



# **Safer for Whom?**

**Explaining the Concept of  
Inherently Safer Technology and  
Product Substitution in  
Non-technical Terms**

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## **Introduction**

Few terms in chemistry are as misunderstood as “inherently safer technology.” While it seems self-explanatory, the term as used in chemistry and engineering may not be familiar to non-scientists. IST, as it is commonly called, is a concept involving chemical processing procedures, equipment, protection, and, when feasible, the use of less hazardous substances in these processes.

Many non-scientists have been led to believe that the only road to inherent chemical safety is by way of reducing the amount of hazardous substances used in chemical manufacturing and processing. IST, however, is limited by the laws of physics and nature; a simple reduction in the use of hazardous chemicals is often not possible within the confines of a particular reaction or process. Such reductions can even result in transferring risk to other points in a chemical process or the supply chain, without actually reducing it. To place the current IST debate in context, this paper begins with an illustration of the limitations of chemical substitutes, then discusses the difference between a hazard and a risk, finishing with an explanation of why reducing a hazard in a process does not necessarily reduce the overall risk.

### **You can't make medicine out of table salt.**

Chemistry is bound by the laws of physics and nature. In fact, most natural processes involve chemical reactions in one form or another. These physical laws place restrictions on what can and cannot be done when trying to make a chemical. For instance, a molecule (i.e., a chemical) is made up of atoms (e.g., sodium, carbon, chlorine, etc.) that are in specific locations or positions on the molecule. In organic chemistry, the goal is to take the atoms from one molecule and move them to locations on another, different molecule so that it takes on a specific function or behavior.

The laws of physics and nature dictate if, how and when those atoms can be moved. Due to these constraints, chemists are often left with few alternatives, which is why hazardous chemicals are used—and appropriately managed—by chemists in universities, government and industry. The fact of the matter is that scientists usually cannot produce the materials that make our standard of living possible without using very specific chemicals. Making medicine is a good example.

Often, to make medicine it takes multiple steps. Each step in the process carefully moves atoms from one molecule to locations on another molecule. Eventually, the scientist will obtain the desired chemical that performs a precise medicinal function. The movement of these atoms, from one molecule to another, is commonly called a chemical reaction and can only take place using certain materials. The materials used to make medicine must be reactive by nature, which also means that they will possess certain hazardous characteristics. The chlorine atom, for instance, when it is located on a specific part of a molecule, allows these steps to take place. One common misconception, though, is that any chlorine atom will do. That is not the case. Chlorine atoms take on different behaviors, or physical properties, depending on the atoms to which they are attached.

Table salt consists of the sodium (Na) and chlorine (Cl) atoms, which make up the chemical sodium chloride (NaCl). The chlorine atom used to make medicine, on the other hand, often comes from phosgene, or carbon oxychloride (COCl<sub>2</sub>). Phosgene has one carbon, one oxygen and two chlorine atoms. The sodium atom that is attached to the chlorine atom in table salt gives the chlorine a different nature than the one attached to the carbon and oxygen atoms in phosgene. The very specific nature of the chlorine atom in phosgene is critical to its role in drug manufacturing. To use table salt in the drug manufacturing process would require the application of electric energy to the salt, resulting in the formation of chlorine gas, which is corrosive and poisonous by inhalation. The complex chemistry associated with making medicine has well-defined physical boundaries and requires the use of reactive chemicals. That is why, generally, medicine cannot be made from table salt.

While table salt is less hazardous than phosgene, it is not realistic to use it as a substitute and achieve the same end product. The use of safer chemicals is a conceptual goal shared by all scientists. There are constraints, however, that the laws of physics and nature place on the scientists, which dictate which chemicals can and cannot be used.

### **Hazard is not the same thing as risk.**

For the past several years, people have debated the hazards and risks of certain chemicals. Part of the length and intensity of these debates may be due to how people define hazard and risk. In the sciences, hazard and risk take on different meanings than the typical dictionary definitions. Before a coherent discussion of IST can take place, it is important to learn and use the definitions adopted by scientists so that chemical information is not misinterpreted. In essence, a hazard may be part of a certain chemical's nature, while risk depends on the circumstances in which the chemical is stored, used or handled.

When discussing chemicals, a hazard is a characteristic of a substance that gives it the *potential* to produce an undesirable consequence *under certain conditions*. The hazard of a chemical does not change (it is part of the chemical's nature) and does not depend on circumstance. Risk, on the other hand, can vary with conditions. It is related to the *likelihood* that an undesirable event could take place and the consequences the event can produce; in other words, the likelihood that a hazardous thing could cause harm.

For instance, a car has hazardous properties (i.e., heavy weight, flammable fuel) that *under certain conditions*—high speed, bad road conditions, driver intoxication, etc.—can produce serious damage. The weight of the car and the flammability of the fuel that propels it—two of its hazards—do not change. Operated under proper speeds and conditions, however, cars are considered to be at a lower (and acceptable) degree of risk because they are less likely to be involved in an accident.

Chemicals can also have hazardous characteristics. Just as conditions affect the risk posed by operating a car, the risk a specific chemical presents depends upon the conditions of how and where the chemical is stored, used or handled. These conditions

are as important as the chemical's hazardous properties when trying to determine its degree of risk. For example, household oven cleaners and drain openers are corrosive—a hazard—and can cause severe burns on skin and permanent blindness if splashed into the eyes and not treated immediately. Despite these hazardous characteristics, they are used in most households because of their grease-cutting properties. When these products are clearly labeled, which is required by law, and used with adequate precautions, they do not pose a significant risk. In fact, anything can be handled safely with the right precautions. Consumers accept that and use products that have hazards accordingly.

**A reduction in hazard does not necessarily mean a reduction in risk.**

IST is a conceptual and often complex framework that covers procedures, equipment, protection and, when feasible, the use of less hazardous chemicals. Its premise is that if a particular hazard can be reduced, the overall risk associated with a chemical process will also be reduced. In its simplicity, it is an elegant concept; however, reality is not always simple. A reduction in hazard will reduce overall risk if, and only if, that hazard is not displaced to another time or location, or does not magnify another hazard. If the hazard is displaced, then the risk will be transferred or increased, not reduced. Here are several examples of how factors related to likelihood affect overall risk when attempts are made to reduce hazard:

Eliminating the use of a hazardous catalyst

A chemical company wants to eliminate the use of a hazardous catalyst, which is typically used in small amounts. The catalyst serves as a booster to start a chemical reaction to make a building block for a drug used to treat cancer. The chemical reaction needs a boost to start, so the company must supply an alternate source of energy to the system. Catalysts tend to be hazardous by nature, which reduces the number of available alternatives. The only other way the company can initiate the reaction without using a hazardous chemical is to increase the temperature and pressure of the system. The overall risk of the system, posed by increasing the temperature and pressure, may actually be greater than the risk associated with the catalyst, because catalysts are used in small amounts and the likelihood of an accident is remote.

Reducing the amount of a chemical stored on site

A manufacturing plant is considering a reduction in the volume of a particular chemical stored on site. The chemical is used to manufacture a critical nylon additive, which is sold to another company and used to make seat belts stronger. Because it is a critical component for nylon strength and seatbelt production cannot be disrupted, the production schedule cannot change. If the amount stored on site is reduced, the only way to maintain the production schedule is to increase the number of shipments to the site. This leads to more deliveries (an increase in transportation risk),

more transfers of chemical from one container to another (an increase in transfer risk); and, since there is now a greater chance that production could be disrupted by a late shipment, there is an increase in economic risk. This analysis only accounts for the risk to the manufacturer and does not include the risk to the customer making the seat belts.

#### How location and individual circumstance affect risk perception

It is difficult to think of a scenario in which moving a hazard does not result in a simple transfer of risk from one location to another. Dennis Hendershot, a respected expert and member of the American Institute of Chemical Engineers, points out how location can highlight different risk perspectives.<sup>[1]</sup> Dr. Hendershot gives an example using chlorine, a hazardous gas that comes in various types of containers. This example compares the inherent safety of a rail car, which typically holds up to 90 tons, versus storage in one-ton cylinders. Neighbors a mile away from the facility would probably view the one-ton cylinder as inherently safer than a rail car. On the other hand, workers who have to connect and disconnect the cylinders 90 times, instead of just once for the rail car, would probably consider the rail car inherently safer.

In science, risk is dependent on the circumstances and surroundings of a hazard. A simple reduction in hazard will not necessarily result in a reduction of overall risk. IST decisions should be based on risk, not inherent hazards.

#### **IST is a good concept, but is not a security panacea.**

Scientists support the concept of using inherently safer technologies whenever possible. They have one major motivating factor: their own safety. Scientists spend hours each day in laboratories and manufacturing facilities that use and produce chemicals. It is difficult to imagine that any scientist would not want to work under the safest conditions possible. In addition, at most chemical companies, executive offices are in the same buildings, or very close to the same buildings that contain the processing, storage and laboratory areas. These decision-makers too have incentive to provide a safe environment.

There are even economic incentives for chemists to use the safest and least hazardous chemicals possible. These incentives include reduced accidents among laboratory and processing workers, cheaper transportation and disposal costs, cheaper insurance rates and fewer government regulatory requirements.

With all of these incentives in place, the question becomes: Why do chemical companies still use hazardous materials? The simple fact is that the laws of physics and nature are a much larger determining factor in selecting process materials than anything else.

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<sup>[1]</sup> Dr. Dennis Hendershot, American Chemical Society Science & the Congress Project, *Inherently Safer Technologies for the Chemical Industry*, December 6, 2002, Washington, DC.