PRACTICAL PROBLEMS IN THE APPLICATION OF RADIATION PROTECTION STANDARDS IN THE FIELD OF PUBLIC HEALTH

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Abstract—The growth of the nuclear age has been rapid, and enlightenment about the biological effects of radiation has followed. To protect ourselves, a wide variety of standards, recommendations, guides, laws and regulations has evolved. They were naturally first developed by those using radionuclides and machines producing ionizing radiation. They were then the only persons with knowledge of such matters.

Now that public health agencies are rightfully assuming more of the responsibility for this new and growing public health problem, they find that they have inherited many established standards and rules formulated by authors who lacked experience in public health administration. Standards and rules are often inconsistent with public health tradition (which in some respects may not be bad), and in many cases difficult if not impossible to administer adequately within the framework of most public health agency resources and personnel.

UNTIL about ten years ago, the hazard of radiation exposure was considered primarily in terms of occupational exposure. It is true that some efforts were made to minimize the exposure of patients during the medical application of radiation, but it was largely by miscellaneous committee recommendations which could be followed on a voluntary basis by those who were interested.

Although radioactive fallout from nuclear weapons has been recognized since 1945, it was not until about 1955 that it received widespread consideration as a possible public health problem. The anxiety, expressed by many, stimulated studies by several national and international committees[1] of the total population radiation exposure from various sources and also of the known biological effects of radiation. All of the reports indicated that the greatest and probably the most rapidly growing public health problem involving radiation was associated with the medical use of X-rays. Although the health and safety aspects of all atomic energy activities were being most vigorously regulated, little official recognition was being given at that time to the non-atomic energy applications of radiation, notably in the fields of medicine and academic research.

Because of public concern about fallout and a sharply increased interest in X-ray exposures, public health agencies began to enter the field of radiation protection. In attempting to establish workable standards that could be enforced, and to keep them reasonably consistent with existing recognized standards of good practice, they found themselves faced with an inconsistent dichotomy of standards. In the atomic energy field, they inherited a set of meticulously detailed radiation regulations designed to be enforced by a system (as described by Recht[2]) employing "almost military discipline . . . and a tight and efficient system of surveillance". In the non-atomic energy uses of radiation, there

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existed a set of loosely worded committee recommendations intended for voluntary compliance. In fact, the authors of some such recommendations reminded us in the preface of the report that the recommendations were not intended to be used as official regulations. On the other hand, they were the only existing standards suitable for adoption and were widely accepted. It is interesting to note that although the authors of both the atomic energy regulations and the more general radiation recommendations and standards have included many leading scientists in the field of radiation, few contributors appear to have had experience in the field of public health. It is perhaps for that reason, among others, that many standards and procedures established for the protection of the public against radiation exposure are quite incompatible with most other public health practices developed as a result of a century of experience.

When we compare the health hazards of chronic exposure to radiation with those of many other agents, we see that there are close similarities. In the case of radiation, we are concerned primarily with carcinogenic, genetic and non-specific aging effects. As in the case of many other health hazards, we consider them in terms of occupational exposure, residential risks (such as air, water and food pollution) and possible accidents.

Although we are much better informed about the effects of radiation, probably because of a stimulated public interest, we do know much about other agents having similar effects. [3] Tars and oils, carbon tetrachloride and benzol are known to be carcinogenic. Many pesticides and food additives are also suspect. The use of estrogenic hormones to improve the quality of domestic fowl for human consumption has been restricted because of the carcinogenic potential.

Many chemical agents have been found to cause genetic mutations. They include formaldehyde, epoxides, phenol, mustard gas, caffeine, ethyl alcohol and theobromine (found in cocoa). It is true that the genetic effects of chemicals on mammals are not as well understood as in the case of radiation. A relative lack of public and consequently official interest has inhibited extensive research.

It has become obvious that public health agencies should assume the responsibility for protecting the public against the hazards of radiation sources not otherwise under the control of atomic energy agencies. In certain cases, where atomic energy radiation problems have clearly entered the domain of public health, e.g. the possible contamination of water, food or air from fallout, radioactive wastes or nuclear accidents, health agencies should assume complete control of the public health aspects if they are prepared to do so. A strong case has been made for the transfer of all health protection responsibilities from atomic energy agencies, because of a possible conflict of interest. Such agencies have a mandate to promote the use of nuclear energy and its byproducts. It has been argued that the determination of any necessary public health protection restrictions on nuclear development and use should not be the responsibility of the same agency promoting its development and use. In practice, however, it is observed that any imbalance that may exist between efforts to promote atomic energy and efforts by the same agencies to protect the public appear to indicate a degree of overregulation, when compared to society's efforts to protect the public against comparable health hazards. This may result from a sensitive awareness by atomic energy agencies of the conflict, and a desire to avoid possible criticism of not protecting the public adequately.

The great amount of detail in most atomic energy health and safety regulations is well known to most of this audience. It covers a variety of units of measurement and dose expression, various permissible levels of radiation and dose rates for different classes of individuals and in different areas, details of radiation surveys, personnel monitoring, record keeping, reporting, caution signs and labels, employee instructions and notices, storage, waste disposal, contamination control, transportation and many other matters. The meticulous detail with which our U.S. atomic energy rules have been developed can be indicated by the fact that the printed rules covering routine matters of radiological health, exclusive of such special items as criticality hazards, or reactor design and siting, constitutes a substantially greater volume of printed matter than our entire New York City Health Code which was developed to protect

eight million people against every health hazard known to man, including radiation.

There is no intention of criticizing the careful development of refined and detailed standards. It should be pointed out, however, that when each detail is considered to be a legally enforceable regulation subject to inspection, record keeping and enforced correction, the burden upon both the regulatory agency and those regulated becomes very great. From what is known of efforts to control atomic energy related radiation hazards in other countries, the U.S. practice is not unique, as Dr. Recht has inferred in the paper previously cited.

If we now consider the existing standards and rules for the use of X-ray equipment, we observe that they appear to have been intended primarily for large well-staffed hospital X-ray departments. The I.C.R.P. X-ray report [4] has several recommendations employing references to the "head of the department" and "the expert knowledge of the staff". Experience in our country and in many developing countries shows that most medical X-ray equipment is located in physicians' offices or small clinics and hospitals not staffed with the highly trained radiologists and physicists upon whom many existing protective recommendations depend for their administration. It is in such small installations where the greatest deficiencies in equipment and use are usually found.

If radiation and radioactive contamination are considered a public health problem, which now seems to be a generally accepted premise, it seems obvious that the ultimate control and the establishment of control principles should be the responsibility of public health agencies. The World Health Organization has made a strong plea to that end. [5] It appears that this policy has not been followed previously because persons with training and experience in atomic energy, radiation and radiation effects were not available to health agencies. In many countries, health responsibility was given to atomic energy agencies by statute, probably because health agencies were not prepared to assume the responsibility.

For most radiation protection workers, whose experience has usually been limited either to atomic energy programs or to large medical center radiation control programs, a brief outline of the manner in which public health agencies usually operate to control health hazards is in order. In most establishments subject to public health inspection, the staff and employees are likely to be well trained in the appropriate technology, whether it be food processing or restaurant management. They usually know little however about the technical aspects of health protection. Health agencies usually have a program director in each special field who is a highly trained expert in his particular health speciality. Although the field workers who are in constant communication with the establishments under control are usually highly skilled technicians in the processes they survey and in the health standards they employ, they are not usually investigative scientists.

For these reasons public health standards must be as simple as possible and clearly expressed in a manner that will permit uniform interpretation and administration, without undue hardship to anyone and with little risk of a lapse in effectiveness. In other words, the precise determination of whether any individual has or has not been exposed in violation of a code should not constitute a scientific research project as is often the case for some existing radiation protection rules. This obviously requires a certain degree of compromise with the precise scientific evidence, by the establishment of arbitrary measurable working limits. Experience has proven this to be necessary in virtually every other health or safety regulation that exists, whether it pertain to foods, drugs, fire prevention or motor vehicle safety. The alternative requires a staff of investigative scientists that appears to have formed in some atomic energy regulatory programs.

To cite examples, several typical principles of radiation protection that present formidable problems, when a public health agency tries to adopt them for use are:

1. *Permissible Doses*

Most standards are written in terms of a specified cumulative radiation dose to a particular organ or system of organs (viz., the gonads or the blood forming system). This is quite scientific and very precise, but it would be much like specifying that food should contain

no more lead contamination than would result in a concentration of over 100 μg of lead per gram in the consumer's kidneys. It requires an experienced investigator to determine whether such criteria have been met.

Dunster[6] has described the I.C.R.P. permissible dose recommendations[7] as "indispensable, infallible and to some extent incomprehensible". If Dunster, who is one of our most distinguished and experienced scientists in the field of radiation protection, finds them somewhat incomprehensible, it is not difficult to understand the uncertainty with which a public health worker faces this new problem.

2. *Occupational Category*

In the I.C.R.P. Standards, a distinction is made between the maximum permissible doses of occupationally exposed persons (5 rem/year) and other workers in the vicinity of controlled areas (1.5 rem/year). In the United States N.C.R.P. Standards, the same general distinction is made, except that those in the environs are not described as workers and their dose is limited to 0.5 rem/year. In fact, the occupational limit is not actually 5 rem/year but follows the relationship of $5(N\text{-}18)$ based upon past exposure history.

No valid argument can be presented to refute the reasoning nor scientific justification for arriving at various grades of permissible doses. The uncertainties in the biological data upon which the limits are based, however, and the errors inherent in field measurements, as well as in the translation from radiation measurement to critical organ dose are all great. The proliferating uncertainties regarding the actual critical organ doses usually far exceed the numerical distinctions employed in classifying workers and others into permissible dose categories differing by factors of only 3 or 10.

3. *X-Ray Installation Shielding Recommendations*

This category, both the international recommendations[7] and our own national recommendations in the United States provide for considerable speculation about the manner in which any particular piece of X-ray equipment is to be used and its adjacent spaces occupied. Assumptions must be made of the expected operating kilovoltage and workload, the directions in which the beam is likely to be pointed, the degree of occupancy of any adjacent space and also the occupational category of persons likely to be there. Strangely enough, certain recommendations appear to permit a considerably higher exposure of persons not classified as radiation workers than those who are considered occupationally exposed. For example, rest and lounge rooms to be used by occupationally exposed personnel must be shielded to a greater degree than similar rooms to be used by personnel not classified as occupationally exposed to radiation.

A distinction is made between persons in controlled areas and persons outside of controlled areas, with a difference in permissible exposure by a factor of either three or ten, depending upon whether those persons are considered workers or not. Experience in atomic energy establishments has shown that it is feasible in such places to designate areas where certain persons may or may not be permitted access. A tight system of security with guards at every point of entrance often permits the close surveillance of such matters. In a busy hospital X-ray department or in the offices of a physician, at least from our observations in the United States, it is most difficult to delineate areas that might be controlled or uncontrolled and to restrict radiation workers, clerical and administrative workers, patients, and patients' escorts, and to distinguish between those who should be permitted to enter controlled areas and those who must be excluded. In the case of our own atomic energy establishments, the guard at the entrance requires that any person authorized to enter wear a personnel monitoring dosimeter, with the user's name and identification recorded. In the case of most medical installations this is quite impractical.

It would seem that in medical installations, where there is likely to be considerable uncertainty about each person's radiation exposure category and also a lack of control of the movement of individuals, there is the least justification for the current speculation about radiation levels that may be permitted to exist in any room.

A reasonable evaluation of the relative degree of radiation protection according to each individual's permissible dose is troublesome. The

employment of personnel monitoring devices is convenient only for regular employees. In the case of diagnostic X-rays, measurements are particularly subject to error because of energy and geometry reasons.

It is suggested that the structural shielding designs be based upon the maximum workload of the machine and that the X-ray beam be mechanically restricted to a few needed directions as it is now done for teletherapy machines. All adjacent areas could easily and adequately be shielded for any degree of occupancy by any category of person. The added shielding cost would be slight by comparison with the high cost of modern X-ray installations. The degree of certainty about radiation exposures would be vastly improved.

4. *Control of the Size and Direction of Diagnostic X-Ray Beams*

If we consider published reports of population exposure to man-made radiation, it is evident that medical patients receive most of it. When we study technical reasons for excessive or unnecessary exposure, one category is widely agreed upon to exceed all others in magnitude of excessive population dose. It comprises X-rays that strike a patient's body but serve no diagnostic purpose. In other words, the exposure resulting from failure to collimate the X-ray beam down to at least the size of the film being used, constitutes the greatest amount of useless human exposure to man-made radiation.

In spite of the prime importance of this problem, health agencies that seek to solve it are virtually powerless to do so under today's standards. In the case of most other technical or scientific apparatus, where it is necessary to direct a beam of any kind at a target, mechanical means are invariably built into the apparatus. For the purpose of deliberately aiming an X-ray beam of high intensity at a human target, most X-ray equipment lacks even a simple aiming device. The beam size is therefore usually enlarged to about three to five times the necessary size in order that the film not be missed because of poor aiming. Most collimators produce a round beam, whereas they should at least be rectangular to match the film or preferably be shaped exactly to fit the organ or area being examined. Modern technology, if properly applied, could certainly attain that goal.

When we, in public health agencies, observe the manner in which radiation protection is usually administered in national atomic energy programs, we know that we could not expect to devote the time of such highly trained specialists to the detailed investigation of possible sources of radiation hazards without a substantial change in health agency customs and policies. When we analyze the problem further, it appears that a considerable amount of effort is often devoted to the collecting, recording and analyzing of data that might better be classified as scientific research or legal documentation rather than public health administration.

Many other public health enforcement activities consist of observing that someone is doing something wrong, instructing him to do it differently and, for serious offenses, noting what action was taken. The notation is for the purpose of learning about habitual offenders.

There is some difference of opinion about the trend away from this simple straightforward approach in many regulatory activities today. In the opinion of some it is to be deplored. There are officers whose function it is to insure that a certain level of efficiency is maintained, but to be able to prepare their evaluations, they must be supplied with statistics. The number of inspections per man-day, the number and classification of corrected deficiencies per inspection, etc., must be collected and tabulated. The result is a significant increase in the required record keeping. Meticulous records are also kept to furnish evidence of compliance or non-compliance in case of controversy. The overall need for the legal enforcement of health regulations is quite rare and the needed records for those few cases can be accumulated after efforts at persuasion have failed.

SUMMARY

To summarize, the following conclusions and recommendations are made:

1. The protection of the public against radioactive contamination and radiation exposure is basically a public health problem and should be administered by public health agencies

as soon as they are prepared to assume the responsibility.

2. The standards and rules regarding radiation protection should be coordinated and simplified so that they be made more compatible with existing public health practices. In regulations, greater emphasis should be placed on arbitrary permissible environmental radiation levels rather than on accumulated doses to various human organs of different categories of persons, since the latter is virtually impossible to measure routinely with an acceptable degree of accuracy.

Much of the detail embodied in atomic energy oriented radiation regulations should be eliminated. A considerable part of the detail appears to have been introduced for legal record keeping reasons, to provide evidence of compliance or non-compliance. Some records seem to be employed for scientific data collecting reasons. If employers wish such records for their own needs, they may be accumulated, but only those actually necessary to demonstrate a reasonable degree of current compliance should be mandatory.

4. For medical X-ray installations, simpler, uniform and more readily checked standards should be set, particularly for structural shielding and to guarantee adequate beam collimation, the two demonstrated sources of most excessive or uncertain exposure.

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