced in other social activities (Billings et al., 1992; Reilly, 1992)] and for medical counseling made available to the subject.

Other intervening variables need to be assessed. These include (but are not restricted to) personal health practices (such as smoking or diet), activities of the respondent, and exposure histories (such as occupational, residential, or medical). Psychosocial stressors, resources, and access to medical care should be evaluated. Information on these characteristics influences the evaluation of environmental impact on health.

Summary of Data Collection Issues

In addition to the data collection and assessment issues noted above, fundamental mechanics of toxicology further contribute difficulty to the objective of establishing a causality relationship linking exposure with an adverse health outcome. A single environmental pollutant may elicit multiple health outcomes. Conversely, a single adverse health outcome may result from multiple, chronic, low-level exposures. Furthermore, individuals are routinely exposed to a vast array of indoor, occupational, and environmental noxious substances, few of which are quantified, but many of which have the potential for ill-defined biochemical interactions. Further, low-level, chronic exposures often demonstrate latency such that adverse health consequences may not be realized for twenty or more years.

The data needed to evaluate environmental equity issues are multidimensional, usually coming from many different sources. Because there is a great deal of heterogeneity between individuals within groups, public health concerns reflect more than the simple differences in mean exposures between populations. Hence, sophisticated statistical procedures are required. But, to address environmental equity, an in-depth understanding of the social structure is needed to characterize the process leading to inequitable situations. The next section discusses problems with interpreting the multidimensional social characteristics of the populations for which the distribution of exposures and of health effects may be known.

PROBLEMS WITH INTERPRETATION

The interpretation of findings from research studies is more of an art than a science (Johnson and Woteki, 1990). This is especially true with regard to making sense out of observed differences between two population sub-groups. Addressing environmental equity requires explicit comparisons between groups. Prominent in this regard are racial and ethnic contrasts. It is often very difficult to identify the underlying mechanisms that produce particular patterns of results. However, an understanding of the dynamics that may have produced a particular pattern of results is essential for researchers and policy makers, in order to separate those factors that are amenable to change from those that are not.

When racial/ethnic differences are found, how do we decide if they should be interpreted as stemming from genetic/biological factors or environmental ones? Since biological evolution

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Race as a Concept

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Our understanding of the conceptualization. There are severe into racial and ethnic and ethnicity are not are not well understood over a one year period and estimates of the

influences and is influenced by the habitual behaviors of a group in response to environmental conditions (Jackson, 1992), researchers must additionally consider whether presumed biological differences are due to innate biological factors or to acquired biological ones. For example, the hemodynamic profile of hypertension in Blacks differs from that of Whites. Given that Blacks, in general, consume substantially less potassium than Whites, it is unclear whether these differences are due to innate biological differences or to variations in dietary patterns (Williams, 1992). This issue is not unique to understanding racial differences. Researchers can well ask whether differences between the elderly and younger populations are due to the universal and inevitable biological effects of aging, or to illness, cohort effects, stress, health behaviors, or other factors. Similarly, are gender differences due to inherent biological differences or merely to socialization differences within particular cultures?

Race as a Concept

An enhanced sensitivity to the interpretation of racial/ethnic differences in health requires the appropriate conceptualization of race. Much of the research on racial differences in health is based on assumptions that are without scientific merit. These are: 1) that race reflects underlying genetic homogeneity; 2) that the genes which determine race also determine health status; and 3) that the health of a population is largely dependent on the genetic constitution of that population (Kreiger and Bassett, 1986). Biologists and anthropologists indicate that the concept of races as human populations that differ genetically from others is without scientific basis (Lewontin, 1972; Gould, 1977, 1981; Polednak, 1989; Jackson, 1992). There is more genetic variation within races than between them and racial categories tend not to represent biological distinctiveness. Racial classification schemes are arbitrary and race is more of a social category than a biological one (Cooper and David, 1986). The fact that we know what race we belong to tells us more about our society than about our genetics (Kreiger and Bassett, 1986).

There are obvious biological aspects to race. Skin color is determined by genetics, but so is eye color. Why we focus on one more than the other is linked to the social and cultural meaning of race. It is likely, then, that racial differences in diseases related to environmental toxins, as well as in susceptibility to pollutants, are determined more by social factors than by genetic ones. At the same time, we can never completely rule out genetics without empirical verification.

Our understanding of racial differences is further complicated by the growing recognition that the conceptualization and measurement of the race variable is problematic in health research. There are severe reliability and validity problems in classifying the United States population into racial and ethnic groups. Hahn (1992), for example, indicates that the categories of race and ethnicity are not consistently defined and measured by federal data collection agencies, and are not well understood or consistently responded to by populations questioned. For example, over a one year period, as many as one-third of the population report a different ethnic identity, and estimates of the Black and the Hispanic population vary considerably depending on how

the question ascertaining race or ethnic status is worded. There is clearly a need for consistent definition of race/ethnicity across different data collection agencies and studies, or at least the collection of data using several different definitions within studies so results can be compared across studies.

Socioeconomic Status Indicators

In addition to utilizing a uniform classification system for race/ethnicity, researchers must also collect other social data to appropriately characterize race effects. Race is a gross indicator of distinctive historical and contemporary experiences. Socioeconomic status (SES) is an important correlate of race, and it is inadequate to present data by race without also controlling for SES. Socioeconomic status is typically operationalized using some indicator of income, education, occupational status, or some combination of the three. Researchers must recognize that these indicators are imperfect proxies for the concept of SES, and that they do not capture all of the relevant dimensions of variations in living conditions that may affect health status. Adjusting results for any or all of these SES indicators does not demonstrate that socioeconomic factors are not operative.

Race is strongly correlated with socioeconomic status, but race is an indicator of more than just socioeconomic status, and merely controlling for SES does not adequately account for the effects of race. A given SES indicator may mean different things and have different socioeconomic consequences for one racial/ethnic group compared to another. Low SES Blacks, for example, are more likely to experience some stressors such as unemployment and marital disruption than their White counterparts (Dohrenwend and Dohrenwend, 1970). A given level of occupational status may also have different health consequences across race. Employed Blacks, for example, are more likely than Whites to be exposed to occupational hazards and carcinogens, even after controlling for job experience and education (Robinson, 1984). Similarly, compared to Blacks, Whites receive higher income returns for a given level of education (Jaynes and Williams, 1989). A given level of income may also provide less purchasing power to Blacks than to Whites. Compared to Whites, Blacks have higher costs of both food (Alexis and Simon, 1980) and housing (Pol et al., 1982; Cooper, 1984). Consistent with these data, some research indicates that SES interacts with race to produce markedly higher levels of psychological distress for poor Blacks than for poor Whites (Kessler and Neighbors, 1986). Interactions between race and SES should be routinely assessed.

In addition, measures of current SES do not fully capture lifetime exposure to deprived conditions. Observed health risks may be associated with the long-term effects of previous socioeconomic conditions. Irrespective of current SES, adults may be affected by deprivations and deficits experienced during childhood (Williams, 1990). For example, lack of preventive medical care in childhood may set in motion irreversible processes that will not be eradicated even if full access to health care is available later in life. Low birth weight babies have higher risks of morbidity on a broad range of indicators of childhood health status (McCormick, 1985). Given the high prevalence of low birth weight infants within the Black population,

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Summary: The Life Course Approach

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this suggests that a substantial portion of African Americans may experience long term health consequences linked to problems of infancy and childhood.

Differential Susceptibility

The importance of assessing differential susceptibility to environmental risks has already been noted. Some populations or groups may be more vulnerable to certain risk factors than others. Cigarette smoking, for example, more adversely impacts Blacks than Whites (Cooper, 1984). It is likely that Black smokers are more exposed to toxic working and residential environments than their White peers. The failure to characterize these environmental exposures, in studies of smoking and health, may overestimate the effects of smoking (Sterling, 1978). This highlights the importance of collecting information on all relevant factors linked to the conditions of life of a particular group that may be predictive of higher rates of disease. Few studies provide such comprehensive assessment. Researchers, nonetheless, should be cognizant of the operation of these multiple factors and temper the interpretation of their data accordingly.

Heterogeneity and Bias

It is customary to report differences on risk factors and health outcomes by race. However, the use of a race comparison paradigm should not obscure the reality of considerable heterogeneity within any racial/ethnic subgroup. Assessment of this variability is necessary and important to identify groups that may be particularly at risk, as well as promotive factors that may be associated with better levels of health and functioning.

In interpreting data, researchers should also consider potential biases that may be introduced through the problem of noncoverage in the sampling of certain subpopulations. If the response rate in a study is considerably lower for one group than another, this could bias the findings in important ways. The noncoverage of Black males in most large surveys, for example, is a serious problem (Williams et al., 1992). African-American males tend to have low response rates in survey research studies. In addition, they are overrepresented in marginal and institutional populations that are likely to be characterized by poor levels of health. And the use of post-stratification weights to make the sample correspond to that of the U.S. census' estimates of the population does not solve these problems. Weighting would adequately address these problems only if we assume that nonrespondents are similar to respondents and that the census has an accurate count of Black males.

Summary: The Larger Context

Race is a composite measure of a broad range of variables that may affect health status. An enhanced understanding of differences in health between population groups requires the identification of the specific potential risk factors linked to group membership, and systematic evaluation of their role as determinants of health. Figure 1 provides a paradigm for research on understanding racial differences in health status. (See King and Williams, in press, for a larger discussion of the application of this framework for the study of racial differences in health status.) It indicates that the term "race" encompasses biological, cultural, socioeconomic, and

Insert Fig. 1

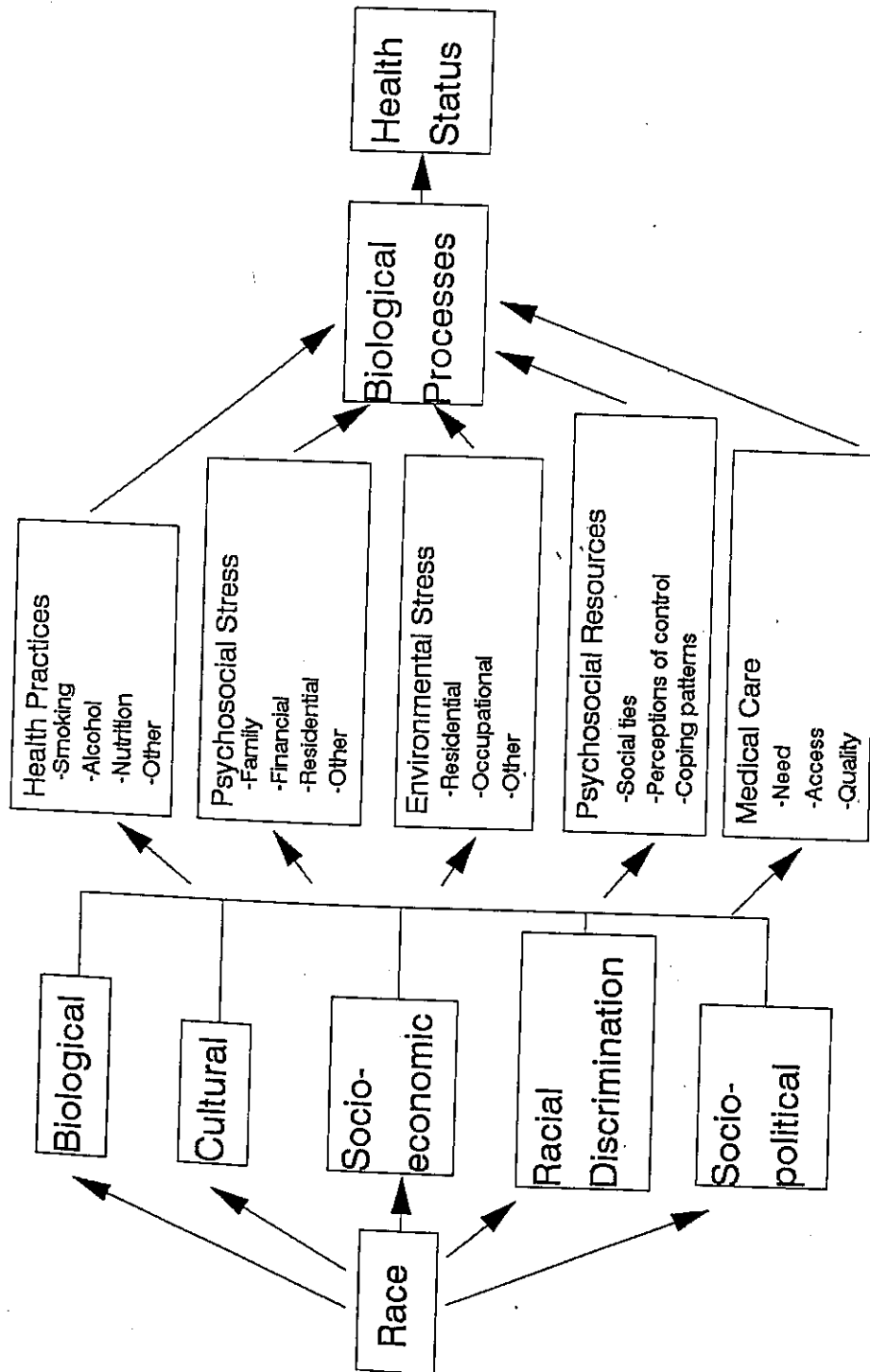


FIGURE 1. A framework for understanding the relationship between race and health.

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sociopolitical factors, as well as racial discrimination. These components of race are interrelated, and may combine additively and interactively with each other. They affect health through intermediary mechanisms and processes. These intervening variables include health practices, psychosocial stress, environmental stress, psychosocial resources, and medical care. Each aspect of race (biology, culture, SES, political power, and racial discrimination) may affect an intermediary factor. The intervening factors in turn relate to each other in ways that produce both additive and interactive effects.

Several aspects of this model are noteworthy. First, although we argue that the biological contribution is likely to be small, biological factors should not be excluded without empirical verification. Researchers should particularly explore interactions between biological factors and environmental ones. Second, while SES is an important component to race, race is much more than just SES. Third, racial discrimination is a critical aspect of race and its possible effects on health deserve sustained research attention.

Finally, this model emphasizes that environmental risks and their health sequelae should not be separated from the larger social context within which people live and work. Frequently, researchers treat health risks and health status as if they were autonomous individual factors that are unrelated to working and living conditions and independent of the broader social and political order. In contrast, the health of population groups appears to be embedded within the larger context of people's lives, and inextricably tied to economic well-being (Williams, 1990). Populations that experience environmental inequities may also be characterized by high levels of poverty, hopelessness, lack of opportunity, and unemployment. It is unlikely that the health problems of these groups can be solved unless these larger issues are also addressed. Some evidence also indicates that the effectiveness of educational initiatives to improve the risk profile of particular populations are also linked to socioeconomic conditions of those populations (Williams, 1990, 1992). Broad-based comprehensive health education initiatives do work, but they work well for individuals in favorable social circumstances. Thus, improvements in living conditions and life opportunities may be prerequisites for getting deprived populations to attend to health education and make behavioral changes (McKinlay, 1975).

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FIGURE 1. A framework for understanding the relationship between race and health.

-Need
-Access
-Quality

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