The report by Kew *et al.* (*1*) provides a detailed documentation of just such an episode on the island of Hispaniola. The authors provide impressive evidence that a single type 1 OPV virus underwent reversion and recombination with a wild enterovirus, and then spread to cause more than 20 virus-confirmed cases of paralytic poliomyelitis. Because there are usually 100 to 250 infections per paralytic case, it can be inferred that this virulent virus infected several thousand individuals. Most of the cases were documented in unvaccinated or incompletely vaccinated children under 15 years of age, where only about 30% of the population had received three doses of OPV. Thus, the outbreak took place under exactly the conditions where it was postulated that OPV might spread (*5*). It is noteworthy that at least two other similar small outbreaks have been observed, in Egypt and the Philippines, under similar circumstances (*8, 9*).

What are the implications of these observations for the "endgame" in poliovirus eradication? Currently, in areas where wild poliovirus has been eradicated, children are still being immunized, either with OPV or with inactivated poliovirus vaccine (IPV, the Salk vaccine). Immunization is maintained to protect children against the possible reintroduction of wild poliovirus or exposure to VDPV. Once complete global eradication of wild poliovirus has been achieved and certified, there are several options. In regions where IPV is available, OPV could be discontinued, with the eventual discontinuation of IPV once monitoring provided the assurance that OPV and VDPV have disappeared from the world. IPV is much more costly to produce and more difficult to administer than OPV (*10*), so this option may not be feasible everywhere, at least in the near future.

In regions where IPV is not currently available, a massive final round of OPV could be administered, followed by careful monitoring for acute flaccid paralysis (the classic sign of paralytic poliomyelitis) supported by laboratory testing of fecal samples for evidence of circulating VDPV. In the event that VDPV were to be identified, it would be necessary to reintroduce routine vaccination or mass campaigns with IPV or OPV. This approach carries several liabilities because it depends on the assumptions that circulating VDPV will be identified quickly, that a stockpile of vaccine would be maintained, and that national and international agencies would provide effective assistance wherever it might be needed. Unfortunately, this strategy could be perceived as offering a double standard of public health prevention, because developing countries would be exposed to a risk that the industrialized nations—those that can afford IPV—could avoid.

The "endgame" poses another dilemma that is not easily addressed. The ultimate goal of the eradication program is the discontinuation of all polio immunization. Inevitably, an increasing number of people would become susceptible to these viruses. To ensure that poliovirus could not be introduced into a susceptible population, it would be necessary to destroy or contain all stocks of these viruses. This presents a challenge in that some fecal samples, collected for many different reasons and held in freezers worldwide, may be inadvertently contaminated with wild or vaccine-derived polioviruses. The World Health Organization is currently setting up a system to identify and minimize these risks, but the surveillance and contingency planning will have to extend long after successful eradication.

The endgame for poliovirus eradication offers challenges that would be daunting even for a chess master, let alone a world where global coordination of public health practice is an ideal yet to be realized.

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PERSPECTIVES: CHEMISTRY

Catalytic Degradation of Chlorinated Phenols

Bernard Meunier

Substances used in chemical synthesis may either be incorporated into the final product or pass through the process and emerge as waste. Increasingly, the chemical industry seeks products with high yield and low waste, allowing them to avoid paying first for material inputs and again for waste disposal. The concept of "atom economy" has been introduced to monitor the fate of the reactants. An atom-economic process is one in which the proportion of materials that is incorporated into the final product is maximized (*1, 2*).

For most chemical processes, however, the hypothetical zero-waste level will not be reached in the near future. Furthermore, products that are not recycled or biodegraded turn into waste at the end of their useful lifetime. New efficient catalytic methods therefore have to be developed to eliminate poorly biodegradable chemicals in industrial sites and in the environment.

For example, chlorinated phenols persist for decades in the environment because of their resistance to microbiological degradation, leading to the accumulation of these toxic molecules (*3*). Polychlorinated aromatic compounds are constituents of many pesticides and insecticides and are also generated in the chlorine-assisted degradation of lignin in the paper industry. Pentachlorophenol and 2,4,6-trichlorophenol (TCP) have been listed as priority pollutants by U.S. and European Environmental Protection Agencies.

These "recalcitrant molecules" are key targets for the evaluation of new catalytic oxidation systems that use metal complexes as catalysts. On page 326 of this issue, Sen Gupta *et al.* report a new oxidative cleaning method for chlorinated phenols, using hydrogen peroxide and iron catalysts (*4*). The metal center of these catalysts is chelated by tetraamido ligands called TAML, a family of macrocycles that has been developed by Collins and co-workers over the last two decades (*5*).

Nearly full conversions of pentachlorophenol or TCP are obtained at 25°C at pH 10 within a few minutes with a very low catalyst loading (0.05% with respect to the substrate to be converted). An excess of hydrogen peroxide (100 equivalents/TCP) was added by portions to limit its catalytic decomposition by the iron catalyst (Fe-TAML). The distribution of the degradation products of TCP (see the figure) indicates that 85% of the initial carbon atoms of the substrate are recovered in noncyclic products. Only 2% of the initial carbon atoms are still present as chlorinated aromatics after the catalytic oxidation of TCP, and no dioxin deriva-

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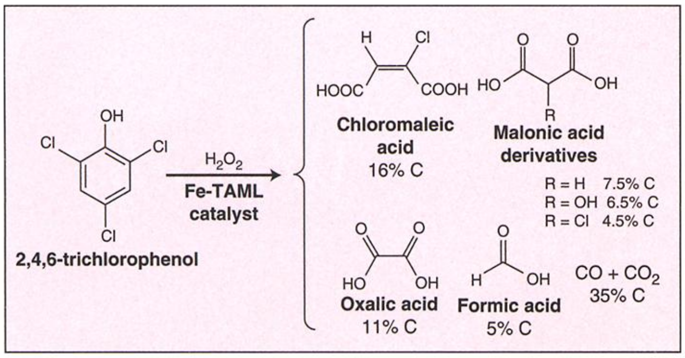

Efficient oxidation. The new catalyst described by Sen Gupta *et al.* breaks up the persistent pollutant TCP into smaller, acyclic products, which can be consumed by microorganisms. The catalyst shows similar activity for another persistent pollutant, pentachlorophenol.

tives are produced during this efficient oxidative degradation. (The remaining 13% are incorporated into other nonidentified minor products.) Furthermore, 83% of the chlorine atoms of TCP are released in the reaction mixture as (benign) free chloride. Another 12% of the chlorine atoms are incorporated into chlorinated products; 5% are unaccounted for.

These data confirm the efficiency of this catalytic method compared with degradation by microorganisms. Biodegradation of these chlorinated phenols is very slow, with only 20 mg/liter of TCP degraded by *Phanerochaete chrysosporium*, a white rot fungus, in 15 days (*6*). Slow microbial mineralization of TCP has also been observed in soil (*7*). An efficient catalytic chemical method for the oxidative degradation of chlorinated phenols, such as that reported by Sen Gupta *et al.*, is therefore highly welcome for treating industrial wastewater before it is released.

This catalytic method is complementary to other methods currently used in the elimination of wastes. Incineration requires high temperatures and long residence times for the full destruction of chlorinated aromatics. Supercritical water oxidation requires high temperatures (450° to 500°C) and high pressures (240 to 300 atmospheres). Wet air oxidation (partial oxidation), chemical or electrochemical treatments, and photodegradation processes (which usually occur with low quantum yields) must also be improved.

The fact that the simple, nontoxic iron complex of Sen Gupta *et al.* can, assisted only by hydrogen peroxide, catalyze the nearly complete degradation of recalcitrant chlorinated aromatic pollutants into biocompatible ring cleavage products makes it a true "green oxidant." Further work will elucidate details of the mechanism of the activation of hydrogen peroxide by these Fe-TAML complexes.

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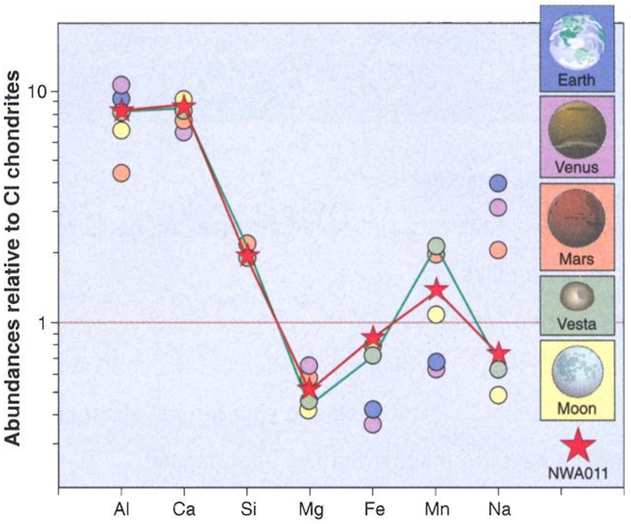
PERSPECTIVES: PLANETARY SCIENCE

A New Solar System Basalt

Herbert Palme

The year 1969 was exceptional for research on extraterrestrial samples. On 8 February, the Allende meteorite fell. The Ca, Al-rich inclusions in this meteorite are the oldest objects known to date, preserving the signatures of the primordial solar nebula from which the planets formed. Analysis of samples from this meteorite prepared laboratories worldwide for the study of lunar samples brought back to Earth in July of the same year. On 28 September 1969, the Murchison meteorite was observed to fall in Australia, providing the first convincing evidence of amino acids of extraterrestrial origin. Also in the same year, a Japanese expedition recovered nine dark rocks, later identified as meteorites, from the ice fields of Antarctica.

Since then, thousands of meteorites have been recovered from Antarctica. It was soon recognized that the large desert areas of the world are also huge reservoirs of meteorites. Today, more than 20,000 meteorites are known, about 10 times more than before 1969. Many are scientifically unexciting ordinary chondrites, but some represent extremely rare types. In 1981, an American expedition recovered an inconspicuous meteorite weighing just 31.4 g; it turned out to be a piece of the Moon. More than 20 lunar samples have now been found, and about as many are thought to be martian samples.



Similar, but not the same. The major element compositions of basalts from Earth, Venus, Mars, Vesta, and the Moon are compared to that of the new basaltic meteorite, NWA011 (*4*). The patterns for Al, Ca, Si, and Mg are remarkably similar. Low Fe in terrestrial basalts indicates a large core. Large variations in Na reflect differences in initial volatile element inventory. NWA011 data from (*1*), all other data from (*5*).

On page 334 of this issue, Yamaguchi *et al.* (*1*) further expand the list of unusual meteorites. They describe a new type of basaltic meteorite, NWA011 (*2*), recently found in the Sahara. Its texture, mineralogy, and chemical composition are similar to terrestrial or known extraterrestrial basalts, implying that this meteorite is a piece of a frozen melt flow on the surface of a planet or planetesimal. Yet, there are also some important differences.

The four inner planets—Mercury, Venus, Earth, and Mars—and the Moon were all more or less completely molten early in their history. They have FeNi metal cores, Mg-rich

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