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SITE X OPERATING MANUAL - HEALTH HAZARDS

May 1943

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SITE X OPERATING MANUAL
HEALTH HAZARDS

May, 1943

The health hazards may be divided roughly into the following groups: 1) Those due to the various radiations coming from the pile and the separation process operation; 2) Radiations from the fission products and radium sources; 3) The radiations from uranium whether in the form of pure metal or of compounds; 4) The chemical hazards from the use of various chemicals used in the separation process; 5) The usual plant hazards. This manual is concerned mostly with the radiation and chemical hazards.

General Considerations

THE HAZARD FROM RADIATION IS EXTREMELY GREAT BECAUSE THE RADIATION CANNOT BE DETECTED BY ANY OF THE SENSES AND BECAUSE THE EFFECTS MAY NOT BECOME APPARENT FOR YEARS AFTER THE EXPOSURE. ADEQUATE PROTECTION CAN BE ASSURED BY PROPER SHIELDING OF ALL EQUIPMENT, OBSERVATION OF ALL OPERATING RULES, AND THE CONSTANT USE OF RELIABLE INSTRUMENTS FOR DETECTING DANGEROUS CONCENTRATIONS OF RADIATION. CONSEQUENTLY ALL THOSE IN A SUPERVISORY CAPACITY MUST ADHERE STRICTLY TO THE OPERATING RULES AND SEE THAT ALL EMPLOYEES DO LIKEWISE. NO ATTEMPTS MUST EVER BE MADE TO COPE WITH ANY UNUSUAL SET OF CONDITIONS WHEN AN UNUSUAL SITUATION ARISES. IT SHOULD BE THOROUGHLY INVESTIGATED BY PERSONS ESPECIALLY QUALIFIED TO SURVEY THE SITUATION WITH RELIABLE INSTRUMENTS. WHEN A PARTICULARLY DANGEROUS SITUATION ARISES THE SPECIALLY TRAINED MEDICAL PERSONNEL SHOULD BE CALLED TO JUDGE THE HAZARDS.

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Types of Radiation

1. Alpha Rays

Alpha rays are the nuclei of helium atoms called "rays" when they are in motion. They may have various amounts of energy, depending upon their source. At Site X the commonest source for these will be from uranium whether in the metallic form or in any of the compounds or isotopes. The alpha particles are relatively heavy and have relatively strong charges. They are therefore stopped by a small amount of air, or a very small thickness of tissue. They travel only about two to three centimeters in the air and penetrate only about 0.1 mm in tissue, consequently they are stopped by the clothing or by leather gloves on the hands.

2. Beta Rays

Beta rays are negative electrons. They are emitted with varying energies from most of the radioactive materials produced in the fission process and from the decaying uranium. They are relatively small paricles with only a single charge and they do not ionize to such an extent as the alpha particles but can penetrate somewhat farther through air and into tissue. They are a serious hazard in the handling of fission products and suitable protective measures must be used to guard against damage.

3. Neutrons

Neutrons are small particles of matter with the same mass as a hydrogen nucleus. They have no free electric charge. They are formed in the pile during operation and there is a small amount of continued formation immediately after shutting down the pile. None are present after a relatively short shut down of the pile, and none are present in the materials in the separation process, nor do any come from the uranium or radium, or the fission products. When they have a high energy content they can penetrate quite deeply into tissue or into the shield around the pile. When they are captured by atomic nuclei, as they all eventually are captured by one process or another, they may cause the emission of high energy gamma rays. The ionization which they cause indirectly by setting charged atomic nuclei in motion, is a very dense type of ionization which, as will be discussed below, is more biologically effective than any of the other radiations except that of alpha rays.

When traveling with high velocity, they are known as fast-neutrons, but when their velocity is reduced due to loss of energy, they are known as slow-neutrons.

4. Gamma Rays

Gamma rays are photons with practically no mass and varying degrees of energy. Gamma rays of any energy have much greater penetrative power than any of the other rays of the same amount

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of energy. The ionization they produce is relatively low per unit of path of the ionizing electrons which they set in motion. Hence, gamma rays are the principal radiation that is used from radium. Their behavior is much better known than that of any of the other radiations and shielding against them is understood thoroughly.

Measurement of Exposure

Changes produced in the human body by radiation are the result of the transference of the energy of the radiation to the materials making up the human body. The principal method of transferring this energy is by ionizing the atoms within the body, therefore from the biological standpoint we are interested in the energy absorbed from a beam of radiation at a given place in a given time, and not in the total flux of energy in that beam of radiation. A measure of the energy absorbed can be obtained by measuring the ionization produced. It is not as yet possible to measure the ionization produced in a solid tissue, hence it is necessary to measure the ionization in terms of that produced in a given amount of air or gas. Since medical men and biologists are interested primarily in x-rays and gamma-rays and since the absorption of these rays is approximately the same per unit of mass (not per unit of volume) in air and in tissue, the unit of exposure has been defined in terms of air ionization. The unit is called a "roentgen" and is designated by the symbol "r". Definition is: "A roentgen shall be the quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air produces, in air, ions carrying one ESU of quantity of electricity of either sign." The specified mass, 0.001293 gram, is the mass of one cubic centimeter of dry atmospheric air at 0 degrees Centigrade, and 760 centimeters Hg. pressure. Note again that this is not a measure of the number of photons passing through a given mass of air, nor of the energy of the photons but only of the energy absorbed. Note also that it is not a measure of rate. The dose rate or exposure rate is expressed in roentgens per unit of time.

Note that when an atom is singly ionized, two electrically charged entities are produced: 1) the electron that is ejected from the atom (the electron is sometimes called a negative ion) and 2) the remainder of the atom, which is the positive ion, when these ion pairs are produced in the space between the plates across which there is a difference of potential, the electrons are attracted to the positive plate and the positive ions are attracted to the negative plate. According to the definition of the roentgen, it is necessary only to measure a total charge in electrostatic units of the ions of either sign. To measure the roentgen absolutely requires the use of a free air ionization chamber, but these are bulky and difficult to manage and so are kept in special places, such as the Bureau of Standards at Washington. Practical, more portable units can be made and standardized by comparison with the standard chamber.

In practice it is common to use a thimble chamber attached to a condenser and an electroscope. The inner wall of the thimble chamber is lined with a conducting material and in the center runs a thin collecting electrode. The whole device is charged by a friction charger to about 400 volts. At this charge the fiber shadow appears at zero on the scale. The ionizing radiation is then allowed to pass through the thimble chamber and ionizes the material in the walls and air space within. The ions are attracted to the electrodes before they recombine and the difference of potential across the electroscope consequently decreases. This causes the fiber to change its position. The scale provided is calibrated in roentgens. It is thereffore possible to measure the number of roentgens in any measured interval off time; dividing the total number of roentgens measured by the number of minutes of exposure gives the exposure rate of roentgens per minute.

Since each ion carries a definite charge it is possible to state the number of roentgens in the number of ion pairs formed in 0.001293 grams of air. Thus, one roentgen equals 2.08×10^9 ion pairs per 0.001293 grams of air. This is equivalent to 1.61×10^{12} ion pairs per gram. Since it takes roughly 33 electron volts to produce one ion pair, therefore the energy absorbed per gram of air per roentgen equals 5.3×10^{13} electron volts, or 84 ergs. Since a gram of air absorbs essentially the same amount of energy as a gram of tissue it is possible to directly compare the two substances as to energy absorbed.

Beta Ray Measurements

Since the ionization produced by photons of gamma-rays or x-rays is largely produced by the secondary electrons, and the beta rays are electrons, it is possible to measure the ionization produced by primary beta rays in roentgens, provided the instrument is properly calibrated.

Fast Neutron Measurements

There is as yet no unit for the measurement of fast neutrons. With this radiation as with x-rays and gamma rays, the biological interest centers on the energy absorbed from them in a given volume of tissue. The process by which the energy of neutrons is transferred to substances differs considerably from that for gamma-rays. With gamma-rays the absorption is dependent upon the density of the tissue; with neutrons rays it is dependent upon the atomic composition of the tissue, that is the elements making up the tissue. There is, therefore, not the same direct relationship between absorption in air and that in body tissue as there exists between air and body tissue for gamma rays. Consequently, the measurement of neutrons by their ionizing effects on air cannot be translated directly to tissue. In order to have a unit for comparison of exposure, biologists in this country have set up an arbitrary unit known as the "Neutron unit" and abbreviated as "n". A neutron unit is that amount of neutron radiation which produces in a 100 r condenser chamber of the standard Victoreen condenser r meter the same amount of ionization as is produced by 1 roentgen of x-ray. Thus the usual Victoreen condenser r meter is used in the same way as with x-rays, but the scale is read as neutron units instead of roentgen units. In terms of the effect produced on human skin, it has been found that 1 neutron unit of exposure produces about the same effect as somewhere between 6 and 10 roentgens. For purposes of protection against the hazards of exposure to neutron rays, it seems best to consider that the effect of 1 neutron unit is equivalent to 10 roentgens of gamma-rays.

This factor of 1 to 10 does not correspond to the direct relationship between the amount of ionization in tissue produced by 1 neutron and 1 roentgen. Actually 1 neutron unit measured as above, produces only about 2.5 times as much ionization per gram of tissue as 1 roentgen. Because of the spatial distribution of the ionization in the tissue, the ionization produced by a neutron is more effective than that produced by gamma-rays, hence the necessity for the 1-10 ratio of biological equivalence.

Tolerance Exposure

Tolerance exposure, or tolerance dose as commonly used, is that amount of irradiation which can be received over the entire body day in and day out throughout a life time without producing subjective or objective signs of radiation damage. It is usually expressed as the amount that can be received in each 24 hours. Since most workers are exposed for only eight hours a day, it is common to express it in so many units per 8-hour day, but it must be thoroughly understood that such expression means 8 hours out of each 24. In other words, it is not possible to repeat the dose in successive 8-hour periods if the worker is required to work more than 8 hours per day. It is, therefore, best to think of the tolerance dose as that amount of irradiation which can be received at any time during one 24 hour period, but not repeated until the next 24 hour period.

The tolerance dose for total body radiation is based largely on the effect produced on the blood forming parts of the body. If all of the blood forming areas could be gathered into one cc, presumably .1 r to that area would cause the same change in the blood picture as the same amount of exposure given over the whole body. It must always be borne in mind that the roentgen is a unit of ionization in a cubic centimeter of air, but when we say .1 roentgen to the whole body, we really mean .1 roentgen to each separate part of the body.

Gamma-ray Tolerance

The National Bureau of Standards, acting on the advice of the Advisory Committee on x-ray and Radium Protection, has established the tolerance dose for x- or gamma-rays of 0.1 r per day. However, they state on page 10 of Handbook #20 as follows:

> "The tolerance dose of 0.1 r per day, stated above, is provisional, and it is advisable to apply generous safety factors."

For this reason, it has been deemed advisable to build in protection measures in fixed installations wherever possible so as to have the intensity such that the operating personnel get no more than 0.01 r in any 24 hour period. It must be continually borne in mind that the tolerance dose is the assumed maximum that can be endured without effects, and it is not to be taken as the optimum to which one should attempt to expose oneself. The less exposure anyone can get, the better it is for him.

Daily exposures of personnel in excess of the tolerance level, should be permitted only in case of extreme emergency and then only with careful exposure measurements and medical control.

Neutron Tolerance Exposure

Since as explained above neutron radiations are more effective in causing biological changes, and since 1 neutron does not mean the same exposure as 1 roentgen, the tolerance dose for neutron radiation of the fast type is set at 0.01 n per day.

It must be borne in mind that one cannot take a tolerance dose of gamma-rays and add to that a tolerance dose of neutron rays. The effects of the two are totally additive. Thus, when there is a mixture of gamma-rays and fast neutron rays, the daily tolerance should be set at 0.01 n or r.

Beta Tolerance

Since the exposure of the body as a whole to beta-rays has not previously been any problem, tolerance exposures for beta rays have not been established. It is possible that they are not as effective as gamma-rays since they do not penetrate very deeply into the body and so do not effect the tissues other than those close to the surface. However, for purposes of safety, the tolerance dose of beta-rays when they effect the whole body has been set at 0.1 r per day. While this figure may be subject to variations as experience is gained, it must be accepted as the safety standard for operating conditions.

Tolerance Exposure for Local Areas

In the handling of radioactive materials such as uranium, radium, and fission products, it is possible to expose local areas such as the hands, without having any great total body exposure. The intensity of any radiation varies inversely as the square of the distance, thus a hand at one centimeter from a source of irradiation will get 10,000 times as much irradiation as a body one meter from the source. Hence one must always consider not only the total body exposure but the local exposure to any part that approaches the radioactive source.

In considering the amount that a local area can stand, it must be borne always in mind that the effect to the whole body is simply the additive effect of exposing each part of the body.

It is well known that different tissues of the body respond differently to the same amount of radiation. The skin and tissues directly beneath the skin are not as sensitive to irradiation as are the blood forming organs. No tolerance dose for hands or other local areas of the body has been established by any National or International committee. On the other hand, it is well known that a great many radium and x-ray workers have lost fingers, hands and arms after many years of over-exposing these parts without developing any general body symptoms from total body radiation. Sometimes the changes initiated in the hands from chronic x-ray or radium exposures have resulted in the formation of cancers which have brought about the death of the individual. Although it is possible that the skin of the hands may tolerate an exposure in excess of 0.1 r per day, it seems best to establish a tolerance dose of .1 r per day for the hands as well as for the total body exposures, until we have evidence to the contrary.

Individual Variation in Radiosensitivity

There are distinct personal variations in the radiosensitivity of the blood forming tissues of different individuals. It is very probable that amongst the personnel at Site X some will be found whose blood will show abnormal fluctuations when exposed to the so-called tolerance dose. This must be taken into consideration and such individuals removed from radiation exposure.

Signs and Symptoms of Over-exposure

1. Total Body

The first detectable sign of over-exposure to any total body radiation is a change in the blood count. This may occur with the person feeling entirely well. To this end, routine blood examinations will be done at stated intervals on all personnel. When blood changes are found the person must be removed from exposure and observed by the medical staff to see what further developments will occur. With minor over-exposures, the blood may return to normal and the patient be able to return to work. With more serious exposures the person may have to be removed entirely from radiation for a long period of time, if not for the rest of his life, in order to re-establish as nearly normal conditions as possible. Whenever a person is known to receive an over-exposure, he should be sent immediately to the Medical Department for immediate and continued observation.

The first symptom that a person observes of over-exposure is a feeling of general tiredness. More serious over-exposure will result in nausea and still greater exposure in continued vomiting.

2. Over-exposure to Local Areas

The first sign of gross over-exposure to the hands is a redness around the nail beds. Later signs are dry skin, brittle and ridged nails, loss of hair on fingers and hands, overgrowth of the skin producing wart-like lesions; later, ulceration of a chronic type. Frequently, the changes go on over a period of years to a development of cancer of the hands.

3. Effects on Testes and Ovaries

Sterility is the loss of ability to have children. It results from a destruction of the cells in the testes that produce sperm, and of the cells in the ovaries that produce ova. To bring about these effects requires relatively large doses of radiation. The ovaries are more easily effected than the testes, but they require a minimum of 200 roentgens, and in younger women frequently require much larger doses. There is no evidence that doses up to the tolerance dose can produce sterility even after a long period of years. Hence except in case of accident with very severe over-exposure, sterility is not a problem at Site X.

Impotence is the inability to complete the sexual act. There is no evidence that any dose of radiation short of a killing dose brings about impotency.

Genetic effects are those on the germ plasm which produce changes in the offspring. While there is evidence in insects and some invertebrates that genetic effects can be produced with relatively small doses of radiation, no such changes have been observed in humans with exposures at the tolerance level, and there is considerable doubt as to whether any such changes have been produced even with larger doses. However, it must be borne in mind that genetic effects are thought to be cumulative, that is, the doses received on successive days can be added up to calculate the total dose that might effect the germ plasm and so produce genetic effects. This is an added reason for keeping the exposure not only down to tolerance level but well below this level when it is possible to do so.

Examinations for Radiation Effects

While some of the effects of radiation have been described in this manual, it must be remembered that the early signs are difficult to detect and yet extremely important. For this reason the Medical Staff at Site X consists of specially trained physicians able to detect such changes. All of the personnel will be expected to go through pre-employment examinations of rather detailed nature and routine re-examinations will be established and it is the duty of every supervisor to see that the men under his care are sent for these examinations at the regular intervals.

All persons having a history of over-exposure to radiation at any time prior to their employment should be excluded from employment in positions requiring exposure to radiation at Site X, until it can be established definitely that they have no persistent changesfrom their previous exposures.

When the routine blood examinations show changesin the blood picture of any person, that person must be removed from radiation exposure until the Medical Staff is convinced that his changes are not due to radiation, or until they have returned to normal.

Any person showing unexplained fatigue or loss of weight, or nausea should be referred immediately to the Medical Department.

All person known to have over- exposure should be referred immediately to the Medical Department, and their decision reached as to whether the patient can or cannot go on with his work.

The hands and other areas possibly exposed to local radiation will be carefully watched on the periodic examinations by the Medical Staff. Any changes notes in the hands by the person himself, or by his supervisor should be a reason for referring him to the Medical Department even between the periodic examinations.

Handling of Radium Sources

Radium sources varying from several micrograms to 2 grams are used experimentally in one way or another. They constitute a definite hazard to personnel. A radium source is a constant emitter of gamma radiation, and hence without proper shielding a person within an effective range of the source is exposed to radiation. Proper shielding of a source when it is not in use is thus imperative. Lead and distance are the two factors, which used in adequate amounts, give the desired protection.

The larger sources (500 mgms or more) are each provided with a lead cart for safety in transportation and to reduce the distance requirement for storage. The thickness of the lead shielding of the cart ($2\frac{1}{2}$ in.) does not, however, provide adequate protection for storage of the source in close proximity to personnel. To reduce the tolerance exposure to 0.1 r in an 8 hour period the required distance, in addition to the $2\frac{1}{2}$ in. of lead in the cart, is:

For 500 mgms Ra..........1.5 m
1000 mgms Ra..........2.0 m
2000 mgms Ra..........2.5 m

To reduce whole body exposure in the handling of a source, a meter length metal rod is provided for attachment to the source. The rod should be used at right angles to the body to keep the maximum distance away from the source. One should know exactly what he is going to do with a source before he removes it from the lead container, so that no time is lost in manipulation. In a group using a source that requires frequent manipulation, the job of transferring the source should be rotated to reduce individual exposure. Once the source is in its experimental position the experimentor should make certain that he is properly shielded from the source if he plans to stay in its vicinity.

The metal container of the radium salt is of sufficient thickness to protect against the beta radiation emitted by the source. The secondary beta rays (electrons) scattered from the outer layer of the metal jacket are a hazard if the sources are manipulated with the hands. The permanently damaged skin of the hands of many radium workers is evidence that close handling is hazardous.

Before a radium source is put into use, and at periodic intervals, it is necessary to test the efficacy of the seal of the container. Radon (a gas) may escape from an imperfectly sealed or damaged source and its presence may be undetected unless the seal is tested. Continued inhalation of radon in concentrations in excess of the tolerance value of 1×10^{-13} curies per cc is hazardous.

Fission products should likewise be handled with caution. Their beta and gamma rays can produce injury entirely comparable to radium, and the greater frequency of handling this material makes the necessity for protection all the more necessary.

Protection should be incorporated into the plans of an experiment before the hazard arises.

Uranium Toxicity

Uranium poisoning must be considered from the chemical and the radioactive properties of the element.

The chemical toxicity of uranium has long been known. Intravenous injection of soluble uranium salts in animals in amounts of 4-6 mgm per kilogram body weight produce severe damage to the kidneys and liver which are on the threshold of lethal. Larger amounts are rapidly lethal.

The industrial hazard of uranium depends upon the possibility of ingestion, inhalation or skin absorption of uranium as a salt or as metallic dust.

Our own experience to date (both with animals and personnel)with uranium oxide, and that of industries which have handled large quantities of the oxide and metal, has not been alarming. We are not sure as yet that uranyl nitrate, and particularly the ether extract of the nitrate, cannot be absorbed through the skin in small quantities. The inhalation of metallic uranium dust seems to present the greatest hazard, since it is possible that absorption through the lung is more probable than through the intestinal tract. The tolerance concentration of uranium dust in the air which we are at present attempting to achieve in practice is the same as that established for lead, namely 0.15 mgms per cubic meter.

Animal experiments in uranium toxicity are being done with various uranium compounds and for different portals of entry. In the meantime, measures should be adopted to:

1. Eliminate possibilities of ingestion or inhalation of uranium salts or the metallic dust.
2. Keep the hands free from contamination by the salts, and particularly the nitrate.

Examination for uranium toxicity at the present time includes (1) urinalysis and (2) kidney function tests when indicated; (3) qualitative and quantitative anaylses for microgram amounts of uranium in the urine. Treatment of uranium poisoning is not well established. A person so poisoned would be treated as a case of nephritis. Treatment is best done by <u>prophylaxis</u>.

The hazard of uranium from the standpoint of its radioactivity has to be considered from three practical aspects: (1) direct handling, (2) storage, and (3) possibility of deposit within the body with attendant radioactive decay.

1. <u>Handling of Uranium</u>

We are of the opinion that the alpha radiation from uranium can be dismissed as a possible external skin hazard. Parker's measurements of the hard beta ray activity from Ux_1 and Ux_2 would indicate that for handling of the metal the worker receives $\sim$ .25r/hr to the hands. For daily handling of uncoated metal where precision work is not needed, lead leather gloves can be worn which give adequate protection. The ordinary commercial leather glove reduces the exposure by only ~ 50%. The .02" Al coating reduces the exposure to ~ .09 r/hr. There is no reason not to wear the protective lead leather gloves even in handling coated metal.

2. Storage of Metal

Parker's measurements bring out that for any surface of metal stored in the 3/4 inch wood boxes, the gamma and beta radiation exposure at any distance does not exceed .08 r/8 hours. Additional protection is unnecessary. As a matter of planning it would be preferable to use a room for storage which is not used constantly by personnel.

3. Deposit of Uranium Within the Body

Depost of uranium within the body to an extent which would be harmful from its radioactivity is unlikely, from present knowledge. In order to produce an internal alpha radiation comparable to the effect produced by the deposit in the bones of 1 μ mg of radium, it would be necessary to deposit approximately 10 gms of uranium. In this case the chemical toxicity of the material would be more urgently in the foreground.

HAZARDS OF FISSION PRODUCTS TAKEN INTO THE BODY

Introduction

The dangers of radioactive materials introduced into the body are fairly well known. Many deaths have occurred in people who, while working with radium, have gradually accumulated small amounts which became localized in the bones. Miners in areas where the radioactive gas radon exists in the air have developed lung tumors resulting in death. More recently both clinical and experimental evidence has accumulated to demonstrate that radioactive materials (including the strontium and iodine encountered among fission products), when deposited within the body, can produce biological damage.

These facts assume great importance when we consider the large amount of radioactivity associated with the fission products. As long as these substances are in the vicinity precautions must be taken to prevent them from getting into the body. It is the purpose of this section to show how they act and how much of them may be tolerated.

Conversion of Curies to Roentgen per day.

Radiologists express the quantity of radiation delivered to an object in terms of the roentgen, (abbreviate as r), and we are accustomed to assess radiological effects in terms of this unit. The strength of a radioactive source is expressed in terms of the Curie in which there are 3.7×10^{10} disintegrations per second. These disintegrations produce beta- and gamma-rays; the absorption of the energy of these rays produces the biological damage. We can convert curies into roentgens as follows:

$$1 \text{ curie} = 3.7 \times 10^{10} \times E \times 1.6 \times 10^{-6} \times \frac{1}{84} \times \frac{1}{W} \times 86{,}400 \text{ (roentgens per 24 hours.)}$$

$$= \frac{\text{dis.}}{\text{sec.}} \times \frac{\text{Mev}}{\text{dis.}} \times \frac{\text{ergs}}{\text{Mev.}} \times \frac{1}{\text{ergs per gm. per r}} \times \frac{1}{\text{gms. tissue}} \times \frac{\text{sec}}{\text{day}} = \frac{r}{\text{day}}$$

whence Intensity, I, of Q curies is given by

$$I = 61 \times 10^6 \, M \, \frac{Q}{W} \quad \text{r per 24 hours}$$

In this equation M is the energy of the emitted particle, in million electron-volts and W is the mass (volume) of body tissue in which all the radiation emitted from Q curies is absorbed.

Radiation Hazard of Fission Products

It is at once obvious that the intensity of the irradiation from an internal source depends upon the concentration of its energy (Q/W). Therefore the effect of a beta- ray will exceed that of a gamma- ray of equal energy, since the beta- ray is absorbed in a smaller volume of tissue around the source. This assumes great significance when we realize the fact that most of the fission products tend to deposit in the bone, which is highly radiosensitive, and which will absorb all of the emitted beta- rays.

In order to determine the hazard due to any fission product it is necessary to know what the body will do with it -- in other words, we must know the metabolism of it.

Metabolism of Fission Products

A fission product may get into the body through the mouth (ingestion) or lungs (inhalation). Swallowed material passes through the intestinal tract (gut) in about 24-36 hours. During this time a portion of it is picked up (absorbed) by the blood; the remainder is excreted in the feces. A fraction of any material inhaled will be exhaled in succeeding expirations. Of that which is not exhaled, a portion will adhere to the surface of the bronchi and gradually be removed by ciliary action. This portion will end up in the gut.

The remainder of the lung-deposited material will either be absorbed into the blood or remain fixed in the lung tissue. The material absorbed into the blood, from either gut or lungs, may be picked up by one or another tissue of the body and deposited within that tissue. All the material not deposited from the blood is excreted in the urine and feces and thus leaves the body.

Analysis of this sequence of events, which depends upon the chemical properties of the element involved, reveals that there are three places where overexposure to radiation may occur: in the gut, in the lungs and in the tissue or tissues in which the material is deposited and concentrated. The amounts of radioactive material which each of these can tolerate is dependent upon the concentration and upon the disintegrations occurring while the material remains at the point in question.

Most of the fission products are very poorly absorbed from the gut. Iodine and bromine are nearly 100% absorbed and strontium about 8%, while the others are absorbed to the extent of less than 0.1%, the unabsorbed material passing out in the feces. From the lung, from 100% down to 20% of the inhaled material is absorbed.

About 20% of absorbed iodine deposits in the thyroid gland. Xenon does not deposit in any particular tissue but is distributed in low concentration nearly uniformly throughout the body. Of the other fission products, about 50% of the absorbed atoms are deposited in the bone marrow. The excretion of unabsorbed material is prompt, but the deposited material is so slowly excreted that radioactive decay is in general more effective in removing it.

Tolerances for Fission Products

In calculation the amounts of fission products which the body can tolerate, one must consider the above factors and set as the maximum permissible (tolerance) amount that quantity which will not exceed the safe irradiation dose to <u>any</u> tissue, whether it be gut, lung, bone, etc. In the following table are listed the tolerance amounts for ingestion or inhalation, and the maximum permissible concentrations in air that can be breathed without exceeding the tolerance concentrations in one or another tissue.

Material		Tolerable amount in μC, to be taken Once	Tolerable amount in μC, to be taken Daily	Max. Conc. in μC/l., to be inhaled for 8 hours per day: One day	Max. Conc. in μC/l., to be inhaled for 8 hours per day: Daily
Mixed (200 days, 0.9 Mev)	Swallowed (a)	300 (B)[1]	1.0(B)[1]	-	-
	Inhaled (b)	4.4 (L)[1]	0.015(L)[1]	0.0009	0.000003(L)[1]
Strontium	Swallowed (c)	70 (B)[1]	1.0 (B)[1]	-	-
(55 days, 0.6 Mev)	Inhaled (b)	6.6 (L)[1]	0.08(L)[1]	0.0014	0.000016(L)[1]
Iodine (8 days, 0.15 Mev)	Swallowed (d)	135 (T)[2]	1.2 (T)[3]	-	-
	Inhaled (d)	135 (T)[2]	1.2 (T)[3]	0.028	0.0003 (T)[3]
Xenon	Swallowed	-	-	-	-
	Inhaled	-	-	0.14 (E)[3]	0.014 (E)[1]

(a) 1% deposited in bone, no excretion

(b) 50% remains in lung, " "

(c) [illegible]% deposited in bone, " "

(d) 20% deposited in thyroid, no excretion

[1] To reach 0.1 r/day max. rate

[2] " " 10 r/day " "

[3] " " 1 r/day " "

The figures in row 1 (for "mixed" material) have been calculated on the assumption that the average half-life and energy of the mixed fission products are those of Ruthenium (200 days and 0.9 Mev), with 2% and 50% absorption from the gut and lung into the blood, half of this being deposited in the bone and not subsequently excreted. The tissue setting the tolerance value is indicated by the letter in parentheses, B for bone, L for lung, T for throid, E for exterior of body.

Symptoms of over-exposure

Signs and symptoms of overdosage may not appear for months or years after the exposure. If the bone tolerance is exceeded we may expect changes in the blood picture within a matter of hours, as discussed in the foregoing section. Gut and lung overexposure do not immediately manifest themselves, but may result in tumors after long exposure to amounts only slightly above the tolerance level.

Detection of Internal Fission Products

Over-exposure to fission products can be detected physically in at least two ways: by examination of the excreta for radioactive material, (and) by examination with a Geiger counter of parts of the body for gamma- radiation, which is often associated with beta- radiation and perhaps by activity of expired air. In order to treat effectively a person who has ingested or inhaled an excess of fission material, the treatment must be started immediately; once firmly deposited in bone or lung, or once passed through the gut, there is much less that can be done. Any individual suspected of over-exposure should report at once to the medical staff for check-up and treatment.

STUDY OF CHEMICAL HAZARDS IN EXTRACTION PLANT

Following is a brief summary of the principal chemical hazards which will exist in the operation of the plant. It will serve in a general way as a basis for preliminary education and for the ordering of necessary protective equipment. Additions will be made as soon as modifications in chemical procedures are decided upon.

Graphite

Respirators should be worn where the amount of the dust in the air is great, as in building and taking down of piles. Where the graphite is being machined, adequate ventilation must be installed to keep down the dust content of the air.

Nitric Acid and Nitrous fumes

Nitric acid will probably be received in carboys and removed to tanks by siphoning. Severe burns are caused by contact. The proper type of protective gloves, clothing and goggles must be worn. An emergency shower must be used immediately when appreciable exposure has occurred and goggles should not be removed until the outside of the goggles have been thoroughly washed with water. Nitric acid may cause ignition when in contact with combustible materials and explosion may occur through contact with hydrogen sulphide and certain other chemicals.

When nitric acid is spilled, nitric acid fumes are evolved and are quite dangerous. If organic or reducing materials such as sawdust, iron filings, etc., are present, nitrous fumes are evolved. Large quantities of nitrous fumes are evolved in the solution of metal with nitric acid. The dilution of this gas due to the high stack (200 ft.) will be such that probably the maximum concentration at the ground will be about 10 parts per million of air, which is a safe level. However, with a low wind velocity, this may be exceeded and it is anticipated that measurements will be made to determine the maximum concentration. While NITRIC acid fumes are dangerous to life, the patient usually has a warning in that there is severe irritation to the nose and throat and upper respiratory passages. This warning is not present with NITROUS fumes, due to its relative insolubility, the damage being mainly to the lung tissue itself in a manner similar to that of the war gas phosgene. Occasionally an individual is apparently allergic to nitrous fumes. Such individuals may develop asthmatic-like attacks on exposure to very much less concentration of gas than that tolerated by the average individual. Even with considerable exposure, the employee may have no distressing signs or symptoms for several hours. Pulmonary oedema may then develop rapidly and end fatally. For the above reasons, when there has been any exposure to nitrous fumes the employee should be sent at once to the medical division where he will be placed under observation. Cannister gas masks should be used in case of emergency conditions.

Sulphuric Acid

The fumes from sulphuric acid should be considered in the same category as those of nitric acid, and the same precautions applied. The same precautions used in handling nitric acid should be used in handling sulphuric acid. In addition, woolen clothing should be worn by men handling moderate quantities of sulphuric acid.

Sodium Hydroxide

This should be handled in a manner similar to that for acids. If either strong acid or alkali get on the skin, or in the eye, the best treatment is thorough washing with water. The patient should then be sent to the medical department. Showers should be immediately available.

Hydrofluoric acid.

This produces erythema, vesiculation, deep and progressive destruction of the tissues, suppuration and slowly healing ulcers. The gas is very soluble and inhalation produces severe irritation of the nose, throat and upper respiratory passages. Warning therefore is sufficient so that the operator immediately leaves the exposed area and the damage to the lung tissue, therefore, is minimal.

A deposit of hydrofluoric acid beneath the finger nails is particularly painful. When hydrofluoric acid comes in contact with the skin, rapid treatment with a neutralizing ointment containing magnesium oxide is essential. This special ointment for hydrofluoric acid burns should be available near the operating plant. It is valuable both for treatment and prophylaxis if exposure is anticipated. Small quantities of fluoride which produce no apparent effect when administered once, according to certain reports in the literature will lead to marked changes when their administration is continued over a long period of time. During the last fifteen years fluor spar (calcium fluoride) has been handled in large quantities in the manufacture of hydrofluoric acid at the Dye Works and a careful check of the men has failed to reveal any bony changes, any damage to the lungs, or enamel changes. It is felt that our main problem will be to protect the individuals from splashes of hydrofluoric acid on the skin, by using extreme care in handling the material and the use of protective clothing. Cannister gas masks should be available for emergencies.

Lanthanum

Lanthanum ammonium nitrate has been handled in fairly large quantities at the Linsey Light Company in West Chicago for some years. As far as they are able to determine no trouble has occurred. Crystalline material is slightly acid and so it is necessary to use rubber gloves in handling it.

Barium Nitrate

Barium is a very toxic chemical. The soluble barium salts and the carbonate and sulphide are sufficiently absorbed from the alimentary canal to produce fatal effects. The sulphate which is used in roentgen work is insoluble and nontoxic. Sodium or magnesium sulphate are antidotes for barium poisoning.

The symptoms of barium poisoning consist of vomiting, colic, violent diarrhea, convulsive tremors, slow heart pulse and high blood pressure, hemorrhages into the stomach, intestines and kidneys. Death occurs after a few hours or days. Several of the barium compounds are skin irritants. The fatal dose is probably 0.8 - 0.9 grams of the chloride. Linsey Light handle about 50 lbs. of barium chloride daily with reasonable precautions and have had no ill effects to the men. The Krebbs plant at Newport handles several tons of barium chloride and much of the sulphide and sulphate daily with no trouble to date to our knowledge. However, the only possible contact there is in sampling the chloride and reasonable care is used. The solubility of barium nitrate is 5 parts in 100 parts of water at 0° C, and 34.2 parts in 100 parts of water at 100° C; while that of barium chloride is 31 parts in 100 parts of water at 0° C and 59 parts in 100 parts of water at 100° C. Barium nitrate is slightly soluble in acid. The toxicity of barium nitrate is probably of somewhat the same order as that of barium chloride.

Workers handling this material, therefore, should be warned that the compound is very toxic when ingested, quantities of less than 1 gram being possibly fatal. Gloves should be worn to protect the hands from dermatitis and to prevent possible ingestion. Hands should be carefully washed before eating. Should any of the material accidentally be ingested, the individual should [illegible] treatment.

Potassium Dichromate and Sodium Dichromate

The chromates produce a rather characteristic nephritis and are said to produce a glycosuria. Taken by mouth the chromates produce corrosive effects and nephritis in one to forty-eight hours. Symptoms begin with sore throat, vomiting, diarrhea, albuminuria and hematuria. Nervous symptoms develop. Blood pressure is low, hemorrhages into the gastro-intestinal tract occur. Less than .5 gram of potassium dichromate may cause severe poisoning and the fatal dose is below 8 grams. These chromates are severe skin irritants. Workers handling this material should be advised of its hazardous nature and that even small doses may prove fatal. Gloves should be worn and care should be used in washing the hands before eating. Good housekeeping and cleanliness should be enforced.

Zirconium Nitrate

There has been little or no commercial use of this material for a number of years, so not much is known of what would happen when handled in commercial quantities. Dr. Edwin M. Larson, Instructor in Chemistry at the University of Wisconsin, has done more work with this material, probably, than almost anyone else. He informs us that to date he knows of no toxic effects under the usual methods of handling and that experimental work in animals has demonstrated no toxicity.

It will probably be satisfactory to handle this material in a manner similar to that of lanthanum ammonium nitrate, using rubber gloves to protect the hands. Any unusual reactions observed should be reported.

Ammonium persulfate.

This is a powerful oxidizing agent. Ingestion of even small amounts should be avoided. Gloves should be used in handling the material. Potassium persulfate may cause explosion in a fire. Ammonium persulfate should be handled with care, safe guarded in storage against mechanical injury and isolated from combustibles.

Bismuth Nitrate $Bi(NO_3)_3 \cdot 5H_2O$

This compound decomposes in cold water. As handled no special precautions need be taken except the wearing of gloves to prevent contamination of sores or abrasions with this material as Bismuth might be absorbed in this way and cause serious chronic toxic effects. Precautions should be taken to prevent ingestion.

Arsenous acid

Arsenic compounds are very toxic and are absorbed even through the intact skin. The arsenous compounds are more toxic than the arsenic compounds. They are general protoplasmic poisons.

Arsenous oxide may be harmful in amounts greater than 5 milligrams by mouth. Antidotes are of doubtful value. Care should be used in handling the material to minimize skin contact and the chance of ingestion. Gloves should be worn, protective clothes kept clean and hands should be washed before meals.

Phosphoric acid

This should be handled in the same manner as the other acids described. The above covers the more probable chemical compounds which may be handled in bulk form.

FISSION PRODUCTS

It is conceivable that in working on pipe lines, repair of centrifuges, etc., there may be contact with minute quantities of the solutions containing fission products. The waste products should be handled as strong acids or alkali. Gaseous fission products will of course be driven off through the stack. Fission products which might be encountered in the separation and purification process would be in microgram quantities. Under such conditions it is not felt that they will cause any trouble from the standpoint of chemical toxicity. However, it is conceivable that contact may be obtained with minute quantities of material at the cells, or even larger quantities of material in the waste disposal system. Antimony fluoride would be extremely irritating to the skin even in minute quantities. Gloves should be worn and coverall clothing, to prevent contamination of hands or clothing.

Krypton and Xenon. These are rare, inert gases and so require no further consideration.

Lanthanum, Praseodymium, Neodymium and Yttrium, are rare earth metals whose pharmacological and chemical properties are very similar to those of aluminum. Their chlorides precipitate protein and are therefore astringent and antiseptic. Their insoluble salts such as the oxalate are practically non-toxic by mouth, even in the enormous dose of 50 grams per dog. There should be absolutely no danger from these chemicals in the small quantities produced.

Cesium and Rubidium. These resemble potassium in their pharmacological action. These metals tend to be deposited in the bones. Rubidium iodide and bromide were introduced into therapeutics with the improbable claim that they produced less iodism and bromism. The doses are the same as those of potassium salts. Obviously microgram quantities of these compounds should cause no trouble from the chemical standpoint.

Strontium resembles calcium in its pharmocological action and could be used to replace it or sodium in some medicines. The salts are weaker and less toxic and in dilute solutions little is absorbed. Obviously it would be innocuous in small quantities.

Zirconium was discussed under the heading of "Zirconium Nitrate".

Columbium. Its uses are increasing at the present time. The importation of several hundred tons to this country and its purification and conversion to a ferro alloy with 50% to 60% cadmium is a common practice. No mention is made of [illegible]

Molybdenum is not fixed in any of the parachymatous organs and is rapidly excreted in the urine. Its only effect found to date is influence on the coagulation and sedimentation rate of the blood. A comprehensive report from the Bureau of Mines gives no reference to toxicological properties.

Antimony. There is some difference in opinion regarding the toxicity of antimony. Schrumpf and Zabel report illness in type foundry workers but it is possible that the trouble might not have been due to antimony but to lead which was also present. Johnson states he has never observed a case of antimony toxicity although his experience has been fairly comprehensive. Obviously in the small quantities handled under our conditions there is nothing to worry about.

Tellurium. The toxic action of tellurium is similar to that of inorganic arsenic, especially the toxic effects on the capillaries. However, tellurium is less toxic being rapidly reduced to the metallic state. The most outstanding effects are suppression of sweat and a very persistent garlic odor, especially of the breath due to the methyl telluride. Contact even in small quatities should be avoided by proper clothing and gloves as it will cause dermatitis and is readily absorbed through the skin. Even minute absorption results in a very unpleasant garlic odor of the breath which may persist for months and should such an odor be noticed, it should be reported to the medical office at once.

Iodine, needs no comments since the danger of radioactivity is so much greater than that of any chemical effects. The prophylactic administration of inactive KI in a daily dose of 100 mg. will adequately protect the thyroid against deposition of radioactive I, should it become necessary.

Barium has been discussed under the heading of "Barium Nitrate".

<u>Cerium</u>. Millions of pounds of this material have been handled at Linsey Light with no precautions and they state that to their knowledge no toxic effects have ever been observed.