The Injury Problem

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Synopsis - Abstract

Many kinds of environmental hazards injure man. Included are various microorganisms, toxins, including heavy metals, and the several forms of energy, ionizing radiation, electrical, thermal, and mechanical. All these hazards are of practical interest because of the damage they produce. Yet society's approach to reducing such damage has varied greatly. The microbial hazards, for example, are approached in terms of the interactions involved, and maximization of loss reduction. By contrast, mechanical energy damage losses are approached largely with moralization and other once commonplace aspects of medicine's pre-scientific past. Scientifically based alternatives are available. These are discussed, especially from the standpoint of human interactions with the energy hazards in the environment.

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The biosphere of which we all are a part is laced with many hazards. When man tangles with these, specific injuries can, and frequently do, result. These environmental hazards to which man and other living things are susceptible are of three principal types:

1. The living and near-living organisms that produce the various infectious diseases such as plague, cholera, and poliomyelitis,

2. The various simple and complex toxins, including lead, nitrogen mustard, and aspirin, and

3. The several forms of energy, including ionizing radiation, and electrical, thermal, and mechanical energy.

There is general consistency in the evolution of the ways in which human societies regard the injuries due to human interaction with the various environmental hazards. First is a prescientific stage, in which notions of etiology bear insufficient

relationship to the relevant causal sequences actually involved to have much effect on either frequency or severity. This prescientific stage is typified by plague and malaria prior to discovery of their infectious agents, as well as by the 18th century "Devonshire Colic" before the role of lead repairs to cider making and storage was pinpointed.[1]

Because in the absence of sufficient etiologic understanding countermeasures have little or no effect, the prescientific stage of knowledge of the sources of injuries produced by any kind of environmental hazard is typified by many disparate and competing folk remedies, panaceas, and notions of causation. Moreover, extra-rational explanations abound in this stage, especially in the form of views that regard the injuries suffered as retribution for improper societal or individual behavior. Responses to plague in medieval Europe, and to various earthquakes and volcanic eruptions are among the many illustrations of this prescientific stage. Since this stage is fundamentally characterized by failure to see pattern in the undesired events, people in the first stage tend also to hold the view that the particular type of damage "just happens." The still prevalent prescientific term and

concept "accident" provide excellent illustration of this stage, as do the prescientific meanings of such terms as malaria and plague.

In at least the advanced countries, there is next a second stage, one of transition. In this, the notions of the first stage, commonly even among relevant professionals, provide the basis of resistance to the dawning of more scientific ideas of etiology and, derivatively, of efficacious countermeasures. The period of nasty debate associated with the introduction of the idea that a previously undocumented kind of environmental hazard – certain plasmodia – caused the bodily damage known as malaria (and by that very name theretofore literally explained) well illustrates this typically turbulent second stage. The many other examples include the period of some thirty years between Snow's brilliant documentation in 1855 that cholera was bourne by contaminated water, and the final absence of professional opposition.[2]

This turbulent, transitional stage leads directly to the third stage in understanding of injury caused by damaging human interaction with environmental hazards. This final stage is

typified by clear, well documented knowledge of etiology, an associated structuring of theory, and the resultant placing of countermeasures on a sound and, hence, efficacious basis. Success has defeated the prescientific approaches, and extra-rational explanations have fallen from favor, although their persistence at the level of folk culture is often prolonged. This third stage is especially well illustrated by contemporary approaches in advanced societies to a host of infectious environmental hazards that once caused panic even in the same areas.

It is, however, no happenstance that I have mostly illustrated the last two stages with infectious disease examples. Understanding of general principals and of detail concerning injuries due to living environmental hazards as a group has generally outrun analogous scientific knowledge concerning the damage produced both by the many known and potential toxins and by the several forms of energy, although the kinds of damage due to ionizing radiation tend to be an exception, perhaps partly because they had little cultural history and therefore little carry-over of prescientific notions.

There has been scant scientific scrutiny of the reasons for the discrepancy throughout the last one hundred years between the rapid advance of knowledge and theory concerning living environmental hazards, on the one hand, and those of the toxin and energy groups on the other. From antiquity until about the beginning of the 19th century, there appears to have been no great difference: Understanding of all three groups of hazards was primitive, but by no means nonexistent. If anything, it could be argued that knowledge of principles and specifics with respect to both toxins and the then-major energy-hazards was more advanced than with respect to infectious agents. A variety of poisons were used in personal and political crimes. Moreover, throughout all known history, forms of energy – especially mechanical, but frequently also thermal – have been used, through the medium of a wide variety of often quite sophisticated weapons, as the means of carrying out virtually all individual and collective violence. Yet, as with toxins, general principles and needed specific information, such as measures of body resistance to given rates and amounts of energy transfers, largely failed to be either sought or found.

The general lag of scientific approaches to reducing damage associated with toxic and energy hazards is beginning to be corrected because their prominence in the modern environment can no longer be ignored even in competition with the long dominant, other concerns of the medical and, especially of the public health professions. In this context, it is noteworthy that much of the pressure for far more attention to such hazards in the environment is coming from the general public, as has been illustrated by such recently controversial subjects as D. D. T. throughout the world ecosystem, mercury in marine food chains, lead-caused brain damage to slum children from paint-eating, pulmonary damage from combustion products in tobacco smoke and the general air, and the mechanical energy hazards on our highways.

In the case of the energy-hazards, the author of the treatise on Head Injury attributed to Hippocrates had identified qualitatively two of the small number of basic principles with respect to the extent to which mechanical energy-transfers injure:

> "Of those who are wounded in the parts about the bone, or in the bone itself, by a fall, he who falls from a very high place upon a very hard and blunt object is in most danger of sustaining a fracture and contusion of the bone, and of having it depressed from its natural position; whereas he that falls upon more level ground, and upon a softer object, is likely to suffer less injury in the bone, or it may not be injured at all. . . ."[3]

In 1942, DeHaven, who had begun to understand the issues while a Candian pilot observing apparent discrepancies in crash results during WWI,[4] published a classic paper: "Mechanical Analysis of Survival in Falls from Heights of Fifty to One Hundred and Fifty Feet"[5] which picked up the same thread as Hippocrates, but this time with the addition of needed quantitative data. This initiated the growth of the central corpus of modern knowledge relative to mechanical energy hazards, concerned with the (great) extent to which the structure of the properly packaged human body provides resistance to mechanical energy exchange. Scientific

understanding in this field has been furthered greatly by a number of other subsequent workers, especially beginning in the early 1950's by John P. Stapp and his colleagues with their rocket-sled and other decelerations of themselves and other human volunteers.[6]

More recently, it has been possible to categorize qualitatively the entire sequence of steps in the processes that lead to the end results in energy-damaged people (and property) that accumulate on society's public-health balance sheets. This in turn allows parallel classification of countermeasure options for the reduction of such individual and societal losses.[7, 8, 9] In fact, it is one indication that this field is approaching the abovementioned third stage in understanding of interactions between man and these environmental hazards, that the resultant conceptual framework, a countermeasure classification, works equally well in approaching reduction of the damage from all forms of energy (and in parallel of all toxins as well), whether such hazards are interacting with man (or property) briefly or for longer periods, and whether the damage is acute or chronic.

One logical framework for classifying scientifically based countermeasure strategies for reducing energy-damage of any kind is described in the following paragraphs.

The first strategy is to prevent the marshalling of the form of energy in the first place: preventing the generation of thermal, kinetic, or electrical energy, or ionizing radiation; the manufacture of gunpowder; the concentration of U-235; the build-up of hurricanes, tornadoes, or tectonic stresses; the accumulation of snow where avalanches are possible; the elevating of skiers; the raising of babies above the floor, as to cribs and chairs from which they may fall; the starting and movement of vehicles; and so on, in the richness and variety of ecologic circumstances.[7]

The second strategy is to reduce the amount of energy marshalled: reducing the amounts and concentrations of high school chemistry reagents, the size of bombs or firecrackers, the height of divers above swimming pools, or the speed of vehicles.[7]

The third strategy is to prevent the release of the energy: preventing the discharge of nuclear devices, armed crossbows,

gunpowder, or electricity; the descent of skiers; the fall of elevators; the jumping of would-be suicides; the undermining of cliffs; or the escape of tigers. An Old Testament writer illustrated this strategy in the context both of the architecture of his area and of the moral imperatives of this entire field: "When you build a new house, you shall make a parapet for your roof, that you may not bring the guilt of blood upon your house, if any fall from it." (Deuteronomy 22:8). This biblical position, incidentally, is fundamentally at variance with that of those who, by conditioned reflex, regard harmful interactions between man and his environment as problems requiring reforming imperfect man rather than suitably modifying his environment.[7]

The fourth strategy is to modify the rate or spatial distribution of release of the energy from its source: slowing the buring rate of explosives, reducing the slope of ski trails for beginners, and choosing the reentry speed and trajectory of space capsules. The third strategy is the limiting case of such release reduction, but is identified separately because in the real world it commonly involves substantially different circumstances and tactics.[7]

The fifth strategy is to separate, in space or time, the energy being released from the susceptible structure, whether living or inanimate: the evacuation of the Bikini islanders and test personnel, the use of sidewalkes and the phasing of pedestrian and vehicular traffic, the elimination of vehicles and their pathways from community areas commonly used by children and adults, the use of lightning rods, and the placing of electric power lines out of reach. This strategy, in a sense also concerned with rate-of-release modification, has as its hallmark the elimination of intersections of energy and susceptible structure – a common and important approach.[7]

The very important sixth strategy uses not separation in time and space but separation by interposition of a material "barrier": the use of electrical and thermal insulation, shoes, safety glasses, shin guards, helments, shields, armor plate, torpedo nets, antiballistic missiles, lead aprons, buzz-saw guards, and boxing gloves. Note that some "barriers," such as fire nets and other "impact barriers" and ionizing radiation shields, attenuate or lessen but do not totally block the energy from reaching the structure to be protected. This strategy,

although also a variety of rate-of-release modification, is separately identified because the tactics involved comprise a large, and usually clearly discrete, category.[7]

The seventh strategy, into which the sixth blends, is also very important – to modify appropriately the contact surface, subsurface, or basic structure, as in eliminating, rounding, and softening corners, edges, and points with which people can, and therefore sooner or later do, come in contact. This strategy is widely overlooked in architecture with many minor and serious injuries the result. It is, however, increasingly reflected in automobile design and in such everyday measures as making lollipop sticks of cardbord and making some toys less harmful for children in impact.[7]

The eighth strategy in reducing losses in people and property is to strengthen the structure, living or nonliving, that might otherwise be damaged by the energy transfer. Common tactics, often expensively underapplied, include tougher codes for earthquake, fire, and hurricane resistance, and for ship and motor vehicle impact resistance. The training of athletes and soldiers has a similar purpose, among others, as does the

treatment of hemophiliacs to reduce the results of subsequent mechanical insults. A successful therapeutic approach to reduce the osteoporosis of many post-menopausal women would also illustrate this strategy, as would a drug to increase resistance to ionizing radiation in civilian or military experience. (Vaccines, such as those for polio, yellow fever, and smallpox, are analogous strategies in the closely parallel set to reduce losses from infectious agents.)[7]

The ninth strategy in loss reduction applies to the damage not prevented by measures under the eight preceding – to move rapidly in detection and evaluation of damage that has occurred or is occurring, and to counter its continuation and extension. The generation of a signal that response is required; the signal's transfer, receipt, and evaluation; the decision and follow-through, are all elements here – whether the issue be an urban fire or wounds on the battlefield or highway. Sprinkler and other suppressor responses, firedoors, MAYDAY and SOS calls, fire alarms, emergency medical care, emergency transport, and related tactics all illustrate this countermeasure strategy.

(Such tactics have close parallels in many earlier stages of the sequence discussed here, as, for example, storm and tsunami warnings.)[7]

The tenth strategy encompasses all the measures between the emergency period following the damaging energy exchange and the final stabilization of the process after appropriate intermediate and long-term reparative and rehabilitative measures. These may involve return to the pre-event status or stabilization in structurally or functionally altered states.[7]

(Additional information concerning such analysis has been published elsewhere, including with respect to the crucial importance of chosing countermeasure priorities in terms of their ability to reduce the undesirable end results rather than selecting emphasis in terms of primacy in the sequence of causation.[7] In illustration, we use fuses, parachutes, and packaging of parcel post shipments rather than attempting to prevent all shortcircuits or fallings of people and packages. This approach is analagous to using a vaccine to modify the interaction of poliomyelitis viruses with the persons at risk rather than concentrating on modifying human behavior to prevent exposure to the specific environmental hazard that produces the bodily damage.)

In view of the progress noted briefly above, and many related advances, understanding in this field has moved in less than thirty years through a period in many ways parallel to the approximately thirty years of microbiological discoveries and development of preventive countermeasures that preceded the beginning of the present century. It is important that these developments and the theoretical and empirical knowledge they reflect rest firmly on the physics and biology involved, and that countermeasure options choice and implementation, as is true also in turn with more peripheral etiologic factors, involve such other types of variables as those of engineering, and behavioral science, just as do the other fields of preventive medicine and public health. With respect to relevant knowledge involving such less direct variables, there has also been considerable progress in recent years, although here, too, most of the growing body of scientific evidence is not widely known and only a few competent reviews and discussions of subareas of special interest to physicians have been published. Aside from those concerned with emergency and subsequent response and care, these include references 6, 10, 11, 12, 13, 14, 15. There is every indication,

however, that the overall progress in this field will continue, although a major problem is the great scarcity of research-trained physicians and related scientists willing to work in the non-surgical aspects of this important field.

In the foregoing I have introduced briefly some of the foundations that underlie scientific approaches to "The Injury Problem." In closing, I predict that just as the understanding of the causation of other afflictions of man has lead to their classification in etiologic terms, so too will the present "injuries" increasingly be classified in terms of the specific toxins and forms of energy-exchange each involves.[16] This modern, stage-three position is a far cry from the pre-scientific approaches that for centuries have dominated this field, with tragic results. The transition to rationality in which we are now engaged is long overdue, but the forces of conceptual reform are gaining ground.

REFERENCES

1. Baker, G., An Essay Concerning the Causes of Endemial Colic of Devonshire. Reprinted by the Delta Omega Society, Berkeley, Calif., 1958.
2. Frost, W.H., "Introduction," p. ix-xxi, In: Snow on Cholera, Snow, J., Commonwealth Fund, New York, 1936.
3. Hippocrates, "On Injuries of the Head," In: The Genuine Works of Hippocrates. Translated by F. Adams. Baltimore: The Williams & Wilkins Co., 1939.
4. DeHaven, H., "Beginnings of Crash Injury Research," p. 8-11, In: Accident Pathology, Proceedings of an International Conference, Brinkhous, K.M., ed. U. S. Govt. Print. Off., 1970, 249pp.
5. DeHaven, H., "Mechanical Analysis of Survival in Falls from Heights of Fifty to One Hundred and Fifty Feet," War Medicine 2:586-596, July 1942.
6. Stapp, J.P., "Deceleration, Impact, and Blast," p. 118-166, In: Aerospace Medicine, Radel, H.W., ed., 2nd ed., William and Wilkins, 1971.

7. Haddon, W., Jr., "On the Escape of Tigers: An Ecologic Note," The American Journal of Public Health 60:2229-2234, Dec., 1970.

8. Haddon, W., Jr., "Exploring the Options," Conference on Research Directions Toward the Reduction of Injury in the Young and the Old, Sponsored by The National Institute of Child Health and Human Development, Silver Spring, Md., May 12-14, 1971. To be published.

9. Haddon, W., Jr., "A Logical Framework for Categorizing Highway Safety Phenomena and Activity," In press, Journal of Trauma, 1971.

10. Haddon, W., Jr., "The Prevention of Accidents," p. 591-621, In: Preventive Medicine, Clark, D.W. and B. MacMahon, ed., Little, Brown and Co., 1967.

11. Haddon, W., Jr., et al, Accident Research; Methods and Approaches, Harper and Row, 1964.

12. U. S. Congress. Comm. on Public Works, 90th, 2nd. Session. 1968 Alcohol and Highway Safety Report. Comm. Print 90-34, U. S. Govt, Print. Off., 1968.

13. Klein, D., and J. A. Waller, Causation, Culpability, and Deterrence in Highway Crashes, Prepared for the U. S. Depart. of Transportation Automobile Insurance and Compensation Study, July 1970. U. S. Govt. Print. Off., 1970.

14. Waller, J. A. and D. Klein, "Society, Energy and Injury -- Inevitable Triad?" Conference on Research Directions Toward the Reduction of Injury in the Young and the Old, sponsored by The National Institute of Child Health and Human Development, Silver Spring, Md., May 12-14, 1971. To be published.

15. Meyer, R. J., and D. Klein, ed., "Childhood Injuries: Approach and Prospects," Pediatrics, 44:5, pt. 2, 791-896, 1969.

16. Haddon, W., Jr., "The Changing Approach to the Epidemiology, Prevention, and Amelioration of Trauma: the Transition to Approaches Etiologically Rather than Descriptively Based," American Journal of Public Health, 58: 1431-1438, 1968.