MORELS FROM THE APPLE ORCHARDS: A LOOK AT SOME TOXINS, SOME RISKS, AND NEED FOR SPECIFIC RESEARCH

By Bill Bakaitis 2009

A longtime and well known morel hunter from the Northeast is being treated for arsenic poisoning. The consumption of morels collected from apple orchards treated with Lead Arsenate has been the suspected cause. Since morels often fruit abundantly in abandoned orchards, and are widely collected from these sites, there has been widespread concern about the risks of collecting from them.

In this article I will attempt a comprehensive but limited survey of some of the more pertinent factors involved. These include
1. the past use of Lead Arsenate in the industry
2. the geophysical fate of this compound over time
3. factors involved in the uptake and accumulation of these heavy metals by fungi, especially morels
4. Factors involved in the toxicity and accumulation of low levels of heavy metals in the human body
5. Special problems of assessing the risks, interpreting the data, and an outline of research needs for the future.

But first, a story. The reports of this case last summer reminded Sandy Sheine of an article I had written for the newsletters of COMA and MHMA decades ago. Fortunately she and Jerry had a copy of it in their COMA archives and she sent it along to me. She thought, and I agree, that it remains as valid today as it was when first published. Here it is:

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DON'T EAT THE MORELS, PART I: A TALE

(Previously published in Issue 26, Vol.8, No. 1, Winter 1989-90, *Mushroom The Journal*. And in 1980 for the newsletters of COMA and MHMA.)

Some secrets are arrogant, living with a special tension, surviving on the thin line between the known and unknown, thrilling us with the slipperiness of a tie which holds together that which needs release. The more, it seems, we fondle the knot, the looser it becomes, and so, by design, we reveal that which we intend to conceal. It was in this manner that one of the greatest morel hunters around revealed to me the location of one of his favorite patches.

He lives in New York City but makes frequent forays into our area in the spring searching out mushrooms. Bit by bit his pride at finding a great location "under our very noses" pried loose the secret. "On the west side of the river", he said, "on a major road … just over the county line… an abandoned apple orchard… on both sides of the road…. poison ivy out the gazoo, but morels galore." He showed photographs to prove the point; Great shots of twenty or thirty big blonde morels trooping around the base of an apple tree, with more trees and mushrooms fading into the background.

He said he would never tell anyone where it was, but already I knew the precise location, for every spring in late May and early June I make several trips to the East Branch of the Delaware River to fish for shad, and on the way, just across the county line, an abandoned apple orchard spills across the road and floods my mind with thoughts of mushrooms. I think of nothing else for the next ten miles and keep reminding myself that "next year" I should come a few weeks earlier and look for morels.

Last spring I did. I had a spring mushroom identification course in mid-May at the Arboretum and used that as an excuse to search out new sites for field trips. And so it was that Pete Katsaros and I found ourselves poking around in the poison ivy of an abandoned apple orchard one weekend late in April.

The day was cool but bright. The trees were not yet in full leaf and the brightness of the noonday sun cut through their skimpy canopy with ease, causing us to squint and to walk with the sun at our backs. Because of the sun the morels were not easy to see but they were there. The black ones were the most prevalent, but here and there was a tree ringed with small blondes. They seemed to occur in patches, a group here, a group there, usually around the sickliest of the trees.

We were so intent on our search that we failed to notice the owner of the orchard when he showed up. His large four-wheel vehicle appeared suddenly, jerking us both from our reverie. A shotgun hung on the gun rack behind his head, and what turned out to be a .357 Magnum lay exposed on the seat beside him. Static from his radio transmitter punctuated the silence and an eerie tension filled the air. I had a sudden desperate yearning to be fishing the Delaware even though the shad were a month downstream.

He was not an old man, middle aged at best, and yet he spoke as if he had understudied an older, southern Clint Eastwood. "What you Boys lookin' for?" he asked. "My Mama saw you two creepin' around here and called me right away." He jerked his head over his left shoulder commanding us by that gesture to look thataway. Sure enough in the middle of the hillside orchard across the road was a house and there in front of an open door was an older woman whom we took immediately to be Mama. She was watching us through a pair of binoculars. "She seen your every move", he said. "What's the matter, you can't read the 'No Trespassing' signs?"

No, we allowed, we could read the signs, but there were so few, and so old and tattered, and we didn't know where to go to ask for permission and we were just two naturalists out walking and looking at what the spring was bringing to this orchard, and that seemed harmless enough, and we were sorry to bother him and cause his mother to worry, and we were glad to see him and know that he was as interested in the land as we were, and we would be more than happy to leave right this minute and never come back, and…

Just then a hawk circling overhead issued a thin whistle. We all looked up. "Red Tail" said the man in the truck. "Yes", said Peter, "Buteo jamaicensis". "Oh! You two birders?" he asked with a distinctly softer tone to his voice. "Why didn't you say so before?" And the talk turned to birds, and voles, and a den of red foxes on the other side of the stream. And of hunters and trespassers, and DEC and toxic waste and how it was that he got out of the apple business.

Trucks, he said, would pull up in the middle of the night, just ease in off the main road onto his work lanes in the orchard and here and there dump all manner of stuff around. That's why all of those trees were so sickly. His father, an Italian, thought the Mafia had something to do with it. The DEC closed down the orchard and the father died shortly thereafter. Now here he is with a

poisoned apple orchard. He could sell the land for a housing development but would rather keep it for the foxes.

I was almost afraid to ask him if he could remember exactly where some of the dump sites were, but I did, and he pointed out how you could tell the asbestos dumps by the mounds they made, and how some of the chemicals with the wretched names and reputations had caused the trees to get sick and die. He pointed to several places here and there around the orchard, and they were in many cases the very places we had found the morels.

We ate none of these morels and declined to return, even though invited. But I thought of the Buddha several times that spring as I passed on my way to the Delaware. The secret of desire, he said, is to release it. You can have anything in the world you want. The trick is not to want it.

[This complete article under the title "Finding Lots of Morels Is Not Necessarily A Good Thing" has also been posted at
http://web.mac.com/diannasmith1/FUNGIPHOTOS/BILL_BAKAITIS_Articles/BILL_BAKAITIS_Articles.html ……

Sandy Sheine, who reminded me of this article, said she knew the collectors involved and advised them of the dangers presented. I have recently seen them and they appear healthy and happy. By the way, this orchard is now a golf course, almost all of the apple trees are gone but the hillock where the foxes nested remains undisturbed.

And now to the Lead Arsenate issue. Much of the following material comes from information retrieved by internet searches. Both conventional and Scholar Beta Google searches of key words were used. It is not exhaustive, and is often suggestive rather than conclusive, limitations imposed by my layman's understanding and what can be described from the literature as a lack of interest in or understanding of the specific question involved: Does Lead Arsenate accumulate in morels in sufficient quantities to cause problems for human consumption? Some conclusions are presented in the final section.

LEAD ARSENATE IN THE ORCHARD

For the first half of the 20th century, Lead Arsenates (LA) were extensively used in Apple Orchards largely for the control of coddling moth infestations. These and similar compounds have also been used in other agricultural applications, beginning with Paris Green for Potato Beetle control in 1867.

The decades between 1910 and 1950 probably represent the highest application of LA as both farmer-mixed and commercial products were in use during this time. The use was extensive, sometimes with weekly spraying, week after week, season after season. Some 30 million pounds were being used annually.

LEAD ARSENATE USE IN THE APPLE ORCHARD Library of Congress image from http://www.ehponline.org/members/2006/114-8/focus.html

In 1938 the insecticidal properties of DDT (ffirst synthesized in 1874) were discovered and within a decade this polychlorinated hydrocarbon compound was being used to replace LA in the orchard as a more effective control for the coddling moth which by this time had become resistant to LA.

By 1948 the use of LA was effectively ended in the state of Washington as it was in Massachusetts by the early 1950's. From the mid '50's until it was banned in 1988 it was used at a much lower rate and in combination with DDT and other pesticides. Use in New York, Pennsylvania, Georgia, and Michigan appears to have stopped in the mid 60's. Today, Integrated Pest Management, the use of small amounts of narrowly targeted agents during critical periods in the life cycle of pests, has come to be the preferred industry standard.

The heaviest contamination of Lead Arsenate in our Northeastern apple orchards then may have been those that were under cultivation from 1910 through the 1940's.

For more see:

The Apple Bites Back: Claiming Old Orchards for Residential Development
http://www.ehponline.org/members/2006/114-8/focus.html

Historical use of lead arsenate insecticides, resulting soil contamination and implications for soil remediation http://www.absoluteastronomy.com/topics/Lead_hydrogen_arsenate
PERYEA Francis J.

Where's the arsenic in New England orchards?
http://www.dartmouth.edu/~news/releases/2002/may/052902a.html, or,
http://adsabs.harvard.edu/abs/2002AGUSM.H42A..05W

New Jersey offers the report of the Historic Pesticide Contamination Task Force at (http://www.state.nj.us/ dep/special/hpctf/index.html) and i-MapNJ, an environmental mapping tool that lets residents obtain detailed contamination information for specific locations (http://www.state.nj.us/ dep/gis/depsplash.htm). You may find your apple orchard there. Wisconsin has posted a variety of publications at (http://www.datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/accp/lead_arsenate/index.jsp), including tips for safe gardening in lead- and arsenic-contaminated soil, and the State of Washington has a similar site at http://www.ecy.wa.gov/ programs/tcp/area_wide/area_wide_hp.html.

Lead may lurk in backyard gardens
http://www.boston.com/news/science/articles/2008/08/11/lead_may_lurk_in_backyard_gardens/

THE FATE OF LEAD ARSENATE IN THE ENVIRONMENT

Lead Arsenates as applied in apple orchards enter into very complex physical and chemical reactions in the soil. Although designed to be persistent, which they are, these inorganic compounds undergo altered electron-valence states as a function of chemical reactions, the altered compounds often referred to as *species*, then bind differentially to soil structures.

The relationships are very complex depending in part upon metals such as iron, aluminum, and magnesium oxides in the soil along with other clay compositions, the sand content of the soil, fluxes in pH values, rainfall and surface water, as well as temperature and availability of humic acids. Bacterial action, and perhaps enzymes excreted by fungal hyphae are also thought to facilitate this reaction. See http://www.rsc.org/chemistryworld/News/2008/August/15080802.asp]

Because of the higher toxicity of arsenic its fate appears to have been more closely followed in the literature than that of lead. The state of New Jersey, for example, places the toxic threshold of arsenic in the soil at 20 ppm while the threshold for lead is 400 ppm, some 20 times higher. Most of the relevant literature I was able to find therefore seems to concentrate on the fate of arsenic.

In general the sweeter the soils, the more likely it is that the original pentavalent Arsenate (AsO_4^{3-}.) will change into the trivalent Arsenite form (AsO_3^{3-} , or As_2O_3 in groundwater) which usually predominates in the samples analyzed. One study from Western Massachusetts, for example, reported a 14/1 ratio of Arsenite to Arsenate.

As this altered form predominates there are both geochemical and toxicological implications. The tri-valent Arsenite is water soluble and therefore is much more mobile than the penta-valent Arsenate. As such it is therefore more likely to enter into the water supply and also into parts of the food chain. Arsenite is also the more toxic form, reported to be up to 50 times more toxic than Arsenate. It produces more acute toxic reactions in

the human body, and is 10 times more likely to cause chromosomal breakage. It is also much more difficult to remove from drinking water supplies.

In this regard, it is perhaps significant that morels are thought to fruit best in neutral to slightly sweet soils. The implication is that the more toxic, water soluble, trivalent form of arsenic will be more prevalent in the sweet soils that trigger or facilitate morel fruiting. A saving complication, however, is that the very water solubility of Arsenite should allow it to more readily leach from the upper soil horizons and/or rinse off the fruit body of the morel itself..

Complicating the matter of adequately monitoring the persistence of these two forms of LA residue is the fact that, at least until 1999, both the USEPA and WHO guidelines did not differentiate between the two compounds in their acceptable allowance standards and there is some concern that analyses might have failed to differentiate between the two species.

Numerous studies have attempted to measure and describe the fate of LA in the orchards. Their findings vary considerably with most reporting that LA species remain in place bound to the upper few inches of soil. Others find shallow migration. Still others find substantial movement, and some studies, particularly of sandy soils, seem unable to find any significant residue at all. (See http://soils.tfrec.wsu.edu/leadhistory.htm for a review of studies). In a related finding, the longer since application, the less likely it is that both lead and arsenic are able to penetrate the 'soil-plant barrier' and become phytoavailable. This may have implications for accumulation in morels, as discussed in the 'Assessing Risks' section below.

In one study conducted by scientists from Cornell University the range of variability found in 13 New York Apple Orchards ranged from 1.60 to 141 ppm dry weight for lead, an 88 fold difference, and from 1.48 to 720 for arsenic, a 486 fold difference .
Persistence, phytotoxicity, and management and arsenic, lead and mercury residues in old orchard soils of New York State
MERWINJ I. (1) ; PRUYNE P. T. (1) ; EBEL J. G. ; MANZELL K. L. ; LISK D. J. (1) ;
(1) Cornell Univ., New York State coll. agriculture life sci., dep. fruit vegetable sci., Ithaca NY 14853)

Conrad Geosciences Corporation has conducted soil tests from several apple orchards in the Hudson Valley of New York. In a personal correspondence the results of their unpublished surveys have been summarized as follows: "*In general, my orchard soil test results line up with your conclusions about sample variability… Lead and arsenic are both usually present in soil at elevated concentrations within former orchard boundaries we've mapped via historical aerial photos. Most of our sampling has been biased to represent areas within tree drip lines, and within areas that were most intensively cultivated over time. We always collect "background" samples outside the orchard footprint for purposes of comparison. Because State cleanup guidelines for arsenic are much lower than for lead, we find that arsenic values almost always drive the soil cleanup effort. We also find for both lead and arsenic that there is significant lateral*

variability in concentration over short distances, even a few feet. Vertical distribution is more predictable; in general we find that these metals are most concentrated in the upper 4 inches of soil, but a small percentage of sample locations show elevated concentrations below 6 inches. We rarely, if ever, find an impact to groundwater. We have not attempted to correlate lead or arsenic concentration to soil composition or other site characteristics, but we suspect that grain size (e.g. sand v. silt v. clay) may be an important factor."

A Special Pesticide Task Force in New Jersey documented similar results. They found that not only did the orchards vary one from the other, but samples within the same orchards varied by a factor of 10 or more. Samples, in fact, from one orchard found Arsenic levels ranging from 5.5 to 231 ppm, a 42 fold difference. Overall they found Arsenic exceeding clean-up levels (20ppm) in 38% of agricultural sites investigated but found lead exceeding clean-up standards (400 ppm) in only 1% of the sites, even though by raw standards lead was present in the soil on average at levels four times greater than was arsenic. (A mean of 92.64 for lead compared to 22.48 for arsenic by my calculations from their data.)

From the New Jersey data, a 'quick and dirty'* comparison of results for lead and arsenic from 5 orchard sites with that from 6 field crop sites where Lead Arsenate had been used revealed that while the arsenic levels were comparable (18.72 for field crops, 22.48 for orchards), the levels of lead were over twice as high in orchards compared to field crop sites (43.94 for field crops, 92.64 for orchards,) [* mean values of reported medians ppm] This might indicate that arsenic species are altered and dispersed at a higher rate than lead in soils subject to constant disturbance and/or fertilization, especially phosphates. (http://www.state.nj.us/dep/special/hpctf/final/historic.htm#ii_a See table 1,2,3 and notes following.)

At least two recent studies from the northeast (NH and MA) concluded that undisturbed, the lead and arsenic applied to orchards remain effectively bound to the top 8 inches of soil by humic acid, with the trivalent arsenite predominating. Once disturbed, these compounds become free to migrate.

Interestingly, these last two studies did not find in the soil any arsenic compounds which had been transformed by bacterial action into an organic (CH3 Methylated) form. This conversion in other heavy metals, such as mercury, is usually facilitated by anaerobic bacteria often in aquatic environments, but there is also work published which reports that some fungal hyphae and their associated bacteria seem to produce enzymes that facilitate this conversion in normal (aerobic) humus. In general the organic species of arsenic are more bioactive, that is, they are more likely to move into the food chain, but also more likely to be rapidly excreted in the body. They may be considered the least toxic of the arsenic compounds.
http://www3.interscience.wiley.com/journal/2724/abstract

Complicating the issue in the literature are caveats concerning the precise location and treatment of the soils sampled. It is recommended, for example, to collect samples from the drip line of trees of the time the pesticides were applied. The concentrations are likely

to be higher there rather than between the rows, the current drip line or at the base of the tree. One can conclude therefore that random collections of morels or soil even from orchards heavily sprayed will likely have markedly uneven exposure to residual LA from the spraying. Sprinkled throughout some of the more technical sites that I visited are also technical warnings and protocol designed to protect against the alteration of arsenic in the sample by the analysis process itself.

For more see:
GEOCHEMISTRY OF ARSENIC http://or.water.usgs.gov/pubs_dir/Html/WRIR98-4205/as_report6.html

Historical use of lead arsenate insecticides, resulting soil contamination and implications for soil remediation http://soils.tfrec.wsu.edu/leadhistory.htm updated July 2004

Persistence, phytotoxicity, and management and arsenic, lead and mercury residues in old orchard soils of New York State MERWINJ I. (1) ; PRUYNE P. T. (1) ; EBEL J. G. ; MANZELL K. L. ; LISK D. J. Cornell Univ., New York State coll. agriculture life sci., dep. fruit vegetable sci., Ithaca NY 14853, ETATS-UNIS

Distribution of soil arsenic species, lead and arsenic bound to humic acid molar mass fractions in a contaminated apple orchard
http://cat.inist.fr/?aModele=afficheN&cpsidt=17800558

Where's the arsenic in New England orchards?
http://www.dartmouth.edu/~news/releases/2002/may/052902a.html

Arsenic content of some edible mushroom species
http://www.springerlink.com/content/ddypdaq3ft7vtykg/

Speciation and health risk considerations of arsenic in the edible mushroom Laccaria amethystina collected from contaminated and uncontaminated locations
http://www3.interscience.wiley.com/journal/2724/abstract

Guidance for Evaluating Residual Pesticides on Lands Formerly Used for Agricultural Production: DEQ-06-LQ-011
http://www.deq.state.or.us/lq/pubs/docs/cu/GuidanceEvalResidualPesticides.pdf

The report of the Historic Pesticide Contamination Task Force of New Jersey:
(http://www.state.nj.us/ dep/special/hpctf/index.html)

LEAD AND ARSENIC IN MUSHROOMS

Accumulation of heavy metals in fungi is a well known phenomenon. Commercial wood preservatives, for example, typically rely on arsenic and copper for their effectiveness at blocking the soft, white and brown rots caused by wood decaying fungi.

Denis Benjamin, in his authoritative text, *Mushrooms, Poisons and Panaceas: A Handbook for Naturalists, Mycologists and Physicians*, summarizes the state of knowledge of uptake of heavy metals, including lead and arsenic, circa 1995. (p. 122-125) Edible mushrooms (especially *Lepista nuda* and *Lepiota rachodes*) collected from urban area or along roadsides were considered at risk for lead accumulations. He reports that "Arsenic has not proved to be a serious problem although, in truth, it has not been studied systematically worldwide." Morels are not mentioned in his treatment of this issue.

In the recent book, *Mycelium Running*, Paul Stamets discusses bioaccumulation of heavy metals in fungi (p. 100-107) and produces a chart (p. 106) showing various mushrooms with the relative estimated risks of heavy metal bioaccumulation. In this chart and discussion morels show no risk for arsenic accumulation, but do show what appear to be the highest levels for lead, a 70 to 100x accumulation index. He cautions that this is a 'work in progress', and it is unclear from his discussion how he arrived at the bioaccumulation index for M*orchella*.(*) The source he cites in the text (p. 110) for lead accumulation in mushrooms, Garcia et.al 1998, does not include *Morchella* in their investigative sample. Stamets does point out that in the soil lead is liberated and becomes available under conditions of high acidity. Since morels are often thought to fruit best in neutral or slightly alkaline conditions, one wonders about the mechanisms that are presumably in play. Most of his concern for lead and arsenic accumulation seems directed towards roadside accumulations from leaded gasoline used in the past and to those fungi fruiting on mine tailings or near smelters. An assumption, expressed elsewhere (p. 56-57), is that fungi growing in contaminated areas must be able to tolerate and/or metabolize the contaminant. (* As of this writing Mr. Stamets has not responded to a request for clarification of the high lead bioaccumulation factor in *Morchellacea* used in his chart, and I have been unable to find other reliable studies to confirm this assertion.)

Recently Stamets has applied for a patent to use hyphae of various fungi, including *Morchella sp*., as an agent in processes which could be used to remove various toxins and heavy metals from sites of environmental contamination. Paul Edward Stamets *"Delivery systems for mycotechnologies, mycofiltration, and mycoremediation*." July 7, 2003 http://www.faqs.org/patents/app/20080264858

Simple Google searches will reveal dozens of studies which have examined this uptake process in various higher fungi. The easiest way I have found to navigate around this part of the web is via the Google Scholar beta site. From http://scholar.google.com (or from http://www.google.com/) , enter "Lead Arsenate Morchella" (or your other chosen key words) and follow the threads by author or findings. Most of the studies you will find were done in Europe and report on various metals found in various fungi from various sites. A few are listed in the reference section to give a flavor of the research. None that I found seem to relate specifically to the accumulation of lead and or arsenic in morels collected from apple orchards.

One recent article however stands out. Elinoar Shavit has begun to have the Laboratory at Cornell do specific analysis on lead and arsenic concentrations in morels collected from old apple orchards. She is also looking for another co-worker with access to a lab to join her in this work. Her analysis has been published in the winter 2008 issue of *Fungi Magazine*. It is a must read article for anyone interested in this problem. (http://www.fungimag.com/winter-08-articles/Rev_Medicinal.pdf). Although there is some evidence that European morels may accumulate arsenic, she reports from her survey of the literature and her limited empirical analysis that "There is no evidence that North American morels (*M. esculenta*) accumulate arsenic from their growing environment."

In general the relevant literature indicates that saprophytic fungi seem to accumulate heavy metals in higher concentrations than do mycorrhizal ones. The connection between urban centers, along roadways, and near smelters remains a major contributing factor. *Coprinus comatus*, for example, was found to have accumulated values of 6.51 to 10.43 ppm dry weight from a city center in Spain. As some researchers conclude, it could be considered a bioindicator species for lead contamination.

In general, various reports conclude that the consumption of wild mushrooms in normal quantities does not pose any significant risk of heavy metal poisoning, although there appears to be significant variability in the bioaccumulation index of different mushrooms for different compounds, and a Finnish study recommends only occasional consumption of non-mycorrhizal species. Several studies, for example, found Cadmium levels especially high in the common Pink Bottom, *Agaricus (Psalliota) campestris*. Other studies found it highest in *Agaricus abruptibulbus*, others in *Lepiota procera*, and so on. The variability of the results appears, in itself, to be significant. A study from Italy (Cocchi et.al.) details concentrations of various heavy metals in over fifty species of mushrooms and finds that both *Mitrophora hydribra (M. semilibra)* and *Morchella esculenta* "comply with the EU directive 466/2001 with regard to their lead content (3 mg/kg dry weight)." Included in this study is a compendium of available studies on heavy metal accumulation in fungi.

As for morels, one intriguing finding from Turkey found that even though the accumulation of radioactive isotopes of heavy metals in the mushrooms they studied was low, the highest values for one such metal, Cesium 137, were found in *Morchella esculenta*.

And one unpublished study from Canada (Obst, et.al. in gtr 710 pnw) reported "In a few cases, morels exhibited elevated levels of arsenic, cadmium, and lead compared to other sampled morels, although the concentrations were not sufficiently high to be considered a health concern." Specifically, four morels collected from one site had concentrations of lead that could cause concern if a person ate a few pounds of them. They were burn morels collected 1,500 feet from a highway, but more than 40 miles from any other known pollution source.

Overall the presence of lead and arsenic found in morels collected from apple orchards sprayed with lead arsenate does not appear to have been investigated or documented.

FOR MORE SEE:
Mushrooms: Poisons and Panaceas, by Denis Benjamin, c. 1995 W.H. Freeman and Co.

Mycelium Running by Paul Stamets online at
http://books.google.com/books?id=NPI8_-omzvsC&pg=PA106&lpg=PA106&dq=gasoline+lead+mushrooms&source=web&ots=38lA21al_H&sig=dKQRaPLMBUYDX7SIkOwSlGy1tlw&hl=en&sa=X&oi=book_result&resnum=2&ct=result#PPA100,M1

Lead Content in Edible Wild Mushrooms in Northwest Spain as Indicator of Environmental Contamination http://www.springerlink.com/content/f10katb0559uyaxl/

Northern Ireland Fungus Group brief summary of MAFF report on safety of wild mushrooms: http://www.nifg.org.uk/edible_fungi.htm

Lead and cadmium content of some edible mushrooms.
http://grande.nal.usda.gov/ibids/index.php?mode2=detail&origin=ibids_references&therow=674329

Cadmium, lead, arsenic and nickel in wild edible mushrooms
http://www.environment.fi/download.asp?contentid=58008&lan=en

Arsenic content of some edible mushroom species János Vetter*
http://www.springerlink.com/content/ddypdaq3ft7vtykg

Heavy metals in edible mushrooms in Italy *
Luigi Cocchi, Luciano Vescovi, Liliane E. Petrini, Orlando Petrini
http://www.elsevier.com/locate/foodchem

For a number of studies on arsenic and wild mushrooms follow this string:*
http://scholar.google.com/scholar?q=T+STIJVE+AND+ARSENIC&hl=en&lr=&btnG=Search

Radioactivity levels in some wild edible mushroom species in Turkey
http://www.informaworld.com/smpp/content~content=a781790162~db=all

Ecology and Management of Morels Harvested From the Forests of Western North America http://www.fs.fed.us/pnw/publications/gtr710/pnw_gtr710c.pdf

* Thanks to Ron Crovisier, research librarian at Dutchess Community College, for his assistance in this search of the literature.

MOREL DEVELOPMENT AND GENETICS:

In March 2007, David Pilz and his associates published a rich compendium of recent research on Morels entitled *Ecology and Management of Morels Harvested From the Forests of Western North America***.** I relied heavily upon this source for the information in this section of this article. Among the findings of this USDA General Technical Report (GTR 710) are these:

Morels appear to have both saprophytic and mycorrhizal properties, a quality which has been described as "facultatively mycorrhizal". Capable of decomposing organic matter on their own, they will also develop weak hartig nets and other structures typical of ectomycorrhizal fungi and form association (in North America) not only with apple and elm but also with black and Norway spruce and a variety of other trees such as Western larch, Douglass fir, Lodge pole pine, alder and kocust as well as with other vascular plants such as strawberry, blackberry, grasses, and fern. In many cases a "muff" of hyphal material surrounds and then penetrates the root hairs much as endomycorrhizal fungi will, and from this vantage absorb nutrients. The muff, which also contains soil particles, apparently functions similarly to *Morchella* sclerotia in giving rise to fruit bodies under appropriate conditions.

These developmental structures and processes seem to be important in understanding the potential for heavy metal accumulations in morels for at least three reasons:
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1. Most of the residue from lead-arsenate foliar spraying appears to take up residence in the upper few inches of the humus rich soil layers in which the hyphae, muff, and sclerotia reside and from which the morels develop.
2. Saprophytic fungi apparently concentrate lead (and presumably arsenic) in concentrations higher than do mycorrhizal species. Morels apparently utilize both strategies for gaining nutrition.
3. Adhering soil particles probably represent the greatest potential for inorganic lead/arsenic contamination.(discussed below) Not only does the muff contain soil particles, but the developing fruit body of the morel has a quite large, coarse and pitted surface area in which soil particles may lodge.

Another rather remarkable feature of morels is the genetic variability and fluidity within a given mycelial colony. As described in the GTR Report, each morel may be "composed of a variable mixture of mono-, di-, multi, or heterokaryotic hyphae and the pairing of haploid nuclei can occur anywhere." Such colonies should be considered populations of nuclei or genes [rather than as individual morels]. As one geneticist reported, no two morels she has ever analyzed were genetically identical, even if they were growing in a cluster arising from a common mycelium. This inherent genetic diversity can apparently be augmented by the incorporation of new genetic material on a seasonal basis into an already established colony.

Such conditions lead to the remarkable finding that 'within group' genetic variation is greater than 'between group' variation, (a condition analogous in human populations to the genetic variation/similarity of 'black' and 'white' 'racial groups'). The authors of the GTR report therefore caution that in the light of this research, within the genus *Morchella* current species names should be considered as equivalent to common names.

One can easily speculate that such genetic variability not only goes a long way towards informing the morphological diversity apparent in individual morels, but also argues for a similar diversity in other biological properties, such as the ability to repel, accumulate or transport lead and arsenic.

See ***Ecology and Management of Morels Harvested From the Forests of Western North America*** USDA General Technical Report PNW GTR 710
http://www.fs.fed.us/pnw/publications/gtr710/pnw_gtr710c.pdf

MORELS AND OTHER PESTICIDES

Morel hunters are also concerned about the presence of pesticides and herbicides in the morels they collect. There is widespread discussion in popular sources of the dangers of pesticide accumulation, and the edict often given is to avoid collecting in contaminated areas and along roadsides. Understandably, one should avoid eating mushrooms, berries, plants, etc. that have been recently sprayed. The issue of biologically driven uptake mechanisms however is more difficult to assess. Here are summaries of four relevant studies:

1. In 1988, there was an exceptional fruiting of yellow morels (*M. esculenta*) along the Amtrak Railroad, Hudson Division, in at least Dutchess and Columbia Counties of New York State. Bushels of morels were to be found growing in the oily cinders and soil next to the rail bed. The fruiting penetrated at times 50 or more yards into the surrounding forests and also under the crushed trap-rock bed of the tracks themselves. Elm, ash, silantus and sumac as well as Japanese knotweed and *Phragmites*, an invasive reedy grass, seemed to be the plants most closely associated with the heaviest fruiting.

This fruiting was apparently caused by the initiation of a policy of heavy pesticide applications by the Railroad as a way to keep the tracks clear of vegetation. Concerned for public safety, John Haines, NYS Mycologist, and I collected several pounds of morels from the rail-side and had them tested for the pre and post emergent pesticides used in the sprays. (Atrazine, Diuron/Monuron, Round-up/Glyphosate, Weedar/2-4-D) There were no detectable amounts of these pesticides found in the morels, indicating that there was no uptake from either the spring or fall spraying series.

The literature reviewed indicated that although the compounds built around a carbon ring (e.g. DDT, 2,4-D) do bio-accumulate in living systems, their very 'organic' nature led them to be altered and decomposed in the soil by microbial decay and fungal attack. The triazine family, on the other hand, is built around a nitrogen ring and therefore escapes 'organic' processes of accumulation and degradation. Designed to break down under ultraviolet radiation, this later class of substances can easily percolate into the soil and persist for some time.

We were unable to obtain funding to have the morels analyzed for lead. It was also later realized that the oil vehicle for some spraying was probably used crank-case and transformer oil which contains PCB's, hence the 'oily' characteristic of the ashy rail bed. (*)

The results of this study were published in the Newsletters of MHMA, COMA, as well as in *Mushroom, The Journal of Wild Mushrooming*, Winter 1989-90. A digital version of this article along with an updated list of references has been posted under the title "Finding Lots of Morels Is Not Necessarily A Good Thing" at http://web.mac.com/diannasmith1/FUNGIPHOTOS/BILL_BAKAITIS_Articles/BILL_BAKAITIS_Articles.html

(* Of interest is a recent CDC report which mentioned that Lead Arsenate in the past had been used as a railway spray. Along one railway system in Bridgewater Mass. soil samples contained levels of both lead and arsenic as high as 18,000 ppm. http://www.atsdr.cdc.gov/HAC/pha/OldColonyRailroad/OldColonyRailroadPHA071607.pdf ;Table 2)

2. In general, saprophytic fungi, especially those that can degrade lignin and produce white rot are known to be quite effective in degrading a wide range of herbicides and pesticides by external enzymatic degradation. Other processes are used by other types of fungi. Both *Aspergill*us and *Pennicillium*, for example, have been shown to degrade 2,4-D in soils by enzymatic actions, while ectomycorrhizal fungi accomplished the degradation by incorporating the herbicide carbon into their tissue, not by external decomposition of the compound. A rich array of diverse pathways to degrade diverse compounds has been documented in other fungi. See, especially Sarah Maloney (*Pesticide Degradation, Ch. 8)* in *Fungi in Bioremediation* by Geoffrey M. Gadd http://books.google.com/books?id=e4PPIXdtrgEC&pg=PA202&lpg=PA202&dq=2,4-D+fungi&source=web&ots=7SGqhGqUj0&sig=KyRUMMoUtf87QL6tZ-xkCdlxCNE#PPP1,M1

3. The *Morchellacea* are capable of both saprotrophic, and mycorrhizal strategies, utilized perhaps at different times in their life cycles. Stamets observed that *M. angusticeps* produces what appears to be brown rot in cultivated sawdust beds. (p. 270 *Mycelium Running*). A German study investigated how certain wood and litter decaying fungi release "extracellular enzymes capable of oxidizing a wide range of aromatic compounds" and found that "*Lactarius* and *Russula* and the possibly more saprotrophic *Morchella* showed the most intense enzyme reactions." Presumably such mechanisms are those which would be of value in bioremediation processes.

In the absence of empirical evidence to the contrary, and to the extent that this specific finding is upheld for other pesticides, this finding would tend to turn on its head the commonly stated assertion that morels will accumulate organic toxins. (Please note that this is speculation.) Spot tests for oxidative enzymes in ectomycorrhizal, wood-, and litter decaying fungi G. GRAMSS , TH. GÜNTHER and W. FRITSCHE http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=42159

4. In some opposition to the above speculative hypothesis, the GTR 710 report issues this statement P64): "Blanco-Dios (2002) reported the only research we found that examined the effect of herbicides on morels. The article described an area treated for 10 years with herbicides near Galicia in northwestern Spain where malformed sporocarps of *M. conica* appeared in 3 of the 4 years that morels fruited." (p. 64) The implication is that this

species had some biological process altered, although the mechanism is not apparent from this scant information available, and I was unable to retrieve either an abstract or translation of this article.

RISKS OF INGESTING LEAD AND ARSENIC FROM CROPS [MUSHROOMS?] GROWN ON CONTAMINATED SOILS

In short, given everything presented above, one could easily come to the same conclusion that Frank J. Peryea, Ph.D., Washington State University soil scientist and horticulturist, came to when he investigated this issue: "The inherent variation among people, plants, soils, and behavioral factors greatly complicates predicting the relative lead or arsenic hazard of food plants and contaminated soils."

His suggestions for handling plants grown in contaminated soils, however, do bear repeating: here read 'morels' or 'mushrooms' for 'plants', of course.

"Concentrations of lead and arsenic in soil may be 10 to 1000 times greater than their concentrations in plants growing on that soil. Because of this, failure to remove soil particles that adhere or become trapped on the outside surfaces of garden crops can substantially increase dietary lead and arsenic obtained by eating garden plants.
• Wash garden crops grown on lead- and arsenic-enriched soils with water before bringing them into the house. This removes most soil particles, reduces the lead and arsenic content of the crops, and reduces the transport of soil lead and arsenic into the home.
• Once you have brought the produce inside, wash it again carefully, using edible soap or detergent (sold at many supermarkets), water, and a scrub brush to remove remaining soil particles. Pay particular attention to crops like broccoli having rough exposed exteriors that can trap soil. Leafy plants having large surface areas (such as lettuce and swiss chard) can trap and retain large quantities of dust.
• Pare root and tuber crops (such as potatoes, carrots and radishes) and discard the parings.
• Do not compost unused plant parts, peelings, and parings for later use in the garden.
These practices will reduce the lead and arsenic content of harvested home garden produce to the lowest possible levels."
Gardening on Lead- and Arsenic-Contaminated Soils: Frank J. Perya
http://cru.cahe.wsu.edu/CEPublications/eb1884/eb1884.pdf

This advice seems particularly pertinent in the case of morels which not only may spring from a contaminated substrate, but also have a deeply textured outer surface, harbor soil dwelling organisms in their easily accessible internal cavity, and are so highly valued that every shred of mushroom usually goes into the pot. Since many morel foragers also collect and eat ramps (a wild member of the garlic/onion/leek family) along with their morels this concern for adhering soil particles may be doubly important. Notice that the greater concern here is not upon complex biologically driven uptake processes within the plant or mushroom, but upon the much simpler fact that wet dirt and mud is sticky, and that most studies find the LA residues in the top few inches of orchard soil.

Concerning the phytoavailability of LA residues in crops, Peryea concludes:
"In general, plants do not absorb appreciable amounts of Pb [lead] and As [arsenic] and translocate these elements to edible plant tissues, a phenomenon termed the "soil-plant barrier". Lead in LA-contaminated soils is not appreciably phytotoxic. The concentration of Pb in tree fruits grown on LA-contaminated soils is extremely low. In contrast, the Pb concentration in vegetable crops is higher, and in some leafy and tuberous plants can approach or exceed values associated with human health risk. High-Pb soil particles adhering to the surfaces of these plants may account for some of the elevated Pb content. Arsenic in LA-contaminated soils is phytoavailable and can be phytotoxic. While elevated compared to crops grown on uncontaminated soils, the concentrations of As in tree fruits and the edible portions of garden crops grown on LA-contaminated soil are substantially lower than levels associated with human health risk."
http://soils.tfrec.wsu.edu/leadhistory.htm PERYEA Francis J. updated 2004

See also doi:10.1016/j.microc.2005.12.003 *Uptake of lead and arsenic in food plants grown in contaminated soil from Barber Orchard, NC;* Alisha Pendergrass and David J. Butcher.

In a final indication of the dearth of information on the status of arsenic uptake in morels growing in LA contaminated orchards, the CDC's TOXICOLOGICAL PROFILE FOR ARSENIC (2006) reports:
"Carrots growing on land containing somewhat more than the permissible of arsenic in crop land did not contain levels of arsenic that were harmful. However, further research on the uptake of arsenic by a variety of plants in a wide range of arsenic polluted sites (e.g., mining area, orchards previously treated with lead arsenate) would be valuable in assessing human exposure near such sites through the consumption of vegetables from home gardens."
http://www.atsdr.cdc.gov/toxprofiles/tp2-c6.pdf (p. 377) This is a very comprehensive document surveying a wide range of literature but I could not find any reference to mushrooms, edible or not, contained within this section of the document.

To put into perspective the matter of potential lead accumulation in humans from morels collected from apple orchards, we might consider that there is a good deal of lead found in galvanized water pipes and homes in the Northeast. One recent report indicates that "Typically, about 10 percent of the homes tested show unsafe levels of lead" with 83 percent of urban homes tested near Boston "contaminated with lead - 1,000 parts per million on average."
http://www.boston.com/news/science/articles/2008/08/11/lead_may_lurk_in_backyard_gardens/

ARSENIC IN THE BODY

From a number of studies and reports, I was able to extract a number of findings that although they did not focus on consumption of mushrooms, did seem to relate to the biological process and risks presumed to follow from eating morels collected from apple orchards that had been sprayed with Lead Arsenate.

A comprehensive summary of the biological processes and toxicity of arsenic conducted in conjunction with the World Health Organization (circa 1982) can be found at http://www.inchem.org/documents/jecfa/jecmono/v18je17.htm. Some findings follow:

As previously mentioned the water soluble Arsenite is absorbed much more easily by the body than the original Lead Arsenate form of the compound. Both of these inorganic compounds are usually more toxic than organic compounds, though the literature reveals that there are exceptions to these generalizations.

Once absorbed, arsenic passes from the blood in a matter of hours and is widely distributed throughout the body. Many of the toxicological effects of arsenic, especially the trivalent forms, are believed to be associated with its reaction to particular chemical groups (cellular Sulfhydryl (-SH). Tissues rich in these, therefore, are often affected, particularly the gastrointestinal tract, kidney, liver, lung and epidermis. The highest concentrations are usually found in the hair and nails.

In acute or subacute poisoning the clinical signs include fever, diarrhea, emaciation, anorexia, vomiting, increased irritability, exanthemata and hair loss. Signs of chronic toxicity are often dermatological (melanosis, keratosis, desquamation, finger-nail changes), haematological (anaemia, leucopaenia) or hepatic enlargement.

Organic arsenic compounds, such as those found in fish, clear from the body in a few days; a meal or two containing dietary arsenic is not considered toxic. (Adults must consume about 3mg/day for two or three weeks for toxic effects to be seen).

Inorganic arsenic on the other hand, such as might be derived from Lead Arsenate has been assessed to have a biological half-life of from two to forty or more days, depending upon body distribution. These compounds therefore have the potential to accumulate from the daily amounts absorbed from environmental exposure. In circumstances where continued daily intakes of arsenic exceed the total daily elimination accumulation will occur.

What is a safe level of arsenic in the body? "The normal content of arsenic in the human body has been estimated at between 3 and 4 mg (National Academy of Sciences, 1977) and by inference these total tissue deposits of arsenic may be tolerated by man without untoward effects." A recent study cited by the Center for Disease Control estimated the mean daily consumption of inorganic arsenic in the American diet was 10.22 µg/day with a range of 0.93–104.89 µg/day. http://www.atsdr.cdc.gov/toxprofiles/tp2-c6.pdf (p. 358)

In 1966, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) concluded that "until further data are obtained, the maximum acceptable lead of arsenic can be placed at 0.05 mg per kg body weight per day". In 1982, this limit was refined to 0.002 mg/kg bw of inorganic dietary arsenic, and in 2006 the US EPA lowered the standard in drinking water from 50 to 10 mg/liter reflecting an increased concern for public health

safety.. *Environmental Pollution 126 (2003) 157–167* doi:10.1016/S0269-7491(03)00208-2

Given inherent variability, not all individuals have the same reactions to arsenic in their diet. WVM Lai et al, for example, followed the fate of organic metabolites in 9 subjects for three days following consumption and found significant differences in the amount of metabolites in their urine. *Arsenic speciation in human urine: are we all the same?* WVM Lai et al doi:10.1016/j.taap.2003.10.033

Finally, and significantly, a study which examined both the immediate and long term health risks for orchard workers exposed to what was judged to be the highest exposure of Lead Arsenate in the United States found that although there was some age-adjusted hazard risks for male workers in and around the orchard, "the only significantly increased age-adjusted hazard ratio (1.94) was [for] heart disease in male intermediates. No significantly elevated age-adjusted hazard ratios were observed for women in any exposure group."
Mortality in a cohort of orchard workers exposed to lead arsenate pesticide spray
Tollestrup, K | Daling, JR | Allard, J; Archives of Environmental Health [ARCH. ENVIRON. HEALTH]. Vol. 50, no. 3, pp. 221-229. 1995.
http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=ENV&recid=3770538&q=lead+arsenate&uid=&setcookie=yes

LEAD IN THE BODY

During the late 1960's societal interest in the cumulative effects of lead exposure led to a series of studies designed to better understand the way our body processes low levels of lead. The primary sources of this exposure came from the degradation of lead based paints, the combustion of leaded gasoline and the leaching of lead from galvanized water pipes. At the time 'lead poisoning' of children seemed to reach epidemic proportions in some neighborhoods.

The studies revealed that following ingestion, lead is held in seral (blood) suspension for about one month during which time half of it is excreted from the body, largely by the kidneys. The remainder moves through soft tissue at varying rates, some being excreted, but with the greater amount being deposited and *sequestered* in mineralized tissue, namely teeth and bones. This repository acts like a battery, continually accumulating low doses with the result that, over time, a substantial toxic charge has been stored.

In this regard major differences with the way arsenic is processed become apparent, for unlike arsenic which comes to be deposited in dead nails and hair, the lead is sequestered in living bone tissue and will again become available for bodily reprocessing whenever the bones begin to break down. This is likely to occur during two important phases of life.

The first begins during the third trimester of pregnancy when fetal demands for calcium surpass the mother's luxious, blood-borne supplies. This phase, which obviously occurs only in women, ends with the cessation of lactation. Lead released during this pre and post natal period greatly affect the fetus and nursing neonate who are much more sensitive to the toxic effects of lead than are adults. Substantial brain growth in the fetus, for example, takes place precisely during the third trimester and lead released from the mother's bones during this period has been demonstrated to affect both subsequent mental performance and behavior of the child so affected.

The second phase of life where sequestered lead is released along with calcium is during senescence when osteoporosis occurs. Both men and women undergo this process, although most attention in our culture emphasizes the risks to women. Since lead is a known neurotoxin, the lead released during this phase likely contributes to some forms of senility.

Concerning sequestration, as the low level exposure continues, visible "lead lines" appear in the bones. These start to appear at blood levels of about 45 μg/dL and indicate significant chronic exposure. About 6–8 weeks of lead exposure > 45 μg/dL is required to produce “lead lines”.

During normal metabolic processes a recycling process occurs in which lead that is released from the sequestered store undergoes reprocessing similar to that which occurred during the original ingestion. The half life of sequestered lead appears to be about 25 years.

Lead is toxic to the nervous, gastrointestinal, haematopoietic, cardiovascular, and reproductive systems as well as the skeleton and kidneys. It is a powerful neuroteratogen as well. Signs and symptoms vary with dose and at a given dose by age.

Typical signs and symptoms of lead poisoning include: abdominal pain, encephalopathy, seizures, coma and death. Poisoning may also be much more subtle, leading to metabolic abnormalities and anemia, but with no overt symptomatology. In some cases lead may be associated with delayed puberty in girls. One particular sign, “wrist drop”, is a pathognomonic sign for lead poisoning. It is a manifestation of peripheral neuropathy and motor weakness, there is weakness of the extensor muscles of the hand, resulting in “wrist drop”.

The above findings were retrieved from http://www.who.int/ceh/capacity/Lead.pdf.

Until recently it was thought that lead sequestered in bone tissue was passive; it was released during osteoporosis, but was not a cause if this condition. Current research is now finding that sequestered lead may also be influential in the etiology of osteoporosis. *Osteotoxicology: the role of lead in bone diseases. Current Opinion in Orthopedics*. 11(5):360-365, October 2000. Puzas, J. Edward, PhD
http://www.co-orthopedics.com/pt/re/coortho/abstract.00001433-200010000-00006.htm;jsessionid=LGLSLvtL0fpvjpR3wp1yTRLp84zFQjQMPndQ9DLdy1pGNGsjLDyK!-1004083789!181195629!8091!-1

Given the 25 year half life of sequestered lead, its presumed role in both causing and being released during osteoporosis, as well as the consideration that released lead may then be recycled in the body, it is safe to assume that those who may have been exposed to low levels of lead during their lifetimes might be concerned about bone loss as they age. If lead is a cause of osteoporosis, and if low levels of lead have been systematically sequestered in the bones over the years, then bone loss in senescence could potentially trigger a cascade of both ever-increasing bone losses and toxic releases of lead in the body. Fortunately bone scans and treatment regimes are readily available and should be part of every aging mycophagist's health care strategy. This is one process that can and should be nipped in the bud!

ASSESSING RISKS ASSOCIATED WITH EATING MORELS COLLECTED FROM APPLE ORCHARDS

I began this investigation because of Sandy Sheine's prompting and because I too have eaten many a morel collected from old apple orchards, some so old that the apple trees were only a memory among the thirty year old elms freshly falling to blight. Safe to say, there appears to be no clear answer to the questions raised about the risk of eating morels collected from old apple orchards. What I have done below is to group some of the more salient findings in a non-parametric way. These are not crisp assessments. At best they may rise to the power of an ordinal scale. Some findings appear more important than others, but there is no way to judge their relative importance. I think of them therefore as nominal data, clumped together in broad categories. That said, here goes.

1. There appears to be a great deal of variation associated with every aspect considered:
    * the amount and formulation of Lead Arsenate applied to orchards
    * the fate of both lead and arsenic in the soil following application
    * the differences in toxicity among the several species of LA residue
    * the distribution of LA residue within the orchard and at different depths
    * the effect upon different species of fungi, and of fungi to the residue
    * the differences between saprophytic and mycorrhizal processes
    * the inherent genetic diversity of the morel hyphal community
    * the ability of LA residues to adhere to or be transported into morel fruitbodies
    * the variation within the human body in the way these residues are processed.

2. There remains a critical need for empirical data, to actually test for and measure the amounts of lead, arsenic, and other herbicides and pesticides found in morels, and if found, to be calibrated according to the species and toxicity of the compounds.

3. On the negative side, the finding that soils favorable to morel production are also those which favor the conversion of the original more benign Arsenate into the much more toxic Arsenite is quite disturbing and would argue against eating morels collected from LA treated orchards.

4. On the other hand, and in the absence of further data, a number of findings seem to indicate that morels collected from apple orchards are probably safe to eat (so long that they have not been sprayed directly). Consider these:
* The few morels collected and tested by E. Shavit from LA contaminated soil had no detectable levels of arsenic in the fruitbody.
* Three pounds of morels collected from the pesticide contaminated Railroad site (Bakaitis and Haines) had no detectable levels of the four compounds known to have been sprayed on that site.
* The only significant long or short term health risk found in the orchard workers, associates, and consumers from the highly contaminated orchard in the state of Washington was for heart disease for males associated with the industry but not working directly with the spraying.
* LA residues appear to lose their ability to cross a vegetative barrier over time and become less likely to enter into plant/fungal tissue. In a similar fashion, think of wood that has been pressure treated with arsenic compounds in order to prevent fungal decay. In my experience, even though rated for "30 years of effectiveness" it will begin to decay within a few years of ground contact demonstrating reduced ability to invade fungi. The older the orchard then, the less likely seems to be the probability that LA residues are able to transport into mushrooms.
* And finally, it appears significant that with hundreds, if not thousands, of mushroom hunters eating morels collected from apple orchards, few have reported illness typical of heavy metal poisoning. Though suggestive, this lack of reporting does not, in itself, constitute proof.

One way to scientifically attack this problem is by a carefully constructed study. Such a study might locate a sizeable population of individuals who over a period of years had eaten morels collected from contaminated apple orchards and then after careful bio-medical workups compare their rates of morbidity to those of an otherwise similar population. One would want to control for factors such as age, education, and diet, particularly the consumption of other mushrooms known to accumulate lead and arsenic. Such a study could segregate the populations as a function of the length of time they had been consuming the suspected morels and comparing the data collected from these groups one to another and also to the general control group. This is called a cross sectional study.

Another way would be to follow a group of apple orchard morel eaters for a long period of time, assessing their health status on an annual basis, and comparing it to a suitable control group. This is called a longitudinal study. Some go on for a lifespan.

One might think it would be sufficient that those mycophagists reading this (or similar articles) might simply fill out a questionnaire and report their experiences to a central collector. Although this might be interesting, and might turn up a few more case studies, it could not offer proof for either form of the hypothesis, 'safe' or 'not safe'. Readers of a mycological journal, after all, would be doubly biased: biased first by the self selected list of subscribers, and secondly by the self selection of those who chose to report. Such 'self-selecting' survey methods are notoriously misleading.

Given that a scientifically valid study would be quite costly and time consuming, and given that, so far, there has been little formal interest in studying mycological aspects associated with the risks of this heavy metal problem – at least in the US, I must conclude that we are on our own and will have to make these risk calculations for ourselves, much as we have done for other mushrooms.

If one were to do a non-parametric test of significance of the factors grouped in this risk assessment, the five factors nominally grouped together as #4 ('safe to eat') would outweigh the single factor in #3, ('unsafe to eat'). I am probably inclined towards this conclusion.

Another way of saying this might be to notice that the amount of lead consumed by eating morels is probably far lower than the amount of lead that accumulates overnight in lead (galvanized iron) water pipes (and also in some lead-soldered copper pipes). Water samples drawn from such stale pooled sources reliably fail the tests for allowable standards (15 ppb) in home sales (at least in Dutchess County NY). Samples drawn after 20 minutes of pipe flush from the very same water tap usually have no detectable levels of lead.

It seems to me that simply collecting one's morning coffee or tea water in a non-reactive vessel the previous evening - after your pipes were flushed by doing the dishes, laundry, using the toilet, etc. - would grant a far larger safety margin than avoiding a few morels collected seasonally from old apple orchards.

But for those of us who have other loads of lead and/or arsenic the extra amount that might come from suspect mushrooms might tip the balance. And then too there is the non-trivial worry factor. Anxiety itself can degrade healthy biological systems in the body.

When I was discussing this issue with Sandy Sheine, she said that she and Jerry collected all of their morels from elms, and none from apple orchards out of concern about lead. They still ate morels but slept better at night. Old, but not Bold; Not bad advice.

For more on morel collecting strategies over a variety of collecting habitats see http://leslieland.com/blog/collecting-wild-mushrooms-part-1-morels/