Introduction

The Nuclear Regulatory Commission has recently thrown a bit of a monkey wrench into the sales of irradiated gemstones by stating that anyone importing or selling them must have a radioactive materials license. A look at the history of this issue shows us that this is not a new issue; more like an issue that was brought up, forgotten, and is now coming up again. Others have written about this topic in the past, and it’s not my intention to repeat it all – although there are some basic terms and concepts that are worth reviewing. More importantly, I have been working with some large importers on these licensing issues, so I would also like to discuss some of the things that the regulators are looking for in the license applications, and some of the things that must go into setting up an in-house radiation safety program (procedures, instruments, training, etc).

It is important to realize that the responsibility for licensing and regulating irradiated gemstones is shared; the NRC and the Agreement States are responsible for writing regulations and approving license applications, and individual importers are responsible for realizing they are now regulated and for complying with these regulations. In short – if you import irradiated gemstones, you are regulated and it is your responsibility to apply for an appropriate license.

At the moment, I get the impression that the great majority of importers and manufacturers are waiting for the NRC to finalize its requirements regarding both reactor-treated (Swiss blue) and accelerator-treated (sky blue) topaz, while only a few have decided to get a jump on the licensing process. At the moment, the NRC is only prepared to issue licenses for the reactor-treated (for reasons I’ll discuss shortly). On the other hand, there are no scientific or technical issues that should stand in the way of requesting a license for irradiator-treated gems. Again, we’ll go over some of these issues shortly.

The irradiation process

Pure topaz is a hard colorless mineral comprised of aluminum, silicon, oxygen, and low levels of fluorine and hydrogen (Al₂SiO₄(F,OH)₂). What gives topaz its color is the presence of impurities – trace levels of other atoms – that add color by their presence in the crystal and by the distortions they induce in the crystal and its arrangement of electrons. The nature and concentration of these impurities depends on the geology and geochemistry of the mineral deposit. This is important not only because of the effects on topaz color, but also for some radiation safety reasons that I’ll get into in a moment.

About a century ago, scientists noticed that exposing gems to radiation could cause changes in the color. What we have learned is that the irradiation process can induce changes in the arrangement of atoms and electrons in the crystal, and these changes can affect the gem’s color. So, if we put a crystal into a radiation field, we can expect that the color will change.
Gemstones can be exposed to one of three types of radiation – gamma radiation from a radioactive source, particle radiation in a linear accelerator, or neutron radiation in a nuclear reactor. All of these types of radiation will cause ionizations – they will strip electrons from atoms – but their other properties (how far they penetrate into material, how much ionization they cause, how they interact with the materials) are different. These differences help to determine, for example, the intensity of the color that is induced, how radioactive the gemstones become, and other factors.

**Gamma rays** are high-energy photons, just like light or any other photons. They are very penetrating, but they don’t do much damage, and don’t cause as many ionizations as other forms of radiation. Things that have been exposed to gamma radiation do **not** become radioactive. You do not need to have a radioactive materials license to buy, store, or sell gamma-irradiated stones, but the producer (the company that does the irradiation) will need to be licensed.

**High-energy particles** are usually generated in a particle accelerator. While this sounds impressive, you have to remember that a television picture tube is an electron accelerator. The difference between your television and a commercial accelerator is that the commercial units might accelerate larger particles, and they will speed the particles up to much higher energies. Particle-irradiated objects **may** become radioactive, depending on the energy of the particles and the nature of the object being irradiated. High-energy particles cause more ionizations than gamma rays and (unlike gamma rays) they are able to induce point defects in the crystal, but they do not penetrate as far into an object. You will probably need a state radioactive materials license, and may require a federal license to buy, store, or sell these gems, and the producer will also require a license.

**Neutrons** are produced in nuclear reactors. Like gamma rays, they will penetrate to the center of a gemstone; like high-energy particles, they will also induce point defects directly in the crystal and they produce large numbers of ionizations. This combination gives neutron-irradiated gems a deeper color than those irradiated with gamma rays or in particle accelerators. Unfortunately, neutron-irradiated objects **do** become radioactive (although only slightly so). This means that you must have a radioactive materials license to purchase and distribute neutron-irradiated gems and, depending on which state you live in, you may require licensing by your state as well as the NRC.

**Safety Matters**

So, with that, the next logical questions are “Are individual pieces of irradiated jewelry dangerous to the customer?” and “Are large quantities of irradiated jewelry dangerous to our workers?” The answer to both of these questions is “No.” Here’s why.

First, let’s look at what happens to each individual gemstone as it’s irradiated. Take a piece of topaz and put it in a nuclear reactor. While in there, it is bombarded by neutrons, some of which are absorbed by atoms in the stone and make them radioactive. There are five major elements in the bracelet – aluminum, silicon, oxygen, fluorine, and hydrogen. Some of these elements absorb neutrons easily, but they form radioactive nuclides that are very short-lived; that decay to
stable nuclides very easily. So pure topaz will become radioactive, but that radioactivity will fade away over just a few days. It is only the impurities that are capable of causing longer-lived radioactivity. Here’s one example: Say a piece of topaz contains trace amounts of scandium (which is not uncommon). In the reactor, some scandium atoms will absorb a single neutron, turning them into radioactive Sc-46 (scandium 46). Other impurities will undergo similar reactions, forming radioactive atoms of cesium, tantalum, zinc, manganese, and more.

The precise radioactive atoms formed will depend on the impurities that are present, and different radionuclides decay away at different rates (have different half-lives), and they emit different kinds of radiation. This is why some gemstones will be “hotter” than others, and why some will radioactive longer than others – because the amounts and types of impurities determine which radionuclides are formed.

Having said this, the amount of radioactivity induced in the gemstones is very small. There have been many studies of this, and all agree that even the “hottest” gemstones do not become highly radioactive, and none of them will emit high levels of radiation. In fact, these measurements show quite clearly that the radioactivity induced in a gemstone by neutron irradiation is so low as to be measurable, but is far from posing any hazard at all. It is also important to understand that the amount of radioactivity, and the radiation levels, begin dropping the moment the irradiation stops, and keeps dropping all the time. This means that the radiation levels are the highest immediately upon removal from the reactor.

So – some numbers. By my calculations (which match others I’ve seen fairly closely), the radiation dose from, say, a blue topaz bracelet with 6 carats of reactor-irradiated gemstones will produce a radiation dose between 700 and 800 mrem if it is worn continuously for the first year post-irradiation. First, this amount of radiation dose is less than regulatory limits. Second, this level of radiation exposure poses no risk to the wearer. They will not get radiation burns, they will not cancer, and they don’t have to worry about radiation affecting a pregnancy. And third, the actual radiation dose will be even lower because of more realistic wearing habits and because the radiation dose may be further reduced by the stone itself and its setting. The bottom line is that this level of radiation exposure is safe for the wearer, and the dose will be even lower as time goes on.

The risk to workers in the jewelry industry is even lower. First – if you assemble huge quantities of blue topaz in one place, you will be able to measure a radiation dose rate. By my calculations, the dose rate from 3 million carats of blue topaz that was irradiated 3 weeks earlier will be somewhere between 1 and 5 mR/hr at a distance of 1 foot; at a distance of 3 feet, the dose will be lower by a factor of about 10. A radiation worker would have to spend 1000 hours annually in that area to reach a radiation dose limit, and will still be far from any level of exposure that is likely to cause cancer or any other health effects. So, as with your customers, your workers are not at risk from receiving, shipping, or working around packages of blue topaz.
**Regulatory matters**

In spite of the low radiation levels, blue topaz (and any other gemstones that have been irradiated in a nuclear reactor or an accelerator) is radioactive material and has to be regulated and controlled as such. If you are dealing with thousands of pieces or more of irradiated gemstones, you will need to have a radioactive materials license, and probably two (state and federal) because of the *total amount* of radioactivity you will possess. However, each individual piece of jewelry contains so little radioactivity that the individual items are exempt from regulation. The state license will permit you to receive and store large quantities of irradiated gemstones at your facility; the federal license will let you determine whether or not it is exempt from regulation, and will let you distribute the now-exempt materials to retail sellers. Once the gemstones are surveyed and found to be exempt from regulation, you have something that is sort of like a smoke detector – it may be very slightly radioactive, but so little that the “downstream” buyers (retail outlets and customers) simply don’t need to worry about it. In fact, this is probably the best analogy – I don’t need a radioactive materials license to have several smoke detectors in my home. Neither does my hardware store require a radioactive materials license. But the company that manufactures them must be licensed because of the total amount of radioactivity contained in the hundreds of thousands of smoke detectors they have on-hand.

What you will have to do in order to get a radioactive materials license is to fill out a lot of paperwork (or, more likely, ask a consultant to help you fill it out). There are regulatory guidance documents to help out with this, but these are somewhat out of date and could use revision to make them match current practices (for example, they assume that gemstones will be irradiated inside the US, which no longer happens). You will also have to describe your radiation safety program – what sort of radiation detectors will you have, where will you put radiation dosimeters, how will you determine that you have exempt concentrations of radioactive materials, and so forth. And then, you wait to hear from your regulator and, as you wait, you will have to designate a Radiation Safety Officer, send him or her to RSO training, purchase your survey meters, and so forth.

**Setting up a radiation safety program**

One part of your radioactive materials license application will be a description of your radiation safety program. You will have to have procedures, policies, and training; as well as radiation survey instruments.
Radiation safety policies are the overall guiding principles describing how radiation safety will be practiced at your facility. Procedures go into the details. For example, you may have a policy that describes when you will perform radiation surveys of your irradiated gemstone storage area. Your procedures will tell you how such surveys are to be performed from start to finish; how to use a survey meter, how to perform a radiation survey, how to record the results, and how to retain the records. In general, your policy manual will probably be fairly short, but your procedures will probably be somewhat longer. Every part of your radiation safety program – designating and training radiation workers, performing radiation surveys, deciding who needs radiation dosimetry, determining when irradiated gemstones can be treated as exempt from regulation, receiving and shipping irradiated gemstones, and more – will require appropriate policies and procedures that your regulators will expect you to follow.

You can also expect to perform both radiation and radioactive contamination surveys from time to time. This requires choosing appropriate survey instruments, and receiving training to ensure that your readings are reliable. These surveys will help you determine and document that your gemstones meet the criteria required by the NRC, they will enable you to distribute the gemstones as exempt materials, and they will help you to determine that your facility does not contain excessive radiation or contamination levels. The surveys you will have to perform need not take a long time, but they are important.

Licensing is the first step in becoming compliant with the regulations, and I have found preparing the license applications to be fairly straight-forward. Somewhat more complex is evaluating the jeweler’s operating practices and incorporating radiation safety procedures into these practices with a minimum of disruption. However, this too can be accomplished successfully!

Other items that go into your radiation safety program will include designating a radiation safety officer, deciding who will receive radiation dosimeters, and so forth.

**Last thoughts**

This process is not a simple one, and it can take several months until your license is in place. However, the process is fairly straight-forward; the NRC and Agreement States do not ask trick questions and they don’t ask for anything impossible. I’ve worked in radiation safety for over 25 years, and I have almost always been able to work with my regulators to find a reasonable solution to my licensing problems – both for my own program (I was in charge of radiation safety at the University of Rochester for several years) and for my clients. The process may take longer than we would all like, but my experience has been that it is fair.

There is, of course, far more information on this topic than I can get into here. I am in the process of putting more information on my website ([www.andrewkaram.com](http://www.andrewkaram.com)) that should help to
answer other questions. This will include some regulatory information, additional scientific and technical information, some terminology, and more. Feel free to log in, and to contact me if you have any other questions.

Radiation Terminology

The NRC licensing documents use a number of terms that are specific for radiation safety. Some of the more important are explained here. You can find a fairly complete glossary of radiation safety terms at the website for the National Council on Radiation Protection and Measurements (which can be found on-line at http://www.ncrponline.org/News_Events/News_Events.html; the link is on the right side of the page towards the bottom).

**Radioactivity** is a property of an atom that makes it unstable, causing it to give off radiation

- **Curie** is a measure of the amount of radioactivity in an object. An object with 1 Ci of activity will have 37 billion radioactive decays every second. The amount of radioactivity in irradiated gemstones is measured in pCi (1 trillionth of a Ci), nCi (1 billionth of a Ci), and µCi (1 millionth of a Ci).

- **Becquerel (Bq)** is the international measure of radioactivity. 1 Bq is equal to 1 decay per second, so 1 Ci has 37 GBq (giga-Bq) and 1 µCi contains 37 kBq.

**Radiation dose** is a measure of the amount of energy deposited by radiation

- **REM** is one of the units of radiation dose – members of the public are limited to 0.1 rem/yr and radiation workers are limited to 5 rem/yr. It takes about 25 rem in one shot to start to cause medical effects, and about 100 rem to start to give someone radiation sickness, and 10 rem to start to cause a risk of cancer.

- **Deep dose** is the amount of radiation dose to your internal organs.

- **Shallow dose** is the amount of radiation dose to your skin.

**Dosimetry** is a device used to measure radiation dose – usually a film badge or something similar.

**Byproduct material** is material that was made radioactive inside of a nuclear reactor. If a gemstone is put into a nuclear reactor, it is considered byproduct material. The NRC regulates all byproduct material.

**NARM** is Naturally Occurring and Accelerator-produced Radioactive Material. Gemstones exposed to a particle accelerator are NARM. States regulated all NARM until recently, although the NRC is beginning to do so, including gemstones.

**Exempt material** is radioactive material that contains exempted quantities of concentrations of radioactivity according to 10 CFR 40.