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# Assessment of Toxic Agents at the Workplace

## Roles of Ambient and Biological Monitoring

*edited by*

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# MULTIDISCIPLINARY APPROACH TO PREVENTION AND HEALTH PROTECTION BY MONITORING: ROLE OF INDIVIDUAL DISCIPLINES. THE ECONOMIST: ECONOMIC ANAYLSIS OF PREVENTION AND PROTECTION I.

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*Summary*

*It is recognised that the elimination of all risk is impossible; the goal has to be optimum safety. This can be defined by classical economics from the standpoint of determination of risk being left to the market place. Several objections to this concept are discussed. The role of biological monitoring is examined as a bargaining, decision-making and litigation tool for employees, employers and unions; monitoring of benzene is used as an example.*

## Optimizing worker health

> "..... no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life (1)."

This is an ideal to inspire the public and win elections, but it is a pernicious guide to action. The point of debunking this rhetoric is not to chastise politicians or force us to change our moral principles; we all suffer loss whenever a worker is hurt or made ill. Rather, this is a plea for a more helpful guide to action. With a proper statement of the social goal, much of the current confusion concerning occupational safety in the United States would disappear and a clearer plan for action would emerge.

The Supreme Court recently stated the obvious: The elimination of all risk, even of all risk in the workplace, is impossible; zero risk is not a relevant goal (2). All human activity involves risk. The individual, and society, can reject some risks, but must be prepared to accept others.

The goal is not absolute safety, but rather "optimum safety". Two principles can be used to elaborate this concept. The first principle is that, from society's standpoint, an activity should be undertaken only if its output good or service outweighs the health and other risks. For example, some old coal mines around Pittsburgh recently were being reworked by taking the coal used in pillars to support the roof; clearly, the risk exceeds the social value of this output, at least under normal circumstances. The second principle is that resources ought to be directed to lowering risk until they are no longer productive, i.e., until diminishing productivity of safety resources has fallen to the level where the social value of a reduction in occupational disease is just equal to the cost of achieving it.

The above paragraph used a number of loaded phrases, such as the "social value of reduction in occupational disease" and the "social value of output". Defining these concepts requires valuing risk (which risks are acceptable?) and equity (do those who must bear a risk benefit from it?). Individuals disagree about these values and society must decide on the mechanisms for resolving these conflicts. Resolving value conflicts is one of the most important political tasks.

One major proposal for defining optimum risk comes from classical economics (3,4). Assuming that people can be informed and are capable of making decisions for themselves, economics emphasises presenting each worker with information on the implications of various decisions, but then leaving the determination of risk to the market place. Employers and workers, through millions of small decisions, would determine the risk-wage trade-offs to be offered and individual workers would select their preferred trade-offs. This framework emphasises efficiency of resource allocation and, under a set of standard assumptions, can be shown to lead to a solution which maximizes efficiency while giving workers their preferred choice (within their available choice set).

The economic solution is regarded sceptically for a number of reasons. The first is that legislation would be required prohibiting risks above some level, just as in some countries suicide is illegal.

A second objection is that workers are not capable of making decisions involving risk (5). Such an objection is in direct conflict with the vast freedom of choice given individuals to behave in ways that society considers dubious. Society is curiously inconsistent: We allow alcohol, but not drugs. In the USA we allow individuals to subject themselves to risk by riding motorcycles without helmets and by smoking cigarettes, but we prohibit employers from offering jobs that have a similar level of risk. Economists search for consistency and object that, since we cannot and do not want to stop individuals from taking high risks in some activities, we ought to allow them to determine their own risk level in all activities. This plea to rationality and consistency is often lost on practitioners.

The third objection is that individuals with different backgrounds and levels of talent face different choices. Risky, dirty jobs generally fall to the poorest persons, whose alternatives are most limited. We who earn comfortable incomes in non-risky jobs can neither assume that the poor who take risky jobs are happy to do so, nor that their acceptance of the jobs is socially equitable. We must also be careful not to assume our preferences for risk apply to others, which is clearly contradicted by the recreational activities of many of these workers.

In some cases there are no opportunities for low risk employment within a community, for example in a coal mining community, and the worker must leave if he rejects the risk. However, for most cases in the developed countries, there are many opportunities for non-hazardous employment within the community. As a rule, jobs with higher risks have higher pay and are taken by those who are less afraid and more influenced by income. This would be true, even if income levels were ten times as high as today, although it is doubtful that jobs as risky as those with the highest risks today would still be accepted.

Even if one rejects this never-never-land of economic theory, it is important to understand that people desire social goals to be achieved efficiently and at low cost; they desire safety and high consumption. Thus, analysis is needed to clarify the implications of alternative approaches and to find ways to accomplish our goals more efficiently. This requires quantification and estimation of social benefits and costs of each proposal. Analysis can be used to set priorities, standards, and to allocate resources for enforcement, but there are many areas requiring further thinking, including the treatment of uncertainty.

## The role of biological monitoring

The current system of regulating and managing occupational risk is unsatisfactory in dealing with a number of problems. Can an acceptable protective device be made? How good should maintenance be? Should production be shut down when the protective equipment breaks down? What should be done about "hot spots" and periodic excursions? Whatever the rules of the Occupational Safety and Health Administration (OSHA), or even of the parent company, answers to most of these questions are currently worked out at a plant or subplant level with little or no knowledge about the health implications. Biological monitoring would provide decisions, presumably with sufficient speed that health effects could be avoided. The reason for using a toxic substance in the workplace is that it lowers costs in producing a particular good or enhances satisfaction from producing a more desirable good. However, using it increases the risk or actual incidence of disease. In order to retain the advantages of the former while lowering the costs of the latter, we attempt to lower worker exposure. The current methods are either to formulate a standard which is believed to be protective or to select the most stringent standard which doesn't threaten the existence of the industry.

Uncertainty arises both in environmental monitoring and in the selection of a level believed to be harmless. Current safety standards are usually stated in terms of concentrations in air (or water, etc.); uncertainties in monitoring concentrations lead to the building in of a substantial safety factor to account for variations over time and location. Biological monitoring could eliminate this safety factor by measuring exposure directly, thus lowering uncertainty about variations in time and space.

A second large safety factor is encountered in setting an exposure level deemed to be safe. Little evidence is available that would provide confident estimates of what constitutes a safe level of exposure, or even of the level of damage that might be expected at each level. This safety factor could be eliminated by biological monitoring in cases where there is a precursor of serious disease that is a strong indication of future trouble, but is itself reversible or at least not a significant health problem. As long as a worker manifests no sign of ill-health or of the precursors to disease, exposure would be considered satisfactory. If no precursor exists and the first noticeable condition is serious and non-reversible, biological monitoring might still be used to stop the disease from progressing, but this stage is too late to be able to ignore other indicators, such as biological indications of dose.

These two types of biological monitoring, obtaining better indications of exposure and discovering precursors of disease, could do much to lower the cost of controlling the toxic substance and to lower the incidence of occupational disease. Biological monitoring might be more or less expensive than current ambient monitoring, although comprehensive monitoring of each employee at risk would presumably be more expensive.

The major point about both types of biological monitoring is that they are more direct measurements of the point of concern: the actual exposure of each worker and the precursors of disease. Not only is it more intellectually satisfying to measure the issues of interest, but there is the possibility of lower costs and better health. If we had confidence in biological monitoring, we could rescind emissions or ambient standards, except possibly for standards designed to prevent acute effects. Ambient standards would be redundant and less satisfactory than the standards for biological monitoring. More importantly, setting the biological standards would provide the maximum incentives for industry to find ways of lowering occupational disease at least cost. If satisfactory personal protection devices could be developed, they would prove their merit through the biological monitoring. If workers refused to wear the device, or the device wasn't reliable, it would become evident in the monitoring. Industry would be free to find the cheapest way of lowering the incidence of disease be that by substituting a compound or lowering emissions.

Currently, there is a debate as to whether a company can meet exposure standards by removing workers after they have reached the permitted level of exposure. Biological monitoring provides a more satisfactory way of dealing with this question. Work rules are suspected of giving insufficient protection; however, biological monitoring would give a better indication of whether they were protective of worker health.

An important advantage of biological monitoring is the direct information it would give about dose and biological changes indicative of disease. Armed with this information, the individual worker and his union could make more intelligent decisions. If workers desired lower exposure, they could negotiate this at collective bargaining. If individuals found the resulting biological changes intolerable, they could insist on changing jobs, even at the cost of quitting their jobs. This biological information would be invaluable in civil suits, both to establish an employee's claim and to protect the employer from false claims.

There is a fundamental difficulty in determining how much of the dose and change in physiology is due to the occupational exposure. For example, a worker being tested for benzene exposure might have received a substantial dose while filling his automobile on the way to work. Biological monitoring for chronic respiratory disease could not discern what part of the effect was due to smoking habits and other non-occupational causes. Statistical analysis could attempt to discern the contribution of other factors (by contrasting workers who smoked with those who did not for example, but uncertainty would remain. If the employer were deemed to be responsible for all adverse effects, employers would insist on excluding workers who smoked or were at higher risk for whatever reason (5). Present standards are enforced via fines, civil suit, or eventually forcing plant closure (3,5,7). Current fines are small and are not an effective deterrent (3,5); higher fines have been proposed, some of which have been upheld by the courts, and could prove effective (1). Litigation is cumbersome, expensive, and filled with difficulties and uncertainty. Plant closure is such an extreme measure that it is not an effective deterrent. To these enforcement devices for biological monitoring might be added the forced removal of a worker to less risky sites. Such forced changes in work rules might serve as the most effective deterrent, since a plant could run out of workers to perform crucial jobs.

Alternative enforcement procedure would levy a series of fines depending on the dose that each worker had received. For example, in monitoring for benzene by testing phenol in urine, the level of fines could be related to phenol concentration as shown in Figure 1, where the fine gets prohibitive at higher concentrations.

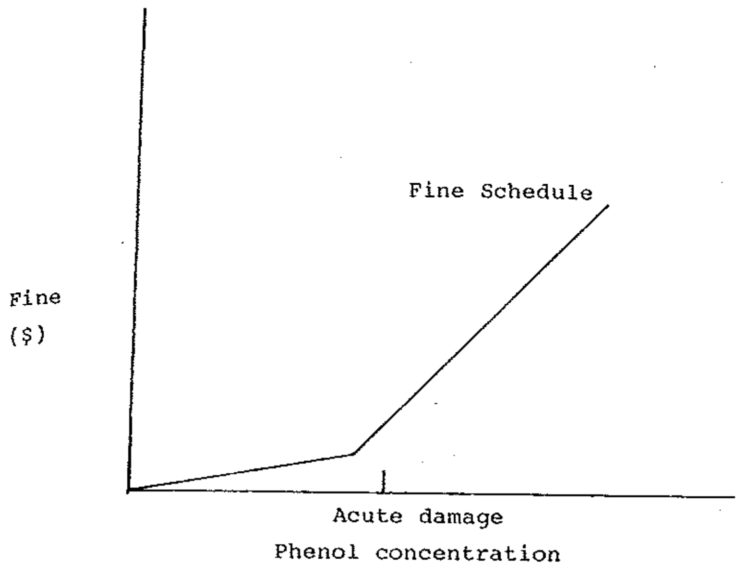


Figure 1. Sample fines for phenol in urine

## Benzene case study

Benzene is a clear, aromatic liquid used widely in industry and commercial products (2,8). Chronic exposure to several hundred parts per million of benzene in air has been fouond to cause haematological disorders, including pancytopenia and mylogenous leukaemia; there is some indication of effects at exposures down to perhaps 10 ppm. Occupational exposure is regulated, and there are proposed regulations for the general population in the United States (9,10).

Ambient air concentration, currently used to measure exposure, is not a good indication of the dose received by individual workers; concentrations vary markedly depending on the precise location of the air being sampled. A personal dosimeter might capture the relevant concentration during a short time period, but can account for neither variations over time nor the volume of air breathed (which varies with exertion level). A continuous monitoring device corrects for the first problem but not the second. More important is the tenuous link between ambient concentration and haematological disorders, since susceptibility differs among individuals.

Two methods of biological monitoring, measurement of benzene in exhaled air and of phenol in urine, provide better indications of individual dose (11,12,13). Monitoring exhaled air is easy and cheap, with few risks of laboratory or subject error. However, the physiological mechanisms which eliminate benzene through exhalation make the time of sampling crucial. Immediately after exposure, exhaled benzene comes largely from resevoirs in the air sacs in the lung and then from benzene in the blood. After perhaps ten hours, benzene stored in fatty tissue (which is more likely to indicate harmful exposure) becomes the predominant source of that being exhaled.

Benzene is metabolised by the liver, with phenol as the major oxidative product (13). This phenol is conjugated as phenylsulphate and excreted in the urine within 24 hours. Phenol concentration in urine is linearly related to benzene exposure. A fairly easy, reproducible method of measuring phenol exists, but its accuracy has been challenged (12,14, 15). Unfortunately, varying amounts of phenol are present in the urine due to other sources such as foods and drugs (13, 16).

While neither monitoring exhaled air nor urine involves invasive procedures, both require worker compliance and are likely to be resented as invasions of privacy. These methods are improvements over ambient air sampling in estimating total dose, although neither focuses on the adverse effects of benzene. Since health is the concern, it should be measured directly by counting blood cells and searching for irregularities. Several methods focused on blood disorders have been proposed. However, a major drawback is the necessity for taking frequent blood samples. Unfortunately, by the time blood disorders are observed, substantial harm has already been inflicted. A complication is that benzene's effects cannot be distinguished from those due to other causes.

Biological monitoring of the harm caused by benzene is not practical at present. Monitoring urine or exhaled air can be an improvement over ambient air monitoring for estimating total dose. The measurement of phenol in urine appears to be the best method for biological monitoring at present.

Information and costs are the primary considerations in deciding among monitoring techniques. Where one technique gives the same information at lower cost or more information at the same cost, decision is easy. Where techniques differ both with respect to information and cost, an examination of the value of the information is necessary. A useful comparison between the costs of ambient and biological monitoring can only be made if the methods yield comparable information, i.e., both yield information on exposure. When the biological monitoring technique measures health effects, as blood monitoring does for benzene exposure, a comparison of its cost with that of ambient monitoring means little.

In estimating the total cost of a monitoring programme, there are a number of costs which must be considered. For ambient monitoring, the estimate must include the capital cost of the equipment, technician labour, equipment maintenance, and materials costs. The cost estimate for biological monitoring must include the costs of technician labour and record-keeping as well as laboratory costs.

Since ambient monitoring and urinary phenol analysis yield the same type of information, i.e., the exposure level, their costs can be compared. The firm's cost of owning and operating a continuous benzene sampler is in the range of $20,000 - $30,000 per year (17). Assuming 35 employees per plant are routinely exposed to benzene (18), the cost per year of urine analysis is approximately $40,000 for one sample per week and $200,000 for five samples per week (18). These costs may be high as they use a laboratory fee which is not based on techniques mass analysis. However, continuous ambient monitoring would probably remain the least costly method for measuring exposure to benzene.

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The cost estimates for blood monitoring, the only technique to measure the health of benzene, are based on a sampling frequency of one per week. This may be too frequent depending on how much blood is taken and from where. Also people vary in their ability to have blood taken on a frequent basis; for some it may not be possible to take blood nearly that frequently. Based on 35 employees routinely exposed and blood sampling once a week, the cost of blood monitoring is approximately $30,000 per year.

For benzene, ambient monitoring provides comparable data at lower cost than testing phenol in urine. Monitoring blood provides additional data that might spot disease at a stage where it could be reversed, or at least arrested. The greater cost of monitoring blood is justified only if the information on irregularities would have a large effect in lowering disease incidence, given high quality ambient monitoring.

The best route to take in monitoring occupational exposure to benzene may well be the use of continuous ambient monitoring in conjunction with a less frequent routine blood monitoring.

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