A CLOSER LOOK AT THE DOSIME® RADIATION SAFETY DEVICE

The Early Warning Wearable that Measures Ionizing Radiation

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INTRODUCTION

Exposure to ionizing radiation can lead to DNA and tissue damage in the human body, which poses potential serious health risks over time depending on the total cumulative dose. By the end of this white paper, you'll learn how a new wearable technology is rerouting the path towards consumer empowerment in the field of radiation detection and safety.

A GLOBAL APPETITE
The wearable technology ecosystem is a rapidly growing industry that is on pace to hit $14 billion this year and is expected to hit $34 billion by 2020.

THE AGE OF WEARABLES

Wearable technology is often touted as one of the greatest applications the Internet of Things (IoT). In the future, humans will have more sensors than cars do. According to CCS Insight, consumers have already purchased millions of wearable devices, including more than 50 million smart watches and 20 million other fitness monitors.

Today fitness monitors and other wearable biosensors can tell when an individual's heart rate, skin temperature and other measures are abnormal. They can suggest the onset of a possible illness and they can now protect us from radiation that is odorless, tasteless, intangible, and invisible.

Within the Age of Wearables, the momentum to make safety a priority is growing and ushering in a new era of wearable technology designed for a consumer's protection. The wearable technology ecosystem is a rapidly growing industry that is on pace to hit $14 billion this year and is expected to hit $34 billion by 2020.

While wearable technology has historically been utilized in the military and healthcare industries, recent advances and the success of fitness trackers and smart watches have triggered a major resurgence of the concept, particularly among the consumer community and workplace community.

Employers around the globe are using wearables to increase worker safety. There are truck drivers wearing "Smart Caps" that include built-in sensors that can detect driver alertness and provide a warning to drivers when their fatigue level begins to rise. Flight crews wearing the new "Dosime" radiation wearable are able to track their exposure to cosmic ionizing radiation. Whenever radiation exposure levels exceed specified limits, the Dosime® device immediately flashes with a visual alarm and alerts the user through configurable text, email and mobile alerts.

The purpose of this white paper is to provide useful research, insight and resources to help you protect yourself and others against the threat of radiation in the world today.

Source: CCS Insight

THE STATE OF RADIATION IN THE WORLD TODAY

Radioactivity is a part of our universe - it has been part of the environment since the earth first formed. Naturally occurring radioactive materials are present in its soil and rocks, can be found in the floors and walls of our homes, schools, or offices and in the food we eat and drink. There are radioactive gases in the air we breathe. Our own bodies - muscles, bones, and tissue - even contain naturally occurring radioactive elements from the food we eat.

In fact, all forms of life on earth are constantly exposed to radiation from the soil, rocks, minerals, and from radioactivity in their bodies. We are also constantly exposed to radiation that originates from outer space and reaches earth. We call this cosmic radiation or cosmic rays.

We also receive exposure from what are called “man-made” radiation. These include X-rays, nuclear medicine radiation used to diagnose diseases, and radiation used for cancer therapy. Man-made radiation also includes small quantities of radioactive material still left in our environment from atmospheric testing of nuclear weapons that occurred in the 1950s and 1960s. Small quantities of radioactive materials released to the environment from coal and nuclear power plants are also sources of radiation exposure to man.

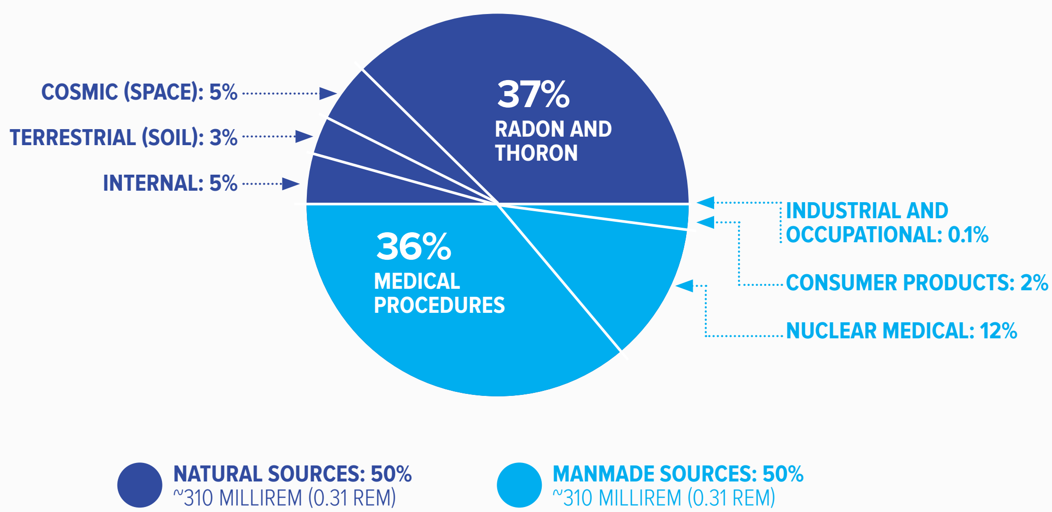
Radioactivity is the term used to describe the disintegration of atoms. Atoms have, at their very center, a collection (nucleus) of particles called neutrons and protons. The number of protons is what determines which element an atom is – every atom with 8 protons, for example, is an atom of oxygen while any atom with 82 protons in the nucleus is an atom of lead. The neutrons don’t have anything to do with which element an atom is, but they can help to keep the atomic nucleus stable. Atoms with the wrong combination of neutrons and protons are not stable – they will have too much energy in the nucleus. Therefore, their nuclei disintegrate or decay, thus releasing energy in the form of radiation. This physical phenomenon is called radioactivity and the radioactive atoms are called radionuclei. The radioactive decay is expressed in units called becquerel (Bq). One becquerel equals one disintegration per second of the radioactive material.

Source: https://www.iaea.org/Publications/Factsheets/English/radlife

As mentioned before, since the beginning of time, all living creatures have been, and are still being, exposed to radiation. Nonetheless, most people are not aware of all the natural and man-made sources of radiation in our environment.

A chart of the public's exposure to ionizing radiation (displayed below) shows that people in the United States on average receive a total annual dose of about 620 millirem (mrem) which is equal to 6.2 mSv (millisievert). Of this total, natural sources of radiation account for about 50 percent, while man-made sources account for the remaining 50 percent. The exposure to people in other countries will be somewhat different since they will have a different natural radiation environment and different access to medical radiation.

DOMESTIC RADIATION EXPOSURE
SOURCES OF RADIATION EXPOSURE IN THE UNITED STATES



Source: NCRP Report No. 160 (2009)

DOSES FROM MEDICAL PROCEDURES

MEDICAL PROCEDURE DOSES	
PROCEDURE	DOSE mrem (mSv)
X-RAYS-SINGLE EXPOSURE	
PELVIS	70 (0.7)
ABDOMEN	60 (0.6)
CHEST	10 (0.1)
DENTAL	1.5 (.015)
HAND/FOOT	0.5 (0.005)
MAMMOGRAM (2 VIEWS)	72 (0.72)
NUCLEAR MEDICINE	400 (4.0)
CT	-
FULL BODY	1,000 (100)
CHEST	700 (7.0)
HEAD	200

Medical procedures account for nearly all (96%) human exposure to man-made radiation. For example, a chest x-ray typically gives a dose of about 10 millirem and a full-body CT gives a dose of 1,000 mrem, as shown in the table to the left.

Note: 1 mrem equals 0.01 mSv

RADIOACTIVITY IN FOOD

NATURAL RADIOACTIVITY IN FOOD		
FOOD	**40K** (PCI/KG)	**226RA** (PCI/KG)
BANANAS	3,520	1
CARROTS	3,400	0.6 – 2
WHITE POTATOES	3,400	1 – 2.5
LIMA BEANS (RAW)	4,640	2 – 5
RED MEAT	3,000	0.5
BRAZIL NUTS	5,600	1,000 – 7,000
BEER	390	---
DRINKING WATER	---	0 – 0.17

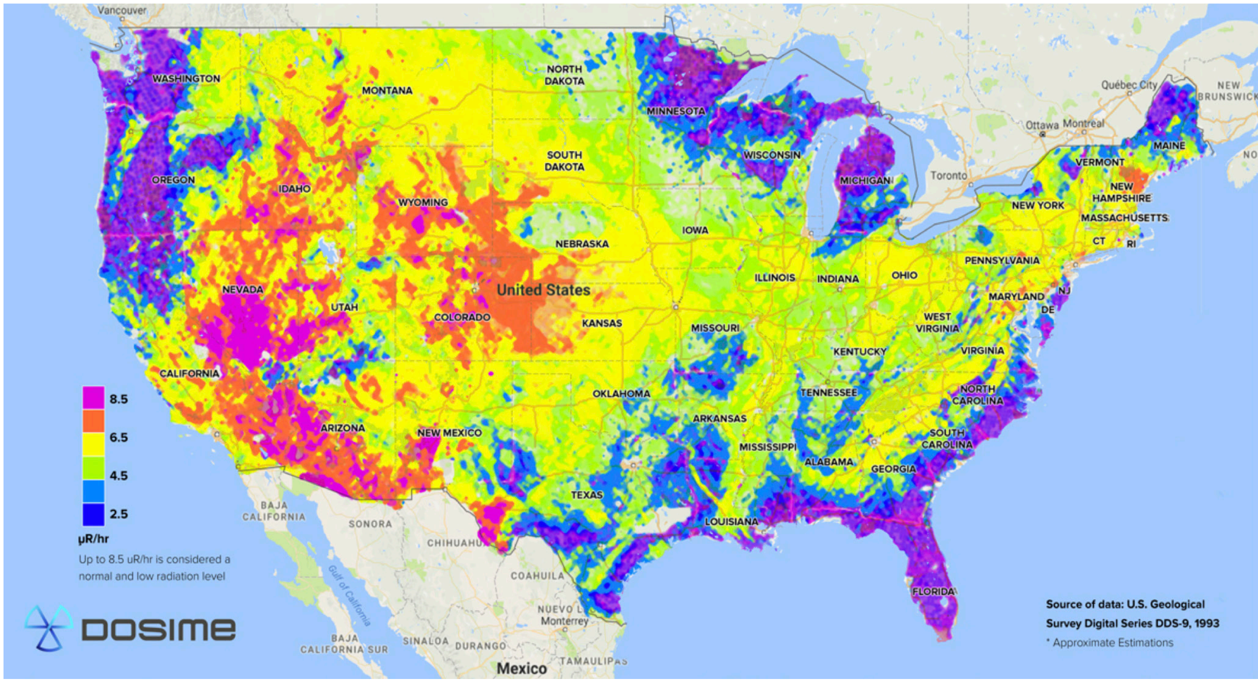
All organic matter (both plant and animal) contains some small amount of radiation from radioactive potassium-40 (40K), radium-226 (226Ra), and other radioisotopes such as carbon-14. In addition, all water on Earth contains small amounts of dissolved uranium and thorium. As a result, the average person receives an internal dose of about 3 mrem (0.03 mSv) of these materials per year from the food and water that we eat and drink, as illustrated by the following table. (Amounts are shown in picocuries (pCi) per kilogram. Twenty-seven pCi equal one becquerel)

We live in a radioactive world, and radiation has always been all around us as a part of our natural environment. As explained above, the annual average dose per person from all sources is about 360 mrem (3.6 mSv), but it is not uncommon for any of us to receive more than that average dose in a given year (largely as a result of medical procedures).

Source: https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html

MAP IT: RADIATION MAP AND DESCRIPTOR

Radiation Exposure Across the U.S.



The above map of the U.S. displays the variation in radiation exposure from 2.5 to 8.5 µR/hr (microR/hr) which is almost equal to 0.003 to 0.009 mrem/hr. Exposure, measured in units of Roentgens (R) is an older unit of radiation dose. The variation is the result of increased cosmic radiation due to altitude as well as due to terrestrial background depending on ground and building materials containing natural occurring radioactive material. For example, the higher radiation doses in the western USA is related to both altitude and geology

Source: U.S. Geological Survey Digital Series DDS-9, 1993

ELEVATION MATTERS.
The annual dose of naturally occurring radiation that people receive primarily depends on geology and elevation — whereas the higher the altitude, the higher the annual dose.

TABLE 1: TOTAL AVERAGE ANNUAL DOSES (MREM/YEAR EDE) FROM COSMIC RADIATION, TERRESTRIAL RADIATION, AND INDOOR RADON

STATE	COSMIC	TERRESTRIAL	RADON	TOTAL
Alabama	27.1	22.5	170	219.6
Alaska	26.6	29.2	97	152.8
Arizona	31.5	29.2	250	310.7
Arkansas	27.5	19.1	142	188.6
California	26.8	23.2	126	176
Colorado	47.5	42.6	610	700.1
Connecticut	26.4	32.7	180	239.1
Delaware	26.3	20.1	112	158.4
District of Columbia	26.4	22.7	no data	not enough data
Florida	26.2	14.3	91	131.5
Georgia	27.6	25.7	273	326.3
Hawii	26.3	29.2	no data	not enough data
Idaho	36.8	29.2	342	408
Illinois	27.4	26.6	343	397
Indiana	27.6	28.7	401	457.3
Iowa	28.3	29.2	727	784.5
Kansas	29.2	29.2	474	532.4
Kentucky	27.7	27.8	470	525.5
Louisiana	26.6	14.6	no data	not enough data
Maine	26.8	29.2	286	342
Maryland	26.4	20.7	476	523.1
Massachusetts	26.4	29.0	228	283.4
Michigan	27.6	29.2	226	282.8
Minnesota	28.5	25.1	383	436.6
Missisippi	26.6	14.6	160	201.2
Missouri	27.6	28.7	350	406.3
Montana	36.3	29.2	no data	not enough data
Nebraska	29.3	29.2	361	419.5
Nevada	36.6	21.2	164	221.8
New Hampshire	27.3	29.2	378	434.5
New Jersey	26.2	28.0	98	152.2
New Mexico	45.7	33.7	269	348.4
New York	26.5	28.8	223	278.3
North Carolina	27.8	24.4	268	320.2
North Dakota	29.9	29.2	730	789.1
Ohio	27.7	28.0	417	472.7
Oklahoma	29.0	28.8	247	304.8
Oregon	27.4	29.2	99	155.6
Pennsylvania	27.2	23.2	293	343.4
Rhode Island	26.3	27.4	no data	not enough data
South Carolina	25.9	23.4	no data	not enough data
South Dakota	30.7	29.2	903	962.9
Tennessee	27.6	25.1	511	563.7
Texas	28.1	18.2	165	211.3
Utah	41.8	29.2	196	267
Vermont	27.3	29.2	no data	not enough data
Virginia	27.2	21.4	260	308.6
Washington	26.9	29.2	79	135.1
West virginia	28.9	29.9	197	255.8
Wisconsin	27.8	29.2	293	350
National Average	29.5	26.6	303	359 (294)

Source: Assessment of Variations in Radiation Exposure in the United States, Prepared for the U.S. Environmental Protection Agency, S. Cohen & Associates, July 2005

DEMYSTIFYING RADIATION

TYPES OF RADIATION

The term radiation is very broad, and, to a scientist, it includes such things as light and radio waves, which are considered non-ionizing radiation. In our context it refers to ionizing radiation, which means that this type of radiation has sufficient energy to produce an electrical imbalance in some forms of matter. Because such radiation passes through matter, it can cause it to become electrically charged or ionized. In living tissues, the electrical ions produced by radiation can affect normal biological processes and may lead to long-term damage to cells.
There are various types of radiation, each having different characteristics. The common ionizing radiations generally talked about are:

- Alpha radiation consists of heavy, positively charged particles emitted by atoms of elements such as uranium and radium. Alpha radiation can be stopped completely by a sheet of paper or by the thin surface layer of our skin (epidermis). However, if alpha-emitting materials are taken into the body by breathing, eating, or drinking, they can expose internal tissues directly and may, therefore, cause biological damage.

- Beta radiation consists of electrons. They are more penetrating than alpha particles and some can pass through a centimeter of water. Beta radiation is much less damaging to the body than alpha radiation, and it can only damage the skin (unless it's taken into the body).

- Gamma rays are electromagnetic radiation similar to light, and radio waves. Gamma rays, depending on their energy, can pass right through the human body, but can be stopped by thick walls of concrete or lead. Gamma radiation is also much less damaging to the body than alpha radiation. X-rays are similar to gamma rays but generally are lower in energy and thus less penetrating.

- Neutrons are uncharged particles and do not produce ionization directly. However, their interaction with the atoms can give rise to alpha, beta, gamma, or X-rays which then can produce ionization. Neutrons are penetrating and can be stopped only by thick masses of concrete, or substances with a lot of hydrogen such as water or paraffin.

Although we cannot see or feel the presence of radiation, it can be detected and measured in the most minute quantities with fairly simple radiation measuring instruments.

RADIATION PROTECTION

Something to remember is that humanity has over a century's worth of experience in working with radiation; in that time, we have learned a great deal about how radiation can affect our health as well as how we can manage the risks and work safely with radiation. Much of today's radiation protection work practices date back to the formation of an international advisory committees – the forerunners of what is known today as the International Commission on Radiological Protection (ICRP). These work practices and the ICRP's recommendations over the last 90 years have been adopted by international Organizations such as the International Atomic Energy Agency (IAEA), World Health Organization (WHO) and the International Labor Organization (ILO) and the Nuclear Energy Agency (NEA) and they form the basis of radiation safety work practices throughout the world.

Basic approaches to radiation protection are consistent all over the world. The ICRP recommends that any exposure above the natural background radiation should be kept as low as reasonably achievable, but below specific dose limits. The individual dose limit for radiation workers averaged over 5 years is 10,000 mrem (100 mSv), and for members of the general public, is 100 mrem (1 mSv) per year from exposure while in an unrestricted area from a facilities operation. These dose limits have been established based on a conservative (meaning over-protective) approach by assuming that there is no threshold dose below which there would be no effect. It means that any additional dose will cause a proportional increase in the chance of a health effect.

There are many high natural background radiation areas around the world where the annual radiation dose received by members of the general public is several times higher than the ICRP dose limit for radiation workers. The numbers of people exposed to such doses are too small to expect to detect any increases in health effects epidemiologically. Still the fact that there is no evidence so far of any increase does not mean the risk is being totally disregarded.

AT WHAT LEVEL IS RADIATION HARMFUL?

The effects of radiation at high doses and dose rates are reasonably well documented. At low doses, such as would be experienced from the daily exposures from the aforementioned activities, the probabilities of harm would be exceedingly low. Yet the chronic doses are cumulative over one's lifetime, and therefore the exposure to man-made radioactive sources has been advised to be kept "As Low As Reasonably Achievable (or ALARA)" according to the International Commission of Radiological Protection (ICRP). This practice is aimed to reduce the onset of long-term effects such as cancers. However, exposure at elevated doses may cause direct bodily harm, or sometimes even death at an extremely high dose levels; such as could be experienced from the act of war (such as in Hiroshima and Nagasaki during WWII), major nuclear power plant accidents (such as Chernobyl or Fukushima accidents), or terrorist events (using radiological dispersal devices or improvised nuclear devices) .Thus knowing how to avoid or reduce the exposure to radiation sources is crucial to protection against the potential harms

At low doses of radiation, there is still considerable uncertainty about the overall effects. It is presumed that exposure to radiation, even at the levels of natural background, may involve some additional risk of cancer. However, this has yet to be established, at least statistically.

To determine precisely the risk at low doses by epidemiology would mean observing millions of people at higher and lower dose levels. Such an analysis would be complicated by the absence of a control group which had not been exposed to any radiation. In addition, there are thousands of substances in our everyday life besides radiation that can also cause cancer, including tobacco smoke, ultraviolet light, asbestos, some chemical dyes, fungal toxins in food, viruses, and even heat. Only in exceptional cases is it possible to identify conclusively the cause of a particular cancer.

RISKS AND BENEFITS

We all face risks in everyday life. It is impossible to eliminate them all, but it is possible to reduce them. The use of coal, oil, and nuclear energy for electricity production, for example, is associated with some sort of risk to health, however small. In general, society accepts the associated risk in order to derive the relevant benefits. Any individual exposed to carcinogenic pollutants will have some risk of getting cancer. Strenuous attempts are made in the nuclear industry to reduce such risks to as low as reasonably achievable.

Radiation protection sets examples for other safety disciplines in two unique respects:

- First, there is the assumption that any increased level of radiation above natural background will carry some risk of harm to health.
- Second, it aims to protect future generations from activities conducted today.

The use of radiation and nuclear techniques in medicine, industry, agriculture, energy and other scientific and technological fields has brought tremendous benefits to society. The benefits in medicine for diagnosis and treatment in terms of human lives saved are enormous. Radiation is a key tool in the treatment of certain kinds of cancer. Three out of every four patients hospitalized in the industrial countries benefit from some form of nuclear medicine studies. The beneficial impacts in other fields are similar.

No human activity or practice is totally devoid of associated risks. Radiation should be viewed from the perspective that the benefit from it to mankind is less harmful than from many other agents. Based on such considerations, the ALARA Principle has become a major guiding direction for protection against radiation exposure by ICRP.

Source: https://www.iaea.org/Publications/Factsheets/English/radlife

HOW THE DOSIME® DEVICE WORKS

WHAT IS THE DOSIME® DEVICE?

- The Dosime® device is a hybrid smart home and wearable personal dosimeter that captures real-time ionizing radiation exposure in one's environment.

- The Dosime® device is connects to a mobile app that provides an immediate assessment of the ionizing radiation levels in the area

HOW DOES IT WORK?

The Dosime® device measures in ionizing radiation exposure and tracks a person's cumulative dose over time. If the device detects a radiation dose rate that exceeds a predetermined threshold limit, the user is immediately alerted with a visual alarm on the dosimeter or cradle and an audible alarm on their smart phone—along with configurable text and email alerts.

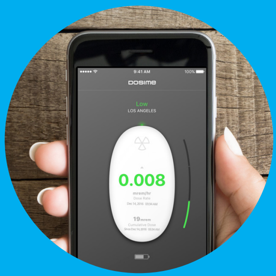
The device can be used in two modes—"home mode" when it is docked in its cradle and charging—and wearable "go mode" when it is undocked and on the move.

Home mode is activated when the device is in its cradle and plugged into an AC outlet. When connected to Wi-Fi, radiation records are transmitted via the cradle to the Host Server. This information can be accessed via your phone, laptop or smart watch. When connected to your phone or laptop the Dosime® device transmits ionizing radiation records to the host server automatically through either a Wi-Fi or cellular network.

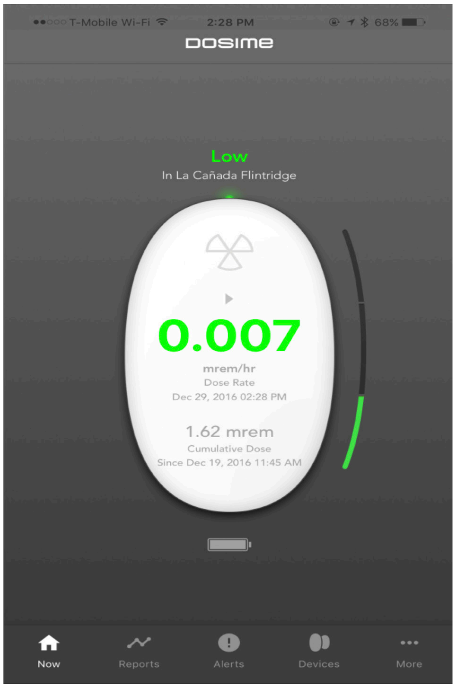
In the wearable go mode the smart watch will show live radiation data when the phone is connected to the device. When not connected to a smart device, the device continues to collect and store your radiation records on the Dosime® device. These records will then be shared to the Host Server when the device is returned to its Wi-Fi connected cradle.

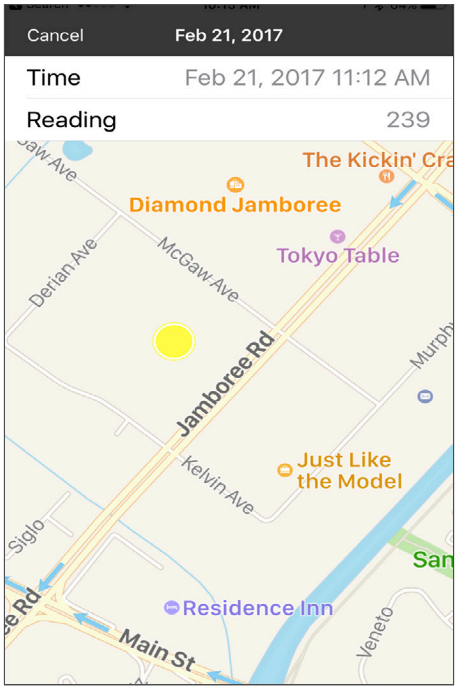
WEAR IT OR PLUG IT INTO YOUR WALL SOCKET

The radiation sensitive detectors in the Dosime® device actively monitor the radiation environment and provide an alert if there is a potentially harmful ionizing radiation dose rate.



The Dosime device provides visual cues and user configurable notifications via text, email and Smartphone Notifications, to simplify personal radiation monitoring and awareness. This Now Screen displays an expected “normal” background dose rate for this geographical area:





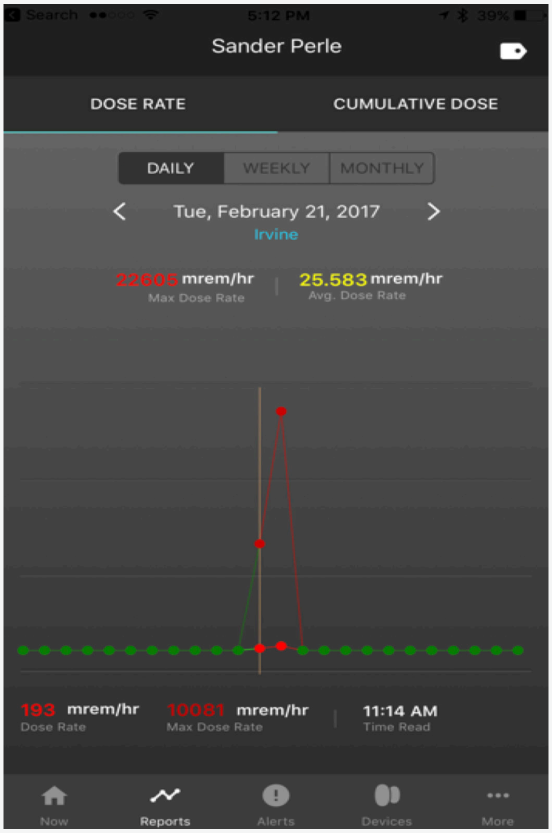
ALERTS:

GREEN (LOW) <10 mrem/hr:
When the Dosime device blinks green, everything is OK. Dose rate fluctuation between 0.005 mrem/hr and 0.030 mrem/hr is normal. Variation can be due to factors such as altitude and naturally occurring radioactive materials in surroundings. Higher readings that still show as Green can be due to procedures such as diagnostic radiology, high altitude flights and building materials containing radioactive material.

AMBER (ELEVATED) >10 mrem/hr AND <100 mrem/hr:
When the Dosime device blinks Amber, your risk of radiation exposure has significantly increased above a normal, naturally occurring rate. Annual public dose limit may be reached within 1 to 10 hours when in the “amber zone.” Move to an area where the dose rate decreases to the Green level (low levels of radiation). If you are outside and you know the source of the radiation, move away from it or get inside a building and stay there. If you do not know the source of radiation, or if you believe the source to be outside, stay inside (shelter in place).

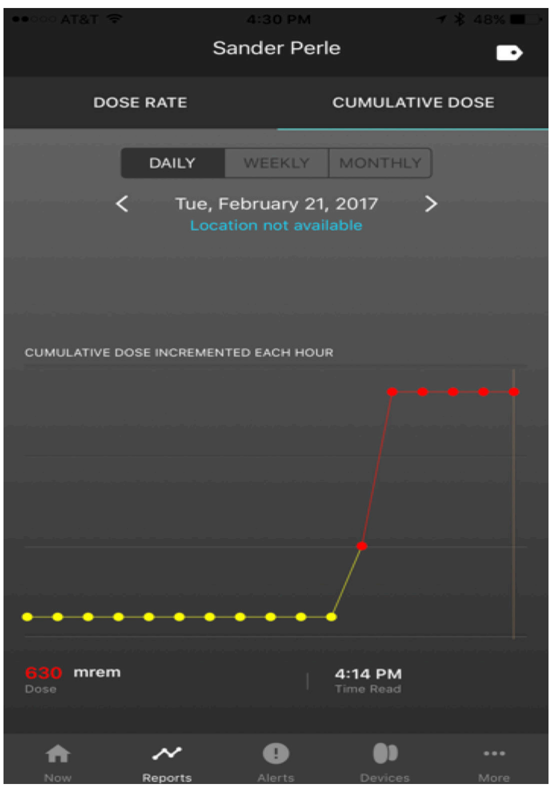
RED (SEVERE) >100 mrem/hr:
When the Dosime device blinks red, you are at a high risk of excessive radiation exposure in your area. Annual public dose limit may be reached within 1 hour when in the “red zone.” Move to an area where the dose rate decreases to the Green level (low levels of radiation). If you are outside and you know the source of the radiation, move away from it or get inside a building and stay there. If you do not know the source of radiation, or if you believe the source to be outside, stay inside (shelter in place).

By going to the Alerts Screen the individual can see all of the Alerts as well as view the Mapping of the area where the Alert occurred:



THE REPORTS SCREEN PROVIDES THE FOLLOWING INFORMATION (DOSE RATE):

- Maximum Dose Rate (mrem/hr) for the Day
- Average Dose Rate (mrem/hr) for the Day
- Location based data
- Clickable Data Point for each hour within the day displaying the Dose Rate, Maximum Dose Rate within the hour and Time Read



THE REPORTS SCREEN PROVIDES THE FOLLOWING INFORMATION (CUMULATIVE DOSE):

- Cumulative Dose (mrem) Incremented Each Hour
- Clickable Data Point for each hour within the day displaying the Cumulative Dose and Time Read

WHO BENEFITS MOST?

State and federal regulations require that specific groups of people have their radiation exposure monitored, but there are many people who we know are exposed to higher-than-normal levels of radiation who are not required to be monitored. Frequent business travelers and flight crew, for example, are exposed to elevated levels of cosmic radiation when they're in the air, but there's no regulatory requirement to monitor their radiation exposure. People working at veterinary clinics, around x-ray testing equipment (x-rays are often used for quality assurance testing in factories), in medical centers, and other locations where radiation is used are also exposed to radiation from the x-ray machines they work around, but they, too, are not always required to be issued radiation dosimetry. These people might want to monitor their own radiation exposure, even if it's not required by regulations, to keep track of how much radiation they receive from their jobs.

Others who might want to monitor their radiation exposure, are those living near nuclear facilities. And, while we don't expect that our nuclear reactors or military bases will suffer accidents that would release radiation and radioactivity into the environment, we also know that it has happened. Having your own radiation measurements will enable you to know for yourself whether or not you're being exposed to higher levels of radiation and, if so, whether or not you're safe.

The overwhelming majority of the time the radiation is not going to be dangerous – in fact, after both the Three Mile Island and the Fukushima accidents there was no immediate risk from radiation exposure to people near the sites. In cases like that, the radiation dosimetry can actually give you peace of mind by providing reassurance. And if radiation levels are possibly dangerous – as happened after the Chernobyl accident – the radiation dosimetry can immediately alert you, and it can even help you to find a safe place to shelter until it's safe to evacuate. Along these same lines, if you are ever exposed during any sort of radiation accident or incident, having your dosimetric information can help your physician to figure out if you were exposed to enough radiation to cause health concerns.

Along these same lines, you have to remember that we all live our lives in a radiation environment. Having a way to measure radiation dose levels you normally expect to see will help you to better understand this environment. But more importantly, you can't know if the levels of radiation have increased unless you know what they normally are. And if there is an accident, you can't know if the radiation levels have returned to normal unless you know what "normal" is in your neighborhood or home.

Finally, you or member of your family might have had a nuclear medicine procedure – millions of people around the world have these procedures every year. If you have had a procedure like this, it's only natural to wonder how much radiation exposure your family members – especially your children – might be receiving from the radioactivity in your body. Here, too, some sort of dosimeter for them to wear might be useful.

CASE STUDY: RADIATION & AIR TRAVEL

Airline crewmembers have tough jobs. They have to maintain passenger and aircraft safety. But flight attendants and pilots also face an invisible force on the job: Cosmic radiation. Those who spend a lot of time high up in the atmosphere — flight crews, for instance — face much higher exposure to cosmic radiation because flying exposes us to additional cosmic background radiation because we are at a greater height above the Earth's surface. This following case study explores estimated cosmic radiation doses for flight personnel in effort to shed light on radiation facts and figures in the friendly skies.

FENG YJ, CHEN WR, SUN TP, DUAN SY, JIA BS, ZHANG HL.

Estimated cosmic radiation doses for flight personnel. Space Med Med Eng 15(4):265–269; 2002.

The average effective dose rate of all flights of Xinjiang Airlines from 1997 to 1999 was 2.38 µSv h-1. The average annual cosmic radiation dose for flight personnel was 2.19 mSv (1 mSv equals 100 mrem). Annual individual doses of all monitored flight personnel are well below the limit of 20 mSv y-1 recommended by the International Commission on Radiological Protection (ICRP).

BOTTOLLIER-DEPOIS JF, CHAU Q, BOUISSET P, KERLAU G, PLAWINSKI L, LEBARON-JACOBS L.

Assessing exposure to cosmic radiation during long-haul flights. Radiat Res 153(5 Pt. 1):526–532; 2000.

The lowest dose rate measured was 3 µSv h-1 (0.3 mrem h-1) (1 mrem equals 10 µSv) during a Paris-Buenos Aires flight. The highest rates were 6.6 µSv h-1 (0.66 mrem h-1)during a Paris to Tokyo flight and 9.7 µSv h-1 (0.97 mrem h-1)on the Concorde in 1996–1997. The corresponding annual effective dose, based on 700 hours of flight for subsonic aircraft and 300 hours for the Concorde, can be estimated at between 2 mSv (200 mrem) for the least exposed routes and 5 mSv (500 mrem) for the more exposed routes.

WATERS M, BLOOM TF, GRAJEWSKI B.

The National Institute for Occupational Safety and Health/Federal Aviation Administration (NIOSH/FAA) working women's health study: Evaluation of the cosmic-radiation exposures of flight attendants. Health Phys 79(5):553–559; 2000.

Radiation dose levels represent a complex function of duration of flight, latitude, and altitude. Based on data collected for this study, radiation dose levels that would be experienced by a flight crew are well below current occupational limits recommended by the ICRP and the FAA of 20 mSv y-1 (2,000 mrem y-1). The National Council on Radiation Protection and Measurements (NCRP) recommends a monthly equivalent dose limit of 0.5 mSv (50 mrem). The ICRP recommends the radiation limit during pregnancy be 1 mSv (100 mrem). Only flight crews flying both a large number of hours during pregnancy (for example, 100 hours in a month) and strictly the highest dose-rate routes (typically global routes such as United States to Buenos Aires or United States to Tokyo) would exceed the NCRP monthly guideline.

FRIEDBERG W, COPELAND K, DUKE FE, O'BRIEN K 3RD, DARDEN EB JR.

Radiation exposure during air travel: Guidance provided by the FAA for air carrier crews. Health Phys 79(5):591–595; 2000.

- Seattle to Portland: 0.03 mSv (3 mrem) per 100 block hours
- New York to Chicago: 0.39 mSv (39 mrem) per 100 block hours
- Los Angeles to Honolulu: 0.26 mSv (26 mrem) per 100 block hours
- London to New York: 0.51 mSv (51 mrem) per 100 block hours
- Athens to New York: 0.63 mSv (63 mrem) per 100 block hours
- Tokyo to New York: 0.55 mSv (55 mrem) per 100 block hours

OKSANEN PJ.

Estimated individual annual cosmic radiation doses for flight crews. Aviat Space Environ Med 69(7):621–625; 1998.

- In this study, crew members averaged 673 block hours and pilots 568 block hours.
- Average annual cosmic ray dose for cabin crews was 2.27 mSv (227 mrem).
- Average annual cosmic ray dose for long-distance flight captains was 2.19 mSv (219 mrem)

Source: Health Physics Society, "Ask the Expert"

RADIATION & AIR TRAVEL: ASK THE EXPERT

I understand that the radiation dose while flying diminishes as you get closer to the equator. Is this true?

Because incoming cosmic radiation particles are deflected by the Earth's magnetic field, the intensity of in-flight radiation is a function of both altitude and latitude. In general, radiation shielding by the geomagnetic field is greatest at the equator and decreases as one goes north or south. At typical flight altitudes of 9,000 to 12,000 meters (30,000-40,000 feet), the difference between the cosmic ray dose rates at the equator and at high latitudes is about a factor of two to three, depending on where one is in the approximately 11-year solar cycle. So if all your flying is in the equatorial zone, you would expect that the dose rates at altitude are two to three times lower than for your colleagues flying more northern or southern routes. Of course, your total exposure will be a function of the hours you spend at altitude. In any case, your annual radiation burden will be well within the limits considered acceptable for occupational exposure by such organizations as the ICRP.

Have there been studies of long-term, low-level exposure to radiation during commercial flights and the effects for flight crews?

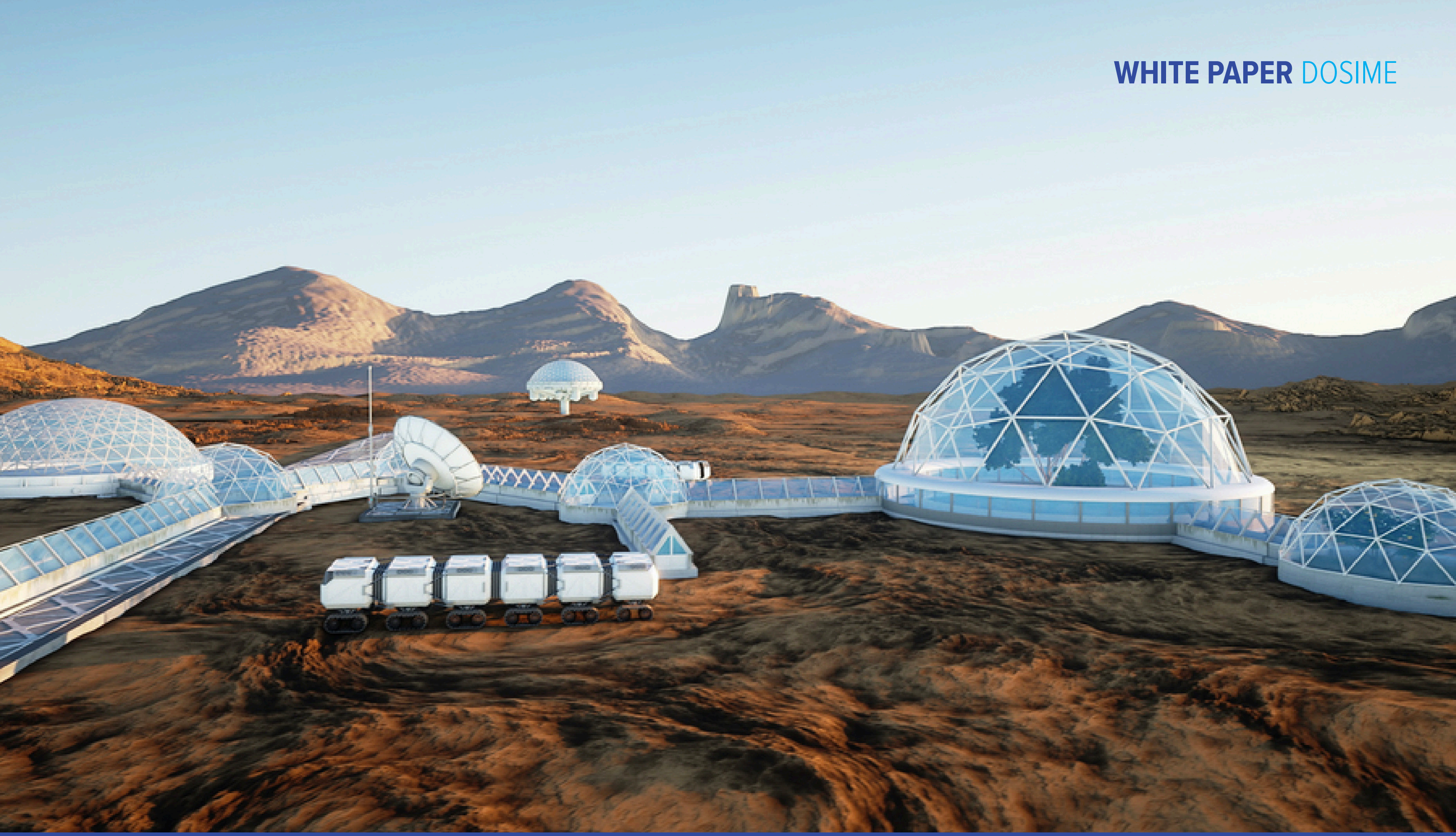
At present, the Airline Pilots Association is conducting dosimetry studies for its membership and NIOSH is engaged in a study of reproductive disorders among flight attendants. Several studies have already been published; some show an increase in various malignancies among crew members while others show no increased risk. The following references all present data showing an increase in malignancies among flight crew members with the exception of the second British Airways paper which, as discussed above, reevaluates data published in the earlier reference. These papers can be obtained through your local library.

For pilots flying below 1,800 meters (5,905 ft.) for 200 hours a year is there any danger from cosmic radiation?

Even at ground level, cosmic radiation is part of our normal environment. The Earth's atmosphere absorbs this radiation, so its intensity is least at ground level. The altitude of interest in this question (1,800 meters) is, of course, ground level in many places. Using the **CARI-6 program** available from the FAA, the calculated cosmic-ray dose rate at this altitude at high geographic latitude is about 0.0001 mSv h-1 (0.01 mrem). It would, therefore, require 10,000 hours of flying at this altitude to reach the 1 mSv (100 mrem) annual limit recommended as a maximum for members of the public exposed to ionizing radiation. It should also be noted that exposures well above this 1 mSv limit are not "dangerous."

Is there any specific limit for air travel for children?

An annual radiation dose limit of 100 mrem (1 mSv) for members of the public has been recommended by both the NCRP here in the United States and by its overseas counterpart, the ICRP. In June 2003 the Health Physics Society, the organization of radiation protection professionals that sponsors this website, reaffirmed that these limits are appropriate. This recommended limit, unchanged for more than 10 years, has generally been adopted into law or regulation by the government agencies that mandate radiation protection programs. No distinction is made between the exposure of adults or minors. However, radiation exposure to the flying public (versus someone who works as a crew member) is not regulated; it is considered a "voluntary" activity. So at least as far as any legal limits are concerned, there are none for this category of exposure, for adult flyers or anyone else.



RADIATION & COLONIZING MARS

If it were possible to colonize Mars in our lifetime, would you go? Did you know thousands have already applied to become one of four astronauts selected to set up a human colony?

A few months before he died, Carl Sagan recorded a message of hope to would-be Mars explorers, telling them: “I’m glad you’re on Mars. And I wish I was with you.”

More than two decades after the pioneering astronomer set out his hopeful vision of the future in 1996, a company from the Netherlands is proposing to turn Sagan’s dreams of reaching Mars into reality. The company, “Mars One” plans to send four astronauts on a trip to the Red Planet to set up a human colony in 2023. But there are a couple of serious snags including radiation --something we know much about. According to the Smithsonian, radiation remains a problem for any mission to Mars. Engineers have yet to nd ways to protect astronauts from cosmic rays and solar radiation–and NASA agrees.

DOMES AS HOMES.

To minimize radiation, the project Mars One team would cover the domes they plan to build with several meters of soil, which the colonists will have to dig up.

According NASA, space radiation is the tallest hurdle to future travel plans to Mars. On the International Space Station, astronauts are bombarded with 10 times as much radiation as they experience here on Earth. On Mars, it is estimated by scientists, that they will encounter more than 100 times this dose throughout the journey.

Throughout the entire trip, astronauts must be protected from two sources of radiation. The first comes from the sun. These energetic particles are almost all protons and they can somewhat be shielded by the structure of the spacecraft.

The second source of energetic particles come from galactic cosmic rays. They accelerate to near the speed of light then shoot into our solar system from other stars in the Milky Way. Some of them are heavy elements, ranging from helium up to the heaviest elements. This can reach a dangerous level that is hard to protect against.

NASA has been hard at work on this problem with research projects like the Twins Study and the One Year Mission, with on-the-ground facilities like the Space Radiation Laboratory, and with biology research in laboratories.

The biggest lingering question about SpaceX's Mars colonization plans–is also radiation. SpaceX's CEO Elon Musk has avowed to create a self-sustaining Mars colony of 1 million people over the next 40 to 100 years. Analysts agree that SpaceX knows how to design the next generation of rockets. And Musk has a clear vision for the types of vehicles he wants to build to make a Mars settlement do-able, too. Analysts believe he can deliver capable spacecraft. Yet many wonder, can he help engineer out the problem of increased levels of radiation that people will experience on a trip to Mars?

RESEARCHERS ARE EXPLORING THREE KEY VARIABLES IN EFFORT TO COMBAT RADIATION ON MARS:

TIME

If SpaceX can create faster rockets, astronauts can spend less time in transit. They can time trips for low-emission points in the solar cycle that also put Earth close to Mars. Solutions might include advanced propulsion techniques.

BARRIERS

Perhaps better barriers between astronauts and space can be constructed? Experts predict advances in nanotechnology and materials may help.

MEDICINE

Researches are working on developing drugs that undo or protect against bodily harm when radiation particles do penetrate the skin

> "The space radiation environment will be a critical consideration for everything in the astronauts' daily lives, both on the journeys between Earth and Mars and on the surface, you're constantly being bombarded by some amount of radiation."
>
> Ruthan Lewis, Engineer at NASA

QUESTIONS, FACTS AND FIGURES

What is Dosime®?

Dosime® is a personal radiation dosimeter that is both wearable as well as a home smart monitoring device.

What is a personal radiation dosimeter?

A personal radiation dosimeter is a device that measures exposure to ionizing radiation. It has two main uses: for human radiation protection and for measurement of dose in the environment, medical and industrial areas.

What is ionizing radiation?

Ionizing radiation has so much energy it can knock electrons out of atoms, a process known as ionization. Ionizing radiation can affect the atoms in living things, so it poses a health risk by damaging tissue and DNA in genes. Ionizing radiation comes from radioactive elements, cosmic particles from outer space and x-ray machines.

What type of radiation does the Dosime® device measure?

The Dosime® device detects, measures and reports x-ray and gamma ionizing radiation.

Does the Dosime® device measure radiation from a microwave oven, radar or ultraviolet?

No, the Dosime® device only detects ionizing radiation.

What type of sensor is used in the Dosime® product and could it be used for fluoroscopy procedures?

The Dosime® device uses two Silicon diodes that are very sensitive for measuring ionizing radiation, x-ray and gamma photons. The Energy Response is flat from 30 keV to 6 MeV and a dose rate of 0.003 mrem/hr to 100 R/hr. The device is appropriate for any radiation measurements where the radiation is either x-ray or gamma, and is therefore ideal for fluoroscopic monitoring procedures.

How does the Dosime® product compare to other dosimeter technologies that users wear and turn in at the end of each month?

The important distinction is when you ask “turn in at the end of each month”. A passive dosimeter is worn and then returned where the individual has no data on their dose received until the dosimeter is returned, received, processed and then reported, taking up to an additional two weeks in some cases. The Dosime® device provides real-time dose rate as well as the cumulative dose. The Dosime® device Type Test data demonstrates superior performance in energy respopnse, linearity, dose rate response and angular response.

How does the Dosime® device report radiation exposure and dose?

The Dosime® device reports radiation exposure in unit of millirem/hour (mrem/hour) and dose in unit of millirem (mrem).

What is the definition of a mrem?

The millirem is a unit of absorbed radiation dose and is often used for the dosages commonly encountered, such as the amount of radiation received from medical x-rays and background sources.

How will I know if I am in a radiation environment that may be potentially harmful?

The Dosime® Now Screen displays dose rate (mrem/hour) and cumulative dose (mrem) in Low (Green), Elevated (Amber) and Severe (Red).

What is typical radiation background?

On average, a U.S. resident receives an annual radiation exposure from natural sources of about 310 millirem. Radon and thoron gases account for two-thirds of this exposure. Cosmic, terrestrial, and internal radiation account for the rest.

Besides background radiation, what other routine sources of radiation can I be exposed to?

Man-made sources of radiation from medical, commercial and industrial activities contribute roughly 310 mrem more to our annual exposure. Computed tomography (CT) scans, which account for about 150 mrem, are among the largest of these sources. A Chest CT scan results in between 600–1800 mrem. About another 150 mrem each year comes from other medical procedures. Some consumer products such as tobacco, fertilizer, welding rods, exit signs, luminous watch dials and smoke detectors contribute about 10 mrem per year. The average annual U.S. radiation dose is 620 mrem.

Can the Dosime® device be worn when I or a member of my family are undergoing a radiological or nuclear medicine procedure?

The Dosime® device can be worn if allowed by the facility and does not interfere with the procedure being performed.

What unusual source of radiation can I be exposed to that the Dosime® device will detect?

The Dosime® device will potentially detect radiation from being near an individual that has undergone a nuclear medicine procedure, depending on the procedure and amount of radioactive material used in the procedure; a radioactive dirty bomb; a large release of radioactive gas from a nuclear facility as well as other sources.

I travel a lot. Will my Dosime® device detect this radiation?

Yes, the Dosime® device will detect radiation exposure during airline travel. A typical airline flight exposes the individual to approximately 0.5 mrem/hour. A New York-Tokyo flights for airline crew is typically 900 mrem/year.

What should I do if my Dosime® device displays an Amber or Red Alert?

Click on the Alert and appropriate information is provided. “Move to an area where the dose rate decreases to the Green level (low levels of radiation). If you are outside and you know the source of the radiation, move away from it or get inside a building and shelter in place. If you do not know the source of radiation, or if you believe the source to be outside, stay inside (shelter in place).”

How will I know that the battery is low?

The Dosime® battery remaining is displayed. Simply place the Dosime® device in the Cradle and recharge the device.

How long does the Dosime® battery last?

Generally the Dosime® battery will retain a charge about 10 days, and the battery remaining can be visually checked.

CROWDSOURCING SAFETY: DOSIME® HOTSPOTS

As more devices are located in an area, crowdsourcing is capable for mapping geographical areas. In that radiation can't be seen, touched, smelled or felt, the only way an individual will be aware that they are in a radiation exposed situation is to have a radiation detecting device. With a Dosime device on their person, they will be aware of the variation in radiation exposure while they are in their home, out walking, driving, going to work, school or the store and in the event an unexpected increase in radiation exposure occurs, they will be immediately alerted to this changing situation, from a normal radiation background to an elevated or even a severe radiation level. With knowledge comes empowerment, and the individual can take the necessary actions to leave this higher than expected radiation area and move to a lower background dose rate area, minimizing any potential adverse consequences.

An individual with a radiation detector becomes the eyes for public safety officials and are capable of alerting the appropriate authorities that there is an unexplained increase in radiation exposure in a specific area, allowing the radiation experts to assess the area and take appropriate public safety measurements to eliminate the potential for harm to the citizens in the area.

There have been many examples of where the public relied on government and public safety entities to inform them that there was a situation that involved exposure to various levels of radiation that have not been timely or accurate. These incidents included the Three Mile Island nuclear accident, Chernobyl and more recently Fukushima. It is essential for the public to be prepared in case of radiation accidents, acts of terrorism (dirty bomb, IED), and even acts of war. Note that Federal agencies are actively preparing for the latter, and they may be seen as almost inevitable. With a personal radiation dosimeter, the public is empowered to be aware of the environment around them and to take the necessary steps to protect their families as well as other individuals in the surrounding area, by informing them of an unexpected increase in radiation exposure.

WHO WE ARE

A NOTE FROM THE CEO

We wanted to invent a sleek wearable dosimeter with scientific-grade detection technology that was affordable to the everyman. And, as the number of users with Dosime® devices increases, the analytics will ultimately be able to crowdsource data to create communities of awareness that help map radiation exposure. It is our hope that by empowering we can bring not only peace of mind --but the real-time ability to manage potential health risks.

--TOM LOGAN

DOSIME, INC.:

Dosime, Inc. is a business entity funded by Mirion Technologies.

MIRION TECHNOLOGIES:

A company based in San Ramon, California that's been in the radiation detection and protection business for over fifty years, recently launched Dosime®, their new user-friendly, smart electronic personal dosimeter. Dosime is able to calculate and determine the amount of ionizing radiation a person is exposed to on a daily basis.

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