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Liberalization of Electricity Markets and Coal Use

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INTRODUCTION

Electricity supply has been regarded for many years as a sector which was best run as a monopoly, and in most cases as a state-owned monopoly. Over the last ten years, this view of electricity markets has changed and in most countries the sector has undergone some reform. Restructuring of the electricity supply industries is a complex exercise based on national energy strategies and policies, macroeconomic developments and national conditions, and its application varies from country to country. In some countries, the restructuring has totally changed the form of the industry, whereas in others the changes have been less dramatic. There are three main areas of reform: the division of the four functions (generation, transmission, distribution and retail / marketing; the degree of competition introduced into the marketplace of each function; and the ownership of the industry (state-owned, private or mixed).

The changes were initiated by a realization that electricity-supply industries need not be monopolies, the cost reduction potential of competition, increased fuel availability and fuel supply stability and the development of new technologies in power generation and information technology. Governments pursue liberalization to reduce the public sector financial burden, to benefit the consumers in the form of lower electricity prices, to improve the competitiveness of the economy and to move to a more globalized energy sector following the globalization of the world economy.

OVERVIEW OF COUNTRIES

This article focuses on reform in developed economies and economies in transition. An overview of the reforms taking place in the electricity supply industries in a number of coal user countries (Australia, Czech Republic, Germany, Hungary, Italy, Japan, Poland, Spain, Turkey, United Kingdom and USA) is given in the report this article is based on. All European Union (EU) member states have introduced legislation and have partly opened their market according to their obligations set out in the EU electricity directive. According to the directive, all electricity supply industries are expected to be liberalized in the long term achieving a single European electricity market, therefore introducing competition between states as well as within each state.

ISSUES AFFECTING COAL USE IN LIBERALIZED ELECTRICITY MARKETS

There are a number of factors and the interplay between these factors that will affect future use of coal in liberalized electricity markets and in some cases the results are quite uncertain. The effects of electricity liberalization on coal were investigated in relation to a number of issues affecting coal use.

Trends in electricity demand and availability of fuel

World electricity production is expected to grow by an annual rate of three percent between 1995 and 2020 according to International Energy Agency (IEA) projections. Coal retains a strong position in world power generation and will continue to do so. However, the use of gas is expected to grow at a faster

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Chemical Precipitation of Mercury: Commercial Claims and New Approaches

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INTRODUCTION

Mercury is a potent neurotoxin and is endemic in the environment. The element can be found in air, sediments, soils, seawater and natural fresh waters. Mercury originates from natural and artificial sources including: volcanoes, forest fires, some coal-fired power plants, crematoria, mineral deposits, seawater, and chloralkali plants. An estimated 18,000 metric tons of mercury have been deposited globally since the beginning of the Industrial Age. The chemical forms of mercury in nature depend on their locations in the environment, which result in various, challenging remediation problems.

During the last few decades, federal and state governments have instituted environmental regulations to protect the quality of surface and ground waters from a number of organic and inorganic contaminants. In response to the regulatory requirements, numerous companies have developed and marketed chemical products to precipitate contaminants from waste effluents. Additionally, some of the products have been used to remove heavy metals from already contaminated surface and ground waters. Contaminated ground waters, for example, may be pumped to the surface and treated. Some companies

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DEFINITIONS

Liberalization	process of market reforms to introduce competition and a less restrictive regulatory framework for companies in the sector
Deregulation or reregulation	modification or repeal of existing regulation or the removal of state control and the introduction of a more formal regulatory framework
Unbundling	splitting the different functions of the industry (generation, transmission, distribution and retail) into separate business within one company or into separate companies
Privatization	the sale of government assets to the private sector
Corporatization	often a first step to privatization. A state-owned company is required to operate as a commercial company in the interests of transparency, economic efficiency and credit worthiness
Independent Power Producer (IPP)	privately owned generating company that sells electricity to the purchasing utility, usually in state-controlled industries
Competitive bidding	the existing generating company invites contractors to tender to build, operate and sell electricity to the monopoly at a specified price
Competition in generation	all licensed generators are allowed to compete to supply the market through long term contracts or a short term market (spot market)
Competition in retail	allows all consumers, including household consumers, to choose their supplier
Stranded costs	costs that were prudently incurred to serve electricity customers within a certain regulatory environment and which cannot be recovered within a new regulated competitive environment
Pool	a spot market for electricity, operated by an independent body. It balances supply and demand and produces a spot price on a short period basis (e.g. half-hourly)

rate. This is primarily because, in countries where gas is available at competitive prices, gas-fired plants are cheaper to build and operate, at least in the short and medium term. Liberalization has played a role in opening the way for gas to compete with other fuels. Whereas oil reserves are mainly concentrated in the Middle East and gas reserves in the Middle East and Former Soviet Union, coal can be found in large quantities throughout the world. Coal is still the favored fuel in locations close to low-cost coal production (for example parts of North America, Australia, and South Africa), in areas where gas is unavailable or expensive (as in those developing countries that have coal available, like China and India), and in areas where there are existing coal-fired units. The move to a more globalized energy sector, open to different players and less restricted than in the past, has resulted in increased fuel availability and fuel supply stability.

Power plant operation

Under central planning, the operation of power plants was decided months in advance based mainly on the technical characteristics and the availability of the units. In liberalized markets, decisions are taken on a short-term basis. In the United Kingdom for example, generators bid into the pool (spot market) every day and sell electricity only if their prices are competitive. Generating companies are no longer obliged to generate electricity; they can choose to generate when they think it is profitable for them.

Coal contracts are also affected by changes in power plant operation. There is a general move to shorter-term fuel supply contracts to match the electricity sales contracts in liberalized markets. Flexibility in plant operation is an advantage in the competitive market where conditions change quickly. An advantage of coal is the fact that it can be easily stored in stockpiles, whereas storing gas is much more complicated and expensive and restricted to certain quantities. Coal stockpiles can ensure supply security for the generator.

Energy policy and government intervention

Governments are expected to influence energy policy even in liberalized electricity markets, although intervention is in principle incompatible with the free competitive market. Governments are concerned with issues such as supply security and diversity in the fuel

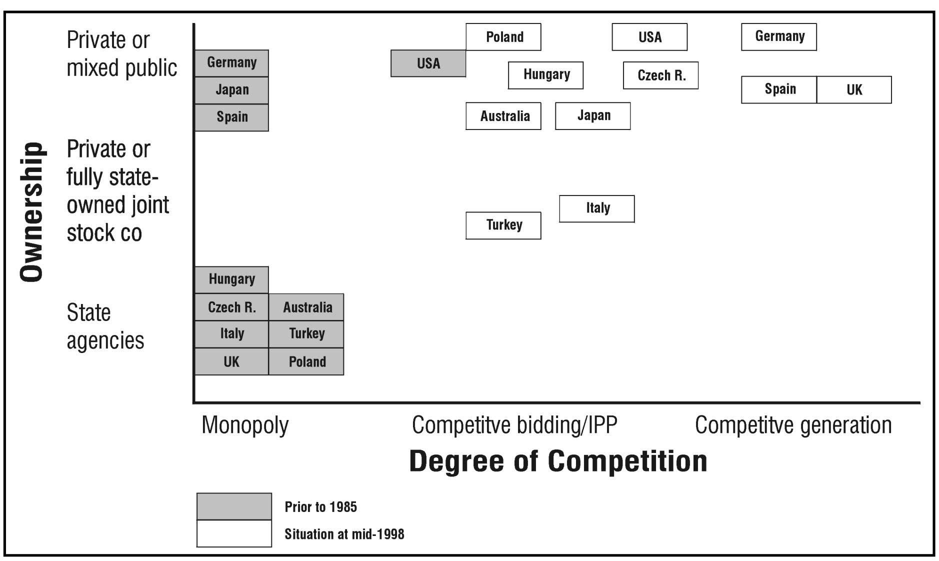

Figure 1. *Status of various electricity supply industries*

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mix, economic efficiency, reliability of the system, environmental performance and social issues including employment. Government intervention in energy policy has to be transparent and openly regulated in liberalized markets.

One factor which could see coal retaining a market share of new generating plants is the need for countries to have a secure supply of electricity without becoming over-dependent on one fuel source. Stranded costs are an issue that has also caused government intervention in liberalized markets. The stranded costs issues have not yet been resolved in most of the countries moving towards liberalization and government intervention is expected to be necessary.

Costs

Coal-fired plants will have to compete with gas-fired plants in many of the liberalized electricity markets. Existing coal-fired plants can benefit from liberalization as they are cheaper than gas-fired to operate. However, when comparing new plants, gas-fired plants may be preferred in regions where gas is available at competitive prices because they are cheaper to build. Although gas-fired technology is cheaper in US$/kWe, there are other factors that should be taken into account. Natural gas is not available in every country and prices are not always competitive. Moreover the infrastructure to produce and transport gas is much more capital intensive than the equivalent costs for coal. As demand for natural gas grows, new infrastructure will be needed. It is estimated that to cover the incremental demand of natural gas in Europe (1.7 percent annual growth between 1999 and 2015), investments of US$100 - 200 billion for infrastructure will be required. Such investments could be undertaken only in the framework of long-term contracts and it is uncertain whether they could be profitable in competitive electricity and gas markets.

Liberalization has changed the culture of the companies in the electricity industry who now have to survive in a competitive market place. As companies try to minimize costs and increase their flexibility to respond to market trends, fuel contracts tend to be shorter and fuel prices are exposed to price fluctuations. Coal procurement is changing, reflecting these changes. The need to minimize risk in liberalized markets brought about the *derivatives* market for coal, a financial market as opposed to the physical market. This is still at an early stage but may help minimize risk in the coal market.

Technology advances - clean coal technologies

Environmental regulations are already in place in many countries and their impact on plant dispatching and choice of new generating plants is likely to grow. Policies to reduce greenhouse gas emissions are expected to play an important role in the future of coal, as countries have committed to emissions-reduction targets under international agreements. In a liberalized market the environmental image of fuels and technologies is important as it can influence decisions taken by developers as well as by consumers. Gas is favored in terms of environmental performance as gas-fired plants achieve higher efficiencies and lower emissions. However, clean-coal technologies with emission controls can successfully comply with strict environmental standards. There has been considerable effort to develop these technologies at competitive costs.

Plant designers and contractors are responding to the new market requirements. They recognize the intensified competition which has resulted from liberalization and that the projects which will proceed are those with low investment costs, short construction times and the highest flexibility. Capital costs for clean coal technologies have decreased but further reductions are needed for them to become competitive. Technology advances have also been achieved in coal mining equipment and labor productivity has improved. On the other hand there is evidence that competition has cut into long-run research, development and demonstration efforts.

CONCLUSIONS

There is not a simple answer as to how coal is affected by liberalization. Experience of the effects is relatively limited as most countries are still undergoing reforms. There are many unresolved questions on the long-term effects. Future developments will depend on the experience gathered. However, coal makes a dominant contribution to worldwide power generation and this is forecast to continue for at least the next 10-20 years.

This article is based on the IEA Coal Research report: Liberalization of electricity markets and coal use, October 1999 by Katerina Rousaki. Ms. Rousaki may be reached at: katerina@iea-coal.org.uk

even claim that their products are so innocuous that they may be pumped into the subsurface for relatively economical *in situ* remediation. In such cases, the product and any precipitates would be left in the subsurface.

Aqueous mercury precipitation has been the focus of our research for the past four years. This research has been conducted along two fronts. The first is the examination of commercially available chemical precipitants. The second is the synthesis of various sulfur-containing ligands that would lock a central mercury atom into a perfectly tetrahedral, $-S_4$, coordination environment. Methylation-resistant precipitates are needed because the usual HgS precipitates can be eventually methylated. That is, inorganic mercury ions (Hg^{2+}) can be converted into highly toxic, bioavailable methylmercury (CH_3Hg^+). The technology that we intend to develop may have *in-situ* applications and would be useful in remediating natural waters, industrial wastewaters such as those from chloralkali plants, and contaminated soils and sediments.

COMMERCIAL REAGENTS

Surprisingly, in contrast to food and drugs, there is no formal and rigorous program in the United States to evaluate the claims of commercial water-treatment products before they are marketed. We have shown that the chemical properties of two commercial products appear to be more complicated than descriptions from their manufacturers or the patent literature. Clearly, the chemistry of these and other treatment products must be known before they are used in treatment facilities or released into the environment.

One of these products is a pH 12 aqueous solution of alkali thiocarbonates ($[Na,K]_2CS_3 \cdot nH_2O$, where $n \geq 0$) and sulfides. We have determined that the product removes heavy metals, such as mercury, copper, lead and zinc, through the precipitation of metal sulfides (HgS, CuS, PbS, and ZnS) rather than metal thiocarbonates ($HgCS_3$, $CuCS_3$, $PbCS_3$, and $ZnCS_3$) as claimed by the manufacturer (Equations 1 and 2).

Equation 1.

$$\mathbf{CS_3^{2-} + Pb^{2+} \rightarrow PbCS_3}$$

Equation 2.

$$\mathbf{CS_3^{2-} + Pb^{2+} (\rightarrow PbCS_3) \rightarrow PbS + CS_2}$$

(continued, page 4)

Chemical Precipitation, (cont.)

Personnel at the company are aware that the product has a noticeable H_2S odor and have developed an odorless alternative. However, they are unaware or do not mention that highly flammable and poisonous carbon disulfide (CS_2) may result from reactions between alkali thiocarbonates (such as those in the product) and aqueous solutions of dissolved heavy metals (Equation 2). Specifically, laboratory studies qualitatively detected low levels of CS_2 in the unreacted product and suggest that CS_2 is a common by-product of reactions between the product and aqueous solutions of divalent heavy metals, such as mercury, copper, lead and zinc. These conclusions are supported by studies summarized in the past literature with other aqueous solutions of sodium thiocarbonate. The potential customers should be aware of this problem, especially if they are seriously considering injecting it into contaminated soils and sediments for *in situ* remediation as advocated by the literature.

The existence of 2,4,6-trimercapto-triazine compounds (TMT = $[C_3N_3S_3]^{3-}$) has been known since at least the late 1800's. The two common forms of TMT are $H_3C_3N_3S_3$ and $Na_3C_3N_3S_3{\cdot}9H_2O$, which are interconvertible (Figure 1). Numerous patents and applications have been developed for TMT compounds, including: silver plating, anion exchange resins, dyes, and vulcanization of rubber. TMT-55 or 2,4,6-trimercaptotriazine trisodium salt ($Na_3C_3N_3S_3{\cdot}9H_2O = Na_3TMT$) is also widely used to precipitate mercury, copper, silver, lead, and other divalent and univalent heavy metals from waste effluents.

Despite their widespread use, very little is known about the chemistry or structural properties of most TMT compounds, including their stability in air and water, and their potential impacts on human health and the environment. For instance, the crystal structure of TMT-55 and all of the dissociation constants for the TMT anions were only recently determined.

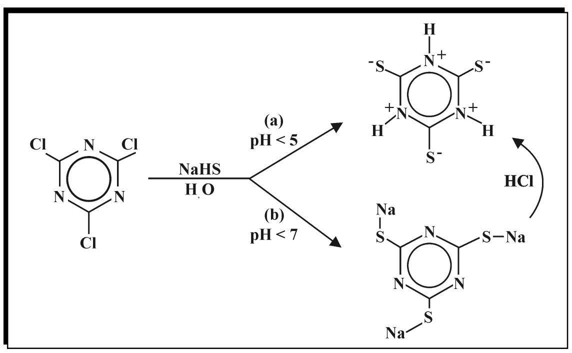

Figure 1. *Reactions to form the TMT compounds: $H_3C_3N_3S_3$ and $Na_3C_3N_3S_3{\cdot}9H_2O$.*

Claims have been made that TMT-55 contains 55 wt% reactive materials and 45 wt% water. However, our chemical analyses and single crystal X-ray diffraction (XRD) data demonstrated that TMT-55 contains only 40 wt% water. The lower water concentration means that the dosage for the product could be lowered, which would result in less release of TMT-55 into the en-vironment and lower treatment costs.

We have begun a systematic exploration of the TMT ligand system with a wide range of cations. Currently, published and preliminary data are available for a comprehensive series of group 1 and group 2 compounds, as well as some silver and mercury compounds that have proven to be difficult to characterize. We examined the possibility that TMT could be used to remove barium from aqueous sources. However, we found that the two precipitates ($Ba_3TMT_2{\cdot}8H_2O$ and $Ba[H_2TMT]_2{\cdot}4.5H_2O$) were too soluble (both about 5 grams/liter to immobilize barium.

The interactions of TMT with various mercury salts is complicated. For instance, a white gel forms when mercury(II) reacts with TMT-55 in water. The gel may dry to chalky white, yellow, gray or resinous green varieties of Hg-TMT. Over days to months in either air or as a water suspension, the white variety may alter to the yellow form and then eventually to the gray. All of these forms are still under-going detailed chemical characterization.

The stability and leachability of different heavy metal (cadmium, lead, mercury and zinc, in particular) TMT compounds may be highly variable. Batch leaching studies of three mercury TMT compounds indicated that the crystalline "white" variety is fairly soluble in water and may release at least 4 milligrams/liter of mercury into distilled and deionized water. In distilled water, cadmium, lead, and zinc TMT compounds may also release more than 10 mg/L of the metals.

NEW APPROACHES: TETRADENTATE (-S_4) CHELATE LIGANDS

It is difficult to filter waste streams or natural waters to remove mercury. Filtering is not only expensive, but it is also ineffective in removing colloidal mercury. This has been the case, for example, in the removal of mercury from seawater with chelating resins. The same problem is expected with mercury in natural fresh waters. Our ultimate goal is to synthesize non-toxic sulfur-containing ligands that could be used to treat contaminated waters or even immobilize mercury in situ in soils and sediments. Ideally, the ligands would be derived from inexpensive natural sources. These molecules will be designed to withstand decomposition under environmental conditions. They will provide an ideal tetrahedral geometry around the bound mercury; that is, they will surround the divalent metal with four sulfurs. The higher coordination should produce a very stable mercury precipitate, where the mercury is more strongly "locked into place" by the sulfurs. An absence of charge on the complex would reduce its solubility in water and result in the effective precipitation of mercury. In addition, it is likely that colloidal suspensions of humic-mercury are the vehicle by which mercury(II) is made bioavailable. These molecules may prove to be useful models of the binding of mercury in humic substances. Of more fundamental interest, these complexes may prove to be useful models for the MerR metalloregulatory protein.
The ligands that we are currently designing possess enough flexibility in their structural "backbones" to allow sulfur atoms to take a tetrahedral arrangement around a central mercury

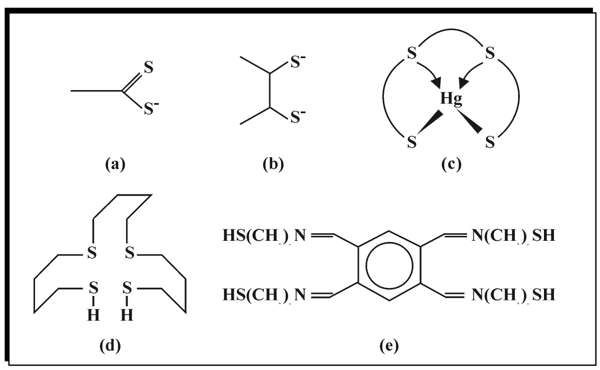

Figure 2*. General depiction of dithiocarbamate (a) and dithiolate (b) units. An ideal tetrahedral arrangement of sulfur atoms around mercury (c). The types of ligands that we propose for the irreversible precipitation of mercury from water (d) and (e).*

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Why Worry about Energy? The Sense and Nonsense of it all.

David Gray, MITRETEK

It was all very quiet on the energy front until about seven months ago when oil prices plummeted to all time lows (it's a good thing that cars don't have to run on Evian water) and suddenly we were faced with the horror of too much cheap oil. Surely cheap oil is good because we pay less for gasoline and diesel and therefore it only costs $40 to fill up the SAV[1] instead of $80 and goodies (like beer and wine) can be transported to the supermarket at less expense and therefore may also become cheaper. Wrong. Simplistic things just does not work in these complex times. Cheap oil is bad. The Saudis can't afford to give money to their people to keep them happy and, most importantly for us, cheap oil is devastating the domestic oil and gas industry.

Well they are finally fixing that. The oil producers (even the non-OPEC[2] ones) realized that overproducing oil is not good in the "free" oil market and that they would make even more money if the price of oil was higher. So they met in Vienna (why do they always meet there?) and decided to cut back their production, thus reducing the glut on the world market. And guess what? The oil price has gone back up to about $18 per barrel. This altruistic action may also save our domestic oil industry. Those abandoned oilrigs can be dusted off and we can start drilling in 7,000 feet of water again in the Gulf of Mexico.

So much for oil What about natural gas? Gas prices are influenced by oil prices so they dropped as well. Gas is good because using it is good for the "Environment" (more on the big "E" later). We use about 22 Quads[3] of gas every year, mostly in the industrial and residential sectors. Because it is so very good for the big E, the master plan is to use a lot more of it in the future, especially for electric power generation. The plan is to increase the use of gas from 22 of those quads to 32 of them by the year 2020. Most of this increase will be to make electric power. The only potential problem in this masterplan is (and this point is strangely overlooked) that we don't have enough gas in this country to consume 32 quads of it every year -- not for many years anyway. And, difficult as this may be for us to believe, there are loads of other people in the world that may want to use some of this gas themselves. If that's the case we can continue to use nuclear power, right? Wrong. That would be very bad for some of the big E although, not unparadoxically, good for other parts of it (more on that later).

So what about coal? Coal is supposedly very bad for the big E although it is very useful for making electricity. In fact if we stopped using it to make electricity, it would be very cold and dark in the winter and even more hot and humid in the summer here in Washington DC, since 56 percent of electricity is made from coal in this country. Mankind has been using coal for a long time, but today we have finally learned how to use it cleanly, although most of the world seems not to know this yet. Clean Coal (CC) technology might sound like an oxymoron but if we are prepared to pay enough money for new CC plants we can make electricity and other products like ultra-clean transportation fuels very cleanly indeed. So, if we are willing to pay the bill, we can continue to use coal and this will not be too much of a bad thing for the big E.

Electricity is a very useful thing to have around, especially if you are like me and like to read in bed at night. You can do that with candles, but the very concept of modern society is synonymous with electricity. We are used to turning on a switch and getting instant electric power in the home, office and industry. But caveat emptor, (quo vadis) this system of reliable, affordable electric power that we take for granted may be in jeopardy. The system of electric utilities has been working so well that some people got together and decided to improve it by a concept that has worked well in the past for a whole host of other industries - deregulation. These people reasoned that the system could be improved by allowing competition to break up the regulated market. Sound familiar? We, the innocent (and generally unconsulted) consumers, will have lower electricity prices, the same or better reliable service, a cleaner big E, and the resulting deregulated industry will become highly profitable. If the last prediction comes to pass, you can be assured that the other three will not.

Now more on the big E. Some people (maybe the same ones that have faith in electricity deregulation) are very worried about global climate change. In spite of the well-known axiom that the only constant thing is change, they have faith that it is mankind that is responsible for the warming of planet Earth. Actually they don't only blame mankind. Cows and rice must also share some of the responsibility for this phenomenon. That certainly is an oxymoron. One way to stop this warming is to limit the amount of carbon dioxide that is emitted into the atmosphere. Therefore the clear message is one of abstinence. Stop burning coal and oil and gas. Or, if you continue to burn these fuels, a system of indulgences will be put into effect. If fossil use is heresy then nuclear use must be the orthodox answer? Wrong, grow trees and then cut down the living trees and burn them. Also use the sun and the wind as much as possible to power our SAVs and computers.

But why worry? Mankind's indomitable spirit will prevail and solve all of these problems eventually, provided that they are all Y2K compatible.

1) SAV - Suburban Assault Vehicle. Those large truck-like objects that seem to predominate on the roads (but are rarely seen off road) and that have a very high probability of killing you if they hit you.

2) OPEC - a gentleman's club of oil producers who really (and I am not making this up) believe in the unfettered working of free markets.

3) Quad - an enormous number of British (actually American) thermal units.

atom. In choosing these ligands, we have intentionally avoided ligands with dithiocarbamate and dithiolate units in them (Figure 2[a] and 2[b]). A survey of the literature demonstrated that these units do not coordinate in a tetrahedral array around a central metal. The "backbones" connecting the two sulfur atoms are not sufficiently flexible to allow for the four-fold geometry. For example, the S-Hg-S' angles for the dithiolates are generally slightly less than 90°. In addition, we have also avoided the use of cyclic sulfur chelates, which are all neutral in charge. Although some of these cyclic species show a strong affinity for mercury, our preference is for simpler, less expensive systems that combine covalent and coordinate covalent bonding in encapsulating a central mercury atom (shown in a general manner in Figure 2[c]). Our current efforts involve the precipitation of stable mercury-chelate complexes, while the cyclic systems are targeted towards filtration applications. Furthermore, there appears to be an absence of a "macrocyclic effect" in the binding of methylmercury (CH_3Hg^+) with cyclic ethers, which results in thioethers being more strongly bounded. Two ligands that we are considering are shown in Figure 2(d) and 2(e). The first is a modified version of a thioether that can be prepared following the literature precedent. A key feature in the ligand is the presence of longer alkyl connecting groups. The same type of connecting groups will be incorporated into a tetrathio-benzene derivative (Figure 2[e]). The molecule can also be assembled using commercially available reagents. It may even be synthesized in one step by combining 1,2,4,5-benzenetetracarboxaldehyde with aminethiols. The value of "n" in the chemical formula of this molecule will have to be determined experimentally, but is likely to be four or greater. Once the ideal ligands have been found, we will try to obtain the components needed to assemble it from cheap naturally occurring sources.

With appropriate modification, these two ligands (and others of the same type) should bind the inorganic (Hg^{2+}) and methylated (CH_3Hg^+) species. By incorporating a dithiol linkage, elemental mercury (Hg^0) may also be bound. Once the distribution of the mercury species is determined in water, sediment or soil specimens, the proper mix of chelate ligands could be prepared to treat the mercury effectively.

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