Ceramic Toxicology

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Considering the number and variety of ceramic materials available to the contemporary potter, it seems inevitable that some of them would be hazardous and a surprisingly large number are. Some of these are toxic, causing illness or even death if taken into the system and others are chemically inert but cause problems if .inhaled. Most clay workers are aware of the dangers of such things as lead compounds and inhaled silica and take at least some precautions to prevent or minimize exposure. There are, however, a host of other ceramic materials which are also dangerous. Because of the fact that they are often not recognized as such, they are hidden hazards of the pot shop and present the potential for serious and permanent health impairment.

Of the nontoxic ceramic materials, crystalline silica in the form of powdered quartz is widely regarded as the most hazardous and the disease it produces, silicosis, has long been associated with ceramics and other dust producing industries. Silicosis, which has been well researched by medical experts primarily because of its prevalence among mine workers, is rarely fatal in and of itself, but those having silicosis are notably more susceptible to other pulmonary disorders and are much less likely to survive potentially fatal diseases such as pneumonia due to their already weakened condition. The pathological evidences of silicosis are nodulation and fibrosis of the lungs; the external symptoms are shortness of breath, chronic cough, pain in the chest and especially, decreased vital capacity or, in lay terms, decreased ability to perform work requiring physical activity.

Most treatises on the subject of silicosis report that one exposure is not particularly dangerous and generally agree that ten to twenty years of exposure are needed to produce really serious symptoms, although disability has been reported after only six months. The factors regulating the length of time necessary to produce symptoms are the concentration of silica dust in the air and the size of the particles. the higher the concentration and smaller the particle size, the shorter the period required to exhibit noticeable symptoms of silicosis.

Studies have shown that coarser particles of dust tend to be trapped in the nasal passages and the upper reaches of the bronchial tract. This region of the lungs is covered by minute hair like cilia which are constantly at work moving foreign particles upward to the esophagus where they 'are either swallowed or expectorated. Dust trapped in this manner is only temporarily irritating and poses no real threat. Finer particles, those which are 5 microns in diameter and less, can escape this natural dust filter and penetrate into the alveoli in the deepest recesses of the lungs. Here there are no cilia and the deposition is permanent. These particles act as constant irritants to the lung tissue resulting in the fibrosis and nodulation mentioned above.

At this point the available literature on silicosis and related lung diseases break down to a confusing welter with some researchers laying the total blame on silica (and asbestos, of which more later) and others indicting a host of other materials on almost equal grounds. In point of accuracy, it is fair to say that it is, for the most part, the earlier research which produced the evidence which lead to the naming of a lexicon of lung disorders which are reportedly almost indistinguishable from silicosis, but as a usual rule somewhat less severe. Recorded in the annals of medical literature are diseases as

aluminosis, kaolinosis, siderosis, talcosis, and stannosis produced respectively by alumina, kaolinitic clay, iron oxide (siderosis really refers to iron carbonate or siderite, but iron oxide is usually listed as the causative factor) talc, and tin oxide.

More recent evidence would seem to indicate that it is impurities of crystalline quartz and asbestos which produce the above named diseases and that talc, kaolin, etc. are in and of themselves relatively harmless. In any case, the dichotomy which still exists between respected medical researchers is a moot point to the modern clayworker. The d= encountered in the average studio is almost never from a single source, but rather, stems from some mix of ceramic materials and 99 chances out of 100 will contain some significant portion of "free silica".

Oddly enough, it is the modem innovations in the preparation and distribution of ceramic materials which greatly increased the potential hazards to the contemporary potter. In earlier times, many glaze materials such as flint and feldspar were marketed in sand form. They were then mixed in the proper proportions and ball milled to a glaze slip of the proper fineness. Clay was either dug or bought in lump form after which it was blunged and the resulting slip stiffened to the plastic state. In neither case was very much dust produced and that which was stirred up was very likely much too large to penetrate into the alveoli of the lungs.

Today, however, most ceramic materials are sold after considerable preparation and are usually water ground or air floated. It is common to find flint which has been graded to pass through a 400 mesh screen. This means that the largest particles will be a maximum of 38 microns in diameter and it is likely that a significant portion will be small enough to penetrate the defense mechanisms of the lungs. Clay provides an even more dramatic illustration in that in some ball clays as much as 75% of the individual particles are less than 0.5 microns in diameter, precisely that size range which is most dangerous. Under these conditions much shorter total exposure time will be needed to produce symptoms.

In addition to silica, there is one other ceramic material which deserves special note; that is asbestos. In the last several years the increasing incidence of lung cancer in workers in the asbestos industry have brought about considerable research on the hazards posed by this natural mineral fiber. Indications are that in an alarmingly large percentage of cases, asbestosis, which exhibits symptoms similar to silicosis, leads directly to lung cancer even after rather minor exposure. Medical literature is filled with horror stories on the dangers of this material including one in which a whole family was afflicted simply because the father's work clothes were washed in the same machine as those of his wife and children.

Considering our present knowledge about asbestos, it is a prime candidate for the list of those materials which should be permanently banned from the pot shop, even in the form of heat resistant gloves.

Since all of the pulmonary disorders mentioned above are reportedly irreversible, the inevitable conclusion must be that prevention is the only safe route. Even so, with the exception of a very few, particularly hazardous materials such as asbestos, all ceramic materials, even in the form in which they are currently marketed, can be handled in perfect safety if adequate precautionary and preventive measures are employed. Among the possible dust control measures, adequate ventilation is more frequently mentioned. Dust producing activities, such as clay and glaze mixing should be isolated as much as possible and those areas equipped with ventilation fans. For maximum efficiency in ridding the atmosphere of dust particles which are trying to settle, the exhaust fans should be placed as close to the floor level as possible with air intakes in or near the ceiling.

Filter respirators can be very effective in preventing the inhalation of airborne dust and should be worn during the course of any dust producing activity. In the United States, the National Institute for Occupational Safety and Health (NIOSH) has set forth criteria for respirators for use in dust producing industries. Criteria change according to the conditions encountered, but in general a mask which removes 99% of all particulate matter in the range of 0.4-0.6 microns diameter is considered to be adequate. Several respirators meeting these standards are available on the open market. Some resemble World War I gas masks and are a nuisance to wear and maintain, but there are others which are light weight, comfortable, inexpensive and just as effective.

Of equal importance is some provision for regular clean up of shop floors and work areas by a means other than a dry broom. Regular hosing is the ideal, but many home studios are not equipped with floor drains. Vacuum sweeping is an excellent alternative but only if the vacuum cleaner is equipped with an adequate dust filter and only very few industrial models are. These are often prohibitively expensive. A regular shop vacuum can be used if it is installed in such a manner that it exhausts to the outside in a non-populated area. As a last resort, a sweeping compound such as oiled sawdust can be used to trap as much dust as possible before the sweeping begins.

Lead and its various compounds is probably the best known toxicant in common ceramic usage. Lead poisoning is often associated with potters; indeed, it is regarded as a classic potter's disease. As early as the later 1700's, movements were underway in Europe which eventually lead to the regulation of lead glazes in the ceramic industry. The studio potter remains one of the few as yet unfettered by these regulations freedom which also makes him/her susceptible to the very dangers they were designed to prevent.

It is a commonly held misconception that the dangers of lead poisoning can be avoided by the simple expedient of restructuring glazes to use lead frits rather than raw lead compounds. Unfortunately, the majority of all lead frits leach significant amounts of lead in even weak acids and would therefore, be quite dangerous if ingested. It has sometimes been cited as a guide to the safety of lead frits that if, in

the molecular structure of the frit, the silica content is double or more than that of lead oxide, the frit will be safe under nearly any condition. Even this rule of thumb must be regarded with some suspicion since it overlooks the fact that other oxides may be present which will effect the solubility of the frit as a whole. Testing the rate at which any frit leaches lead is a relatively simple procedure, but still one best left to a trained laboratory chemist. Rather than trying to research which lead frits are safe for use under normal conditions and which may be prone to leach lead oxide, it is easier to simply remember that any lead frit is safer for use than any raw compound, but all should be handled with care.

One of the greatest dangers of lead is that it is an accumulative poison, i.e. while a single dose could be fatal (as little as one-half gram of absorbed lead oxide has been reported to have caused death) it is also stored in the body so that even very small amounts taken in over a period of time can eventually build to the toxic level. Historically, most potters who have suffered lead poisoning have not died from it, but have lived on in a state of mild to severe mental deterioration as a result of the brain damage which often accompanies the disease. To my mind, it is a moral question as to which is worse.

Since it is on the roster of possible ceramic materials and has in the past been used as an opacifier in low fire glazes, arsenic trioxide deserves at least a passing mention. Fortunately for the modern day potter this extremely hazardous material is of limited availability. Considering that it may be thought of as being over four times as toxic as lead

oxide, it is simply too hazardous to be used. Even in this day of outrageous prices on tin oxide, it would be hard to justify the risk.

Antimony trioxide (Sb203), even thought it is a first cousin to arsenic and produces symptoms and results similar in most ways to arsenic poisoning, is much less dangerous. Reported fatalities are rare even thought from one and on half to three grams could cause death. Antimony in the oxide form is seldom used today, but one of its compounds, lead antimoniate or Naples Yellow, is a commonly use colorant. No data were available on the toxicity of Naples Yellow, but considering its composition, it should be used under stringently regulated conditions.

If there be a second most widely recognized ceramic poison, it is probably barium carbonate. Most potter know about it's dangers and at the same time most potters have in their repertoire of glazes one of those stunning copper blues which is possible only with a high concentration of barium oxide in the glaze. The batch recipe of one of these glazes may call for as much as 50% BaC03. Like barium carbonate, barium chloride and barium hydroxide are partially soluble in water and therein lies their danger. Barium is one of those heavy metals which is difficult to get out of the body once absorbed; as little as one gram has been reported to be fatal and like lead, the effects may be cumulative. If it could be obtained, barium sulfate should be safe for use under nearly any conditions; it is the chief ingredient of the infamous ' barium malts" that patients are required to drink before having a stomach x-ray. the non-solubility if barium sulfate is the reason that adding a small percent of barium carbonate to a clay body will stop scumming from soluble sulfates. The barium carbonate dissolves, in part, in the water in the plastic body and then recombines with the soluble sulfates rendering both non-soluble. In this form, the salts do not migrate to the surface on drying and scumming is halted. During the firing process, the newly formed barium sulfate breaks down with the sulfur content going off as a gas and the barium remaining in oxide form to play a role as a flux.

Actually the list of dangerous materials is quite extensive and includes a number of compounds which under most circumstances are considered benign. Good examples of this are borax and boric acid. Both of these soluble compounds are used medicinally which would lead one to the false assumption that they are safe, when in fact, both can be deadly. Only small amounts of boron are absorbed through normal adult skin, but the absorption rate dramatically increases when applied to cut, abraded and especially burned tissue. Death has been reported due to the application of boric acid to severe burns and one infant is known to have died from having been treated for diaper rash. Taken internally, these soluble compounds are known to be absorbed rapidly into the system. Fatal doses vary from two grams for infants to twenty grams for adults, but individual tolerances vary widely and some are more susceptible than others. The important factor to remember is that soluble boron compounds and most are can be absorbed through the skin, so the glazing operation can be quite hazardous unless some precautions are taken.

Cadmium oxide is another of the cumulative poisons. It can be absorbed into the system by either ingestion or inhalation. Apparently only massive doses are fatal, but its side effects such as damage to the liver, kidneys and bone marrow and pulmonary lesions leading to emphysema occur after much lower levels of exposure. Since cadmium compounds are volatile, particular care should be taken to avoid breathing the fumes that are produced during a firing. Like lead, cadmium can also be leached from glazes and those beautiful reds so often seen on hobby shoo Santa Claus should never be used on ware intended for food of any kind. Keep in mind that even the small doses taken in from either breathing the fumes or eating from cadmium glazed articles can build to toxic levels. Particular care should be

exercised when glazing with raw cadmium glazes.

Carbon monoxide is a colorless, odorless, toxic gas that is a byproduct of incomplete combustion of all sorts. In the process of firing ceramic kilns under reducing conditions, a certain amount of CO is inevitable. Most of this exits through the stack and is dispersed into the atmosphere in non-toxic concentrations. Kilns situated in small or unventilated rooms and fired with considerable back pressure may exhaust CO in sufficient amounts to cause potentially dangerous situations. Concentrations as low as 25 parts per million can cause marked drowsiness and impaired vision. As the concentration increases, the symptoms become more severe and 1000 parts per million is considered lethal. The danger lies in carbon monoxide's affinity for the hemoglobin in the blood, which is reported as 300 times as great as that of oxygen. All symptoms, including possible death, are a result of oxygen starvation. Simple precautions in proper ventilation will prevent accidental asphyxiation due to CO.

Chlorine gas is probably the most dangerous and damaging of the pollutants produced by salt glaze firings. The chance of a damaging dose while firing a salt kiln is remote. Even so, caution should be exercised since individual tolerances vary widely and as little as one part per million has been known to have an effect. In no case should a salt kiln be built and fired in a tightly closed structure.

Potassium bichromate is a deadly poison and because it is completely water soluble can be absorbed through the skin. Cobalt is an important trace mineral in the human system, but overdoses can cause an imbalance leading to irritations and allergies. Of the various copper compounds available to the potter, only the oxides appear to be completely safe for use. Copper sulfate can cause death in surprisingly small doses. Verdigris and even copper carbonate have been associated with a variety of toxic effects.

Manganese dioxide is one of the hidden dangers in the pot shop since most potters are not aware that it is toxic. It can be absorbed by either inhalation or ingestion and gives rise to a variety of symptoms including stammering speech, muscular discoordination, paralysis and a spastic or shuffling gait all of which are symptoms of Parkinson's disease. All of these are caused by an over-growth of some of the connective tissues in the brain. Because of the brain damage involved, complete cures are very rare, but the progress of the disease can be successfully halted.

Most selenium compounds are poisonous, but selenium dioxide is one of the most dangerous. Even simple contact with the skin can cause serious burns. Acute poisoning is similar in its symptoms to arsenic.

Soluble uranium compounds are quickly absorbed into the system and are known to cause kidney damage. Insoluble forms are reported to be harmless by most researchers, but there is some evidence indicating a higher incidence of lung cancer in those exposed to uranium dust. Low fire glazes high in lead oxide produce some of the most beautiful colors from uranium oxide, but are known to leach both lead and uranium and should never be used on articles which could be used for food.

Vanadium pentoxide is absorbed by inhalation. The human body shows very low tolerance, and as little as one microgram per gram of tissue causes serious disturbances. It has been connected to emphysema and severe irritations of the nasal and bronchial passages, leading to a chronic cough.

Zinc oxide has been reported as being toxic, but these are in older treatises and the

effects cited are more likely to have been from contaminations from lead or mercury. Even so, ingested zinc oxide may cause temporary illness.

In addition to above named materials, all of which are in fairly common usage today , there are other materials which could be used in ceramics but are generally not because of scarcity or expense. All beryllium compounds with the sole exception of Beryl are strong sensitzers and can cause skin lesions which are very slow to heal. Inhaled beryillium is even more dangerous and can be fatal. Bismuth.

oxide is thought to be safe, but bismuth subnitrate is toxic. Compounds of__Molvbdenum Thallium. Cerium_Yttrium. Lanthanum. Praeseodvmium and Neodymium have all been associated with toxic effects.

This treatise does not presume to be all inclusive nor should it be taken as a sovereign guide to all of the dangers which can be found in the pot shop. Rather, it is intended to raise the caution flag to my colleagues in the field that all ceramic materials should be treated with respect. We often take a rather cavalier attitude toward the materials and procedures used in ceramics. I have often seen potters stirring glazes with their bare hands ...indeed, I have done it myself, but no more. Stirring a glaze with a heavy concentration of iron oxide in this fashion will often leave the skin discolored even after a concentrated scrubbing. Fortunately, iron oxide is not toxic, but the fact that it remains in the pores and on the skin indicates that other materials which are dangerous may also be hidden there but not seen because of their more neutral color.

I recently learned of a potter in England who is now suffering severe health problems because of his practice of brushing manganese dioxide on bisque ware and then sanding it off to leave the colorant only in the pores of the clay and in scratch marks. In the process, he inhaled a good bit of the dust. The result was beautiful for the ware, but devastating for him.

All of this points to the fact that one should take every precaution to avoid breathing or ingesting ceramic materials particularly those used in glazes. Smoking or eating in pot shops should be discouraged and great care should be taken to clean hands and clothing before meals. Smokers who work with ceramics are ten times more suseptible to the hazards of all ceramic materials and processes.