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Mercury in Drilling Discharges - An Overview

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Abstract

Recently, concerns have been expressed over the potential for bioaccumulation of mercury from drilling discharges in seafood. In response, the upstream segment of the oil and gas industry and federal agencies have reevaluated existing information on this subject and conducted additional research to further evaluate these concerns, finding no substantive basis for these concerns. Although there is some basis for concern over the potential for mercury in seafood in a broad sense, there is no basis for considering drilling discharges a contributor to this potential problem either on a localized or regional basis.

Concerns over the potential for heavy metals like mercury from drilling and other oil and gas production related discharges to bioaccumulate in seafood are not new. With passage of the Clean Water Act in 1972 and implementation of the National Pollutant Discharge Elimination System (NPDES) discharge permit program, heavy metals were among the first groups of materials in discharged drilling fluids that were characterized and studied for possible regulation.

Starting in the late 1970's and continuing through the late 1980's, industry, academia, EPA and other government agencies evaluated the toxicity of, and the potential for bioaccumulation of heavy metals, including mercury, from drilling fluid discharges. No significant adverse impacts were identified through these studies that supported the need for water quality based discharge limits on mercury. As a result, technology based discharge limits were imposed on drilling fluids in 1993 to control heavy metals including mercury. Discharge limits were established for mercury (1 mg/kg) and cadmium (3 mg/kg) in dry barite. These limits were established as indicator pollutants for the broad family of heavy metals based on data that showed that if these two metals are controlled, the whole group of heavy metals is controlled.

A review of more recent studies confirms that these limits are environmentally protective. The chemical forms of mercury in barite are inorganic, are very stable, and are not bioavailable. The chemical conversion of total mercury into methylmercury appears to occur at relatively constant rates across the seafloor of the Gulf of Mexico and does not appear to be related to the presence of drilling fluid discharges.

What is Mercury?

Mercury in its elemental form, at ambient conditions is a dense (specific gravity = 13.5), silvery-white liquid metal. Mercury is a good electrical conductor and has a nearly constant thermal coefficient of expansion. These properties led to relatively widespread historical usage of mercury in industrial, medical, and household applications (Ref. 1). More recently, as our understanding and awareness of the potential risks associated with some chemical forms of mercury has increased, use in all but the most essential applications has decreased. Over the past twenty years these decreases amount to about an 80% reduction in consumption (Ref. 2) (Figure 1.).

Mercury in the Environment

Mercury is ubiquitous in the environment at low levels and its sources are both natural and anthropogenic. A critical distinction when considering mercury in the environment is its chemical form or speciation. Mercury can exist in three elemental forms, Hg^0 (metallic), Hg_2^{+2} (mercurous), and Hg^{+2} (mercuric). In its natural form, terrestrial mercury most commonly occurs as mercuric sulfide (HgS, cinnabar) and much more rarely, in its elemental form. In the atmosphere, natural sources of mercury can include volcanoes and forest fires that release metallic and ionic mercury vapor. Similarly, anthropogenic forms are most commonly the result of combustion of coal and are also mostly metallic and ionic mercury vapor (Ref. 1.).

Mercury moves through the environment in a cyclical process (Figure 2.). The distances traveled by the mercury in this cycle are on a global scale. To illustrate the magnitude of this process, one estimate based on computer modeling indicated that total elimination of mercury emissions in the US would result in only a 9% reduction in regional concentrations of mercury in fish tissues (Ref. 3.). The largest single category of inputs to the mercury cycle is atmospheric emissions from the combustion of coal. The ionic forms of mercury are generally removed from the atmosphere faster than the metallic form. Throughout the process of cycling and partitioning a complex series of chemical reactions can occur. One of the most environmentally important reactions that can occur is methylation.

Methylation is the transformation of inorganic mercury into an organic form - methylmercury. Methylation is a biological process that occurs in an aquatic environment, either in the water column or in the sediment. The rate at which this reaction occurs is highly dependent on site specific conditions. The conditions generally thought to be favorable to methylation of mercury include organic rich sediments, anoxia, warm temperatures, freshwater, enhanced nutrient loading, and low pH, with each of these factors being optimal in relatively narrow ranges (Ref. 4, 5). As a result, the odds of each of these factors being in the right range in conjunction with the other factors at the same time are relatively low. The observed consequence of this is that while variable, methylation rates have been consistently found to be relatively low.

Once methylmercury enters the food chain, it is transmitted and bioaccumulated in the food chain very efficiently, i.e., 70-90% transfer efficiency. Also, once methylmercury binds to muscle tissue, it is relatively stable and leaves the body at relatively low rates with a "half-life" of between 45 and 90 days in most cases. As a consequence, older, larger predatory animals are more likely to have elevated levels of methylmercury (Ref. 6.).

Effects of methylmercury poisoning can include impaired vision, loss of coordination, loss of feeling, neurological impairment and in extreme cases, death (Ref. 1, 6.). The key exposure pathway for humans is considered to be seafood consumption. Other potential pathways have been examined; i.e. consumption of livestock, poultry and vegetables, but none is as significant as seafood (Ref. 1.).

Mercury in Drilling Discharges

The two largest sources of discharges to the marine environment from offshore oil and gas operations are produced water, typically in excess of 99% of the total volume discharged and drilling wastes, which is the majority of the remainder. In the Gulf of Mexico, approximately 2 million barrels per day of produced water are discharged from over 600 facilities (Ref. 7.). However, only about 8 pounds per year of total mercury are discharged with produced water (Ref. 4). Bioaccumulation studies show that mercury levels in fish and shellfish taken near offshore platforms discharging produced water are indistinguishable from the same or similar species of fish and shellfish taken near non-discharging offshore platforms (Ref. 8.). As a result, the discharge of mercury in produced water should be considered below the level of any significant concern when compared to the over 55 tons per year entering the Gulf of Mexico from all other natural and anthropogenic sources (Ref. 4.).

Drilling fluid discharges, while a very small fraction of total offshore discharge volumes, contain comparatively higher levels of mercury than produced water, however these volumes are still considered very small in the context of all other inputs to the Gulf of Mexico. Drilling discharges (muds and cuttings) are estimated to release 338 pounds per year of inorganic mercury to the Gulf of Mexico. This is based on drilling 900 wells per year. This too is a very small amount, approximately 0.3% of Gulf of Mexico inputs (Ref. 4.). As a point of reference, nationally, anthropogenic mercury emissions are estimated to be on the order of 150 tons per year (Ref. 1.) (Figure 3).

To better understand the environmental fate and effects of drilling discharges, three key topics will be considered throughout this paper: the make-up of drilling fluids, the behavior of the drilling fluids when they are discharged, and the allowable and actual levels of mercury that may be present in the discharge.

Most drilling fluids are engineered slurries made up of a few basic components: a liquid phase, barite, low gravity solids and treatment chemicals. The concentrations of these components will vary as a function of the density of the drilling fluid with typical ranges shown in Table 1. Most of the volume of discharged drilling fluids is relatively low-density fluid, with 15-20% barite. As such, barite makes up a relatively small fraction of the total drilling fluid discharge. Additionally, the make-up of drilling fluids represented in Table 1 are generally the same regardless of whether the mud is water based or non-aqueous fluid based.

Volumes of drilling fluids discharged from any well are ultimately a direct function of the individual well's hole size and its depth. While an exact value is impossible to derive, ranges of discharge volumes can be provided. For a water based mud (WBM) well, the total volume of cuttings discharged will normally range between 1,500 and 2,500 barrels and the volume of drilling fluid discharged will range between 5,000 and 10,000 barrels (Ref. 7, 9). For non-aqueous fluid based muds (NAFBM) wells, the total cuttings volume discharged would be about the same, but as mentioned above a significant portion of that volume would still be discharged when drilling with WBM. The volume of drilling fluids discharged with a NAFBM well are much lower that for a comparable WBM well at between 500 and 1,500 barrels of NAFBM, which adheres to the discharged cuttings (Ref. 10). This reduction is due to regulatory prohibitions on the discharge of whole NAFBM and further limits on the retention of the base fluid on the cuttings that are discharged.

The behavior of the drilling fluids when they are discharged is an important factor to understanding the deposition patterns and therefore the potential environmental effects. Discharge plume dynamics for WBM and NAFBM are very different. First, it is important to understand that even from a well that is characterized as a NAFBM well, a significant volume of WBM may be discharged during the early stages of the drilling operation. Second, the volume of discharged drilling fluid from WBM well will almost always be higher than that for a comparable NAFBM well due to regulatory requirements.

WBM discharges will disperse rapidly in the water column creating an upper plume of fine particles that will drift away and disperse or settle over wide areas and a lower plume containing larger cuttings and barite. The particles in the lower plume settle to the seafloor much more rapidly and form a more concentrated pattern near the discharge point.

Discharges of cuttings with NAFBM (the discharge of whole NAFBM is prohibited) consist primarily of large particles that settle rapidly. The plume behavior for a NAFBM discharge is similar to that of the lower plume of the WBM discharge and will result in a similar concentrated deposition pattern on the seafloor.

In both cases, the plume dynamics mean that the area of elevated barite deposition and therefore the potential area for elevated mercury levels is limited to a zone very near the discharge point. Studies have confirmed the discharge plume behavior for both WBM and NAFBM and measured mercury concentrations in sediments are also consistent with this behavior.

Mercury in Barite

Mercury enters drilling discharges as a trace mineral from two primary sources, the drilled formation cuttings and the barite. Barite, a natural mineral substance, is used in drilling fluids to control its density. Mercury is not intentionally added to a drilling fluid, nor does it serve any function in the drilling fluid. The mercury levels in barite ore are known to be quite variable depending on their source. Two questions must be considered in discussing mercury in barite. First, how much mercury is found in barite and second, what is the chemical form of the mercury in barite?

Mercury concentrations in barite ores can vary widely and have been documented to range from as little as 0.05 ppm (mg/kg) to as much as 31 ppm. Veined deposits of barite normally have higher levels of mercury that bedded deposits (Ref. 11, 12) (Table 2). Historically, mercury levels in barite used in drilling fluids have averaged less than the current limit of 1.0 ppm. The long term weighted mean prior to imposition of the EPA limits was about 0.5 ppm. After imposition of the EPA regulations, the mean value appears to have dropped slightly to about 0.4 ppm (Ref. 13.). The factor that has changed since imposition of EPA's regulations is the reduction in variability with respect to heavy metals and the corresponding elimination of discharge of barite with over 1 ppm total mercury. The relatively small change in long term average concentrations indicates that relatively small amounts of high mercury barite have ever been discharged.

Since barite normally constitutes anywhere between 15% and 60% by weight of the total drilling fluid discharge, the calculated average concentration range for mercury in a typical drilling discharge would be between 0.06 ppm and 0.24 ppm. This in turn equates to less than 0.4 pounds of total mercury per well drilled. These levels are consistent with total mercury levels seen in most sediment around drilling discharge sites.

The mercury in drilling discharges is completely made up of inorganic mercury. These forms of mercury are extremely insoluble and are not readily converted into organic methylmercury. Chemical leaching studies have shown that the mercury in barite is essentially insoluble in water with less than 0.1% of the mercury present being leached. Further leaching with 6N hydrochloric acid removed 30-70% (depending on sample source) of the mercury present. This step identifies that portion of the mercury as most likely being associated with zinc and iron sulfides that are in the barite. Further leaching with aqua regia (an even stronger acid) removes the remaining mercury from the barite and thus identifies that portion of the mercury as most likely being in crystalline sulfide forms. (Ref. 12.)

Regulation of Mercury in Drilling Discharges

Concerns over the potential for environmental impact from heavy metals in drilling discharges, including mercury, were among the first raised and evaluated (Ref. 9). Studies have been conducted by agencies, academia and industry to examine discharge amounts, chemical forms and concentrations, bioavailability, bioaccumulation, fates and effects in the environment as well as human health risks. Conclusions by the agencies responsible for regulating drilling discharges are that when conducted within certain limitations, drilling discharges will have only minimal environmental effects (Refs. 7, 14.).

Under the NPDES permit program of the Clean Water Act, the EPA uses two-tiered approach to regulating pollutants, water quality based limitations and technology based limitations. Water quality based limitations are considered first and applied where degradation of water quality below established levels can be demonstrated to be the result of a point source discharge. Technology based limitations are established independent of any demonstrated degradation of water quality and ensure that dischargers utilize "Best Available Technology" (BAT) for treating discharges.

In the case of heavy metals like mercury, in most offshore drilling discharge scenarios will not cause exceedances of ambient water quality standards. Therefore, water quality based regulations are not warranted. The EPA was however able to demonstrate that technology based regulations would be appropriate. While treating barite ore for removal of mercury is not practical, the EPA did demonstrate that industry had sufficient capacity to establish limitations to control heavy metal discharges in drilling fluids based on use of clean barite. As a result, after extensive study and evaluation the EPA adopted the Effluent Limitations Guideline for the Offshore Exploration and Production Subcategory in 1993. As part of these regulations, the technology-based limits on mercury and cadmium in barite were set at 1 mg/kg and 3 mg/kg respectively. The mercury and cadmium limits are also considered a control on other heavy metals as well (Ref. 7, 14.).

Studies of Mercury in Drilling Discharges

The fate of mercury in drilling discharges has been considered as a part of studies at over 30 offshore drilling locations (Ref. 4.). The typical approach used in nearly all of these studies has been to test sediments for mercury levels (usually along with many other metals and organic compounds) and in some cases to test marine life for possible uptake. While it is well known that drilling discharges can contain slightly elevated levels of inorganic mercury and can lead to slight elevations in inorganic mercury levels in sediments near the discharge point, the measured levels were, with a single exception, at or only slightly higher than background levels (Figure 4). Tissue samples from a variety of marine life (mostly fish) collected near drilling sites, however, have not shown corresponding increases in mercury levels and have rarely been found to be above the FDA limit of 1 mg/kg (Ref. 4) (Table 3). When exceedances of the FDA limit have been found, they appear to be unrelated to the presence of a drilling or produced water discharges. Because no cause and effect relationship between drilling discharges and mercury levels in marine life has ever been demonstrated, further investigation has not been justified.

In late 2001 and early 2002, issues regarding the potential for mercury to enter the food chain by methylation of mercury from drilling discharges were raised. These issues were based on data on sediment and shrimp tissue mercury levels drawn from the Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) and on the unsubstantiated assertion by some not involved in the GOOMEX study that the seafloor environment at offshore platforms is ideal for the conversion of inorganic mercury in drilling discharges into methylmercury. Several points must be kept in mind to place the GOOMEX study in its proper context.

- GOOMEX examined three sites that were chosen specifically because there was a comparatively strong gradient associated with discharged materials (two drilling related, one production related) in sediments with distance from the sites.

- GOOMEX found that there were gradients in sediment mercury concentrations with distance from the platform in two of three sites examined. One site examined, platform HIA389, had one sediment sample with a mercury concentration slightly over 3 ppm near the discharge point.

- Mercury concentrations in shrimp tissues were generally higher at the platform with the highest sediment mercury levels, but there was no strong dependence of concentration with distance from the platform, as might be expected if drilling discharges were responsible for mercury levels.

- The scientists who conducted the GOOMEX study did not conclude that the study showed that marine life near platforms was enriched in mercury in any general sense.

- Neither GOOMEX nor any other published study indicated that sediment conditions near platforms are especially conducive for methylation of mercury.

The GOOMEX results cannot validly be extrapolated to apply to offshore platforms generally. In their conclusions, the GOOMEX scientists offer the following cautions regarding use of their results, cautions that have been ignored by others:

> "...with only three platforms... ...it is difficult to generalize about the impacts of platforms, and that any attempt to relate impact differences among platforms to historical production differences among platforms or to natural environmental differences among platform leads to a regression or correlation based on three points" and "...three (platforms) is too few and these platforms are too different for any meaningful conclusions to be reached about 'platforms.'"

The GOOMEX scientists further note as a way of precaution that:

> "... the rank order of contamination levels is also a perfect rank correlation with water depth, distance from shore and all environmental variable related to them." (Ref. 15, 16.)

An examination of all the data on sediment mercury concentrations near drill site shows that the HIA389 site is clearly an exception rather than a typical Gulf of Mexico drill site (Figure 4). Of the thirty sites for which data are available, HIA389 is the only site where a sample with a mercury concentration in excess of 1 ppm has been found. This compares to background levels of mercury in Gulf of Mexico sediments that can range between 0.01 ppm to 0.1 ppm (Ref. 4.) The operational factors that led to the comparatively high levels of inorganic mercury at this site are rarely encountered and reinforce the fact that this was an unusual situation. HI A-389 is currently located within the boundaries of the Flower Garden Banks National Marine Sanctuary, about three miles southeast of the actual reef location. The sanctuary and its boundaries were not established until well after drilling operations were completed (nor were the heavy metals limits on barite in effect), the area was well known as a biologically sensitive area. As part of the lease for this tract, the Minerals Management Service (MMS) included several stipulations including one that required all drilling discharges to be shunted by a pipe to within 10 meters of the sea floor. The purpose of this stipulation was to prevent smothering of live corals on the reef by any low gravity solids associated with the drilling fluid discharge plume. The unintended consequence of this requirement was that the solids in the drilling fluids were deposited in a much smaller area, which in turn resulted in a localized area (<50 m around the discharge point) of elevated mercury levels. At this site, the GOOMEX data show that beyond 100 meters from the discharge point, mercury levels in the sediment are essentially at the regional background levels seen 3,000 meters away.

As already mentioned, the chemical form of inorganic mercury found in barite is extremely insoluble in seawater. Additionally, what little mercury might be released in the water column during discharge may be entirely suppressed by the presence of bentonite, a very common component of drilling fluids (Ref. 5.). Anecdotally, studies like GOOMEX and others confirm these empirical data since slightly elevated levels of mercury can be found in the seafloor sediments many years after discharge.

Methylation of Mercury

Since the mercury in a drilling fluid discharge is nearly insoluble in the water column, it settles on the seafloor. Once there, its long-term fate depends on a number of variables. Some have hypothesized that the environment in the sediments near the base of an offshore platform may create an ideal environment for the conversion of inorganic mercury to organic methylmercury. The hypothesis is based on the idea that the organic material raining onto the sediments as a result of the artificial reef effect of the platform will create the type of oxygen poor, reducing environment that is thought to be favorable to methylation of mercury.

The methylation of mercury is dependent on several variables including an anoxic environment, low pH, presence of organic materials, low salinity, and warm temperatures. In a marine environment like the Gulf of Mexico it is generally difficult to create the right combination of conditions that lead to methylation rates above background levels (Ref. 5.).

The sulfate reducing bacteria most strongly suspected of being primarily responsible for methylation of mercury in seafloor sediment find the most favorable conditions in anoxic sediments (typically 5 to 50 cm below the seafloor surface). In that environment however, the sulfide produced from sulfate reduction binds the mercury creating mercuric sulfide, which is extremely insoluble, thus effectively limiting methylation. In shallower sediments, any pH reduction that might lead to dissolution of mercuric sulfide is very well buffered by seawater. Considering these factors, it is apparent that most offshore sediment environments are not likely to be altered in such a way that would lead to increased methylation rates and that conditions near offshore platforms would not be any more favorable to creation of methylmercury as a result of drilling fluid discharges than sediments away from platforms (Ref. 5).

To test this string of conditions and conclusions, a new study was commissioned by the Synthetic Based Mud Research Program, a joint industry/Minerals Management Service (MMS)/Department of Energy research program. The study evaluated barium, total mercury and methylmercury concentrations at six NAFBM drilling fluid discharge sites that were already being investigated for another environmental study. Three of the sites were exploratory drilling locations and the other three had platforms. The fact the all the drilling sites studied involved NAFBM was a consequence of the need to take advantage of an already scheduled sample collection cruise and rapidly generate information to respond to concerns that were being raised. Based on the conditions recognized as being favorable to methylation however, a NAFBM discharge site would be expected to provide more favorable conditions than a WBM discharge site due to the increased organic input from the NAF base fluid. Additionally, several of the sites studied included prior drilling and discharge activity using WBM.

The study evaluated over 200 sediment samples from these sites, both near-field (<100m from discharge) and far-field (>3,000m from discharge). Sub-samples were taken total mercury/methylmercury analysis from each sediment sample taken, no culling or screening of samples was performed. Measurements of barium and total mercury in the near-field sediments confirmed that sampling was occurring within the drilling fluid discharge plume. Measurements of methylmercury in these same sediment samples show no statistically significant differences between near-field and far-field samples (neither at individual sites nor collectively at all six sites), with near-field samples from all six sites averaging 0.45 ppb (ng/g) and far-field samples averaging 0.44 ppb methylmercury. Nor was there any correlation between levels of total mercury and methylmercury (Ref. 12.). The results of this study clearly show that increased methylation is not occurring in association with drilling discharges and thus drilling discharges should not be considered a risk to seafood quality or human health.

Issue Management

Mercury in the environment is an issue that has been gaining increased attention over the past several years. To address this issue, the White House established the Interagency Work Group on Mercury. When issues over the potential role exploration and production operations might play in this issue began to be raised, members of the E&P industry became doubly concerned. These issues and their resolution would also be of great interest to the public and in the political arenas along the Gulf coast.

In response to the public concerns, the Department of Interior, MMS established an independent review panel, the Subcommittee on Mercury in the Gulf of Mexico, under its Outer Continental Shelf Scientific Committee. The charge given to the subcommittee was to evaluate existing scientific information and provide guidance regarding what actions the Minerals Management Service should take regarding this issue.

To manage the E&P industry's response to these concerns, an ad-hoc Industry Mercury Work Group representing essentially all of the industry associations representing E&P interests and individual operators was formed. The purpose of this work group is to provide a consistent voice for the E&P sector and ensure decisions are made based on sound science. Two critical tasks taken on by this group were to coordinate preparation of a thorough review of all available scientific information on mercury, with an emphasis on E&P operations ("White Paper", Ref. 4) and to facilitate the Synthetic Based Mud Research Program sponsored study to evaluate the levels of methylmercury around drilling locations ("Methylmercury Study", Ref. 15.).

The White Paper provided a thorough understanding of this world-wide issue and clearly placed the trivial level of the E&P contribution in terms of total mass and bioavailability context. Similarly, the Methylmercury Study (already discussed) addressed the concerns being raised over the potential creation of “hot spots” of bioaccumulation and clearly showed there is no reasonable basis for such concerns. These conclusions were further corroborated by the conclusions of the Subcommittee on Mercury in the Gulf of Mexico.

In its final report, the Subcommittee on Mercury in the Gulf of Mexico identified and addressed several direct questions, including the following, with paraphrased responses (Ref. 17.):

- “*Are high concentrations of total mercury observed in sediment at or adjacent to OCS oil and gas drilling sites associated with the drilling mud weighting agent barite?”*

  Barite is the most likely source of excess total mercury found in sediments at offshore drilling sites.

- *“Are concentrations of methylmercury in sediments at or adjacent to OCS oil and gas drilling sites statistically higher than in sediments unaffected by drilling activities?”*

  The concentrations of methylmercury do not vary significantly between near field and far field sites.

- *“Can increases in sediment concentrations of methylmercury at or adjacent to OCS oil and gas drilling sites be directly attributed to mercury introduced with barite?”*

  Mercury introduced with barite at offshore drilling sites is not being converted to methylmercury.

- *“Do discharges at OCS oil and gas drilling sites create environmental conditions that enhance the conversion of [inorganic] mercury to methylmercury?”*

  Changes in near field sediment conditions associated with discharged drilling fluids do not result in higher concentrations of methylmercury.

These conclusions clearly demonstrate that in the opinion of the Subcommittee on Mercury in the Gulf of Mexico, while some elevation of total mercury levels over background can occur near drilling fluid discharges, that total mercury is not being converted to methylmercury and is not posing a risk to human health or the environment.

Summary

Drilling fluid discharges associated with offshore exploration and production operations are known to contain trace levels of inorganic mercury and as a result have been extensively studied by agencies, industry and academia. The weight of evidence indicates concern that the mercury in drilling fluid discharges does not lead to bioaccumulation of methylmercury in seafood. The sulfide forms of mercury in drilling discharges are highly insoluble and do not appear to react or degrade. Studies have consistently shown that the mercury in drilling discharges poses no significant threat to the environment, human health, food safety, or water quality.

The amount of mercury discharged during drilling and production operations in the Gulf of Mexico is estimated to be less than 350 pounds per year in contrast to over 110,000 pounds per year entering the Gulf of Mexico from air deposition and riverine sources. Further, there is no indication that the seafloor environment around the base of an offshore platform is any more favorable to the creation of methylmercury than any place else in the Gulf of Mexico. Regardless, since the Clean Water Act requires controls on pollutant discharges where technology exists, mercury levels in drilling fluid discharges are limited to 1 ppm in whole barite. Studies have shown that this limit is protective of the environment for aquatic species and humans.

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Figures and Tables

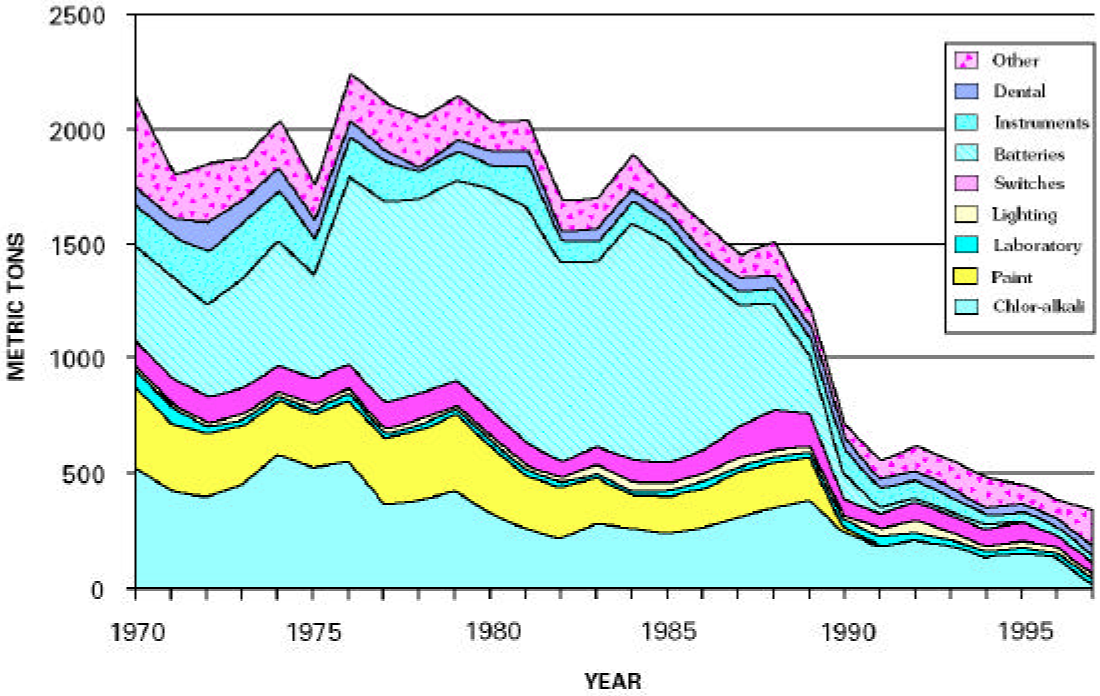

Figure 1. Industrial usage of mercury 1970-97 (Whitney, 2002)

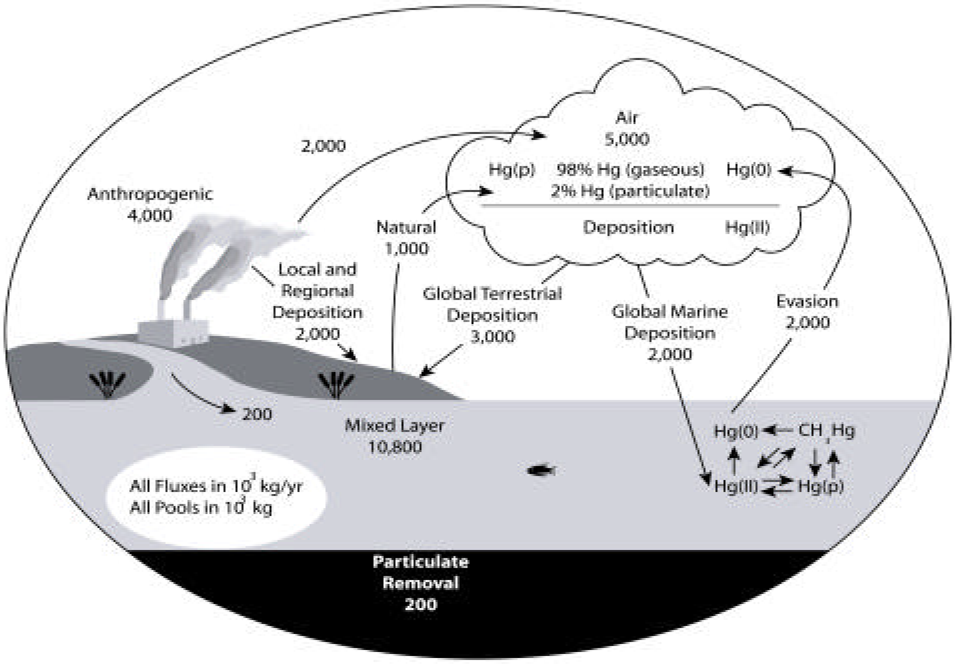

Figure 2. Mercury flux in the environment (Neff, 2002)

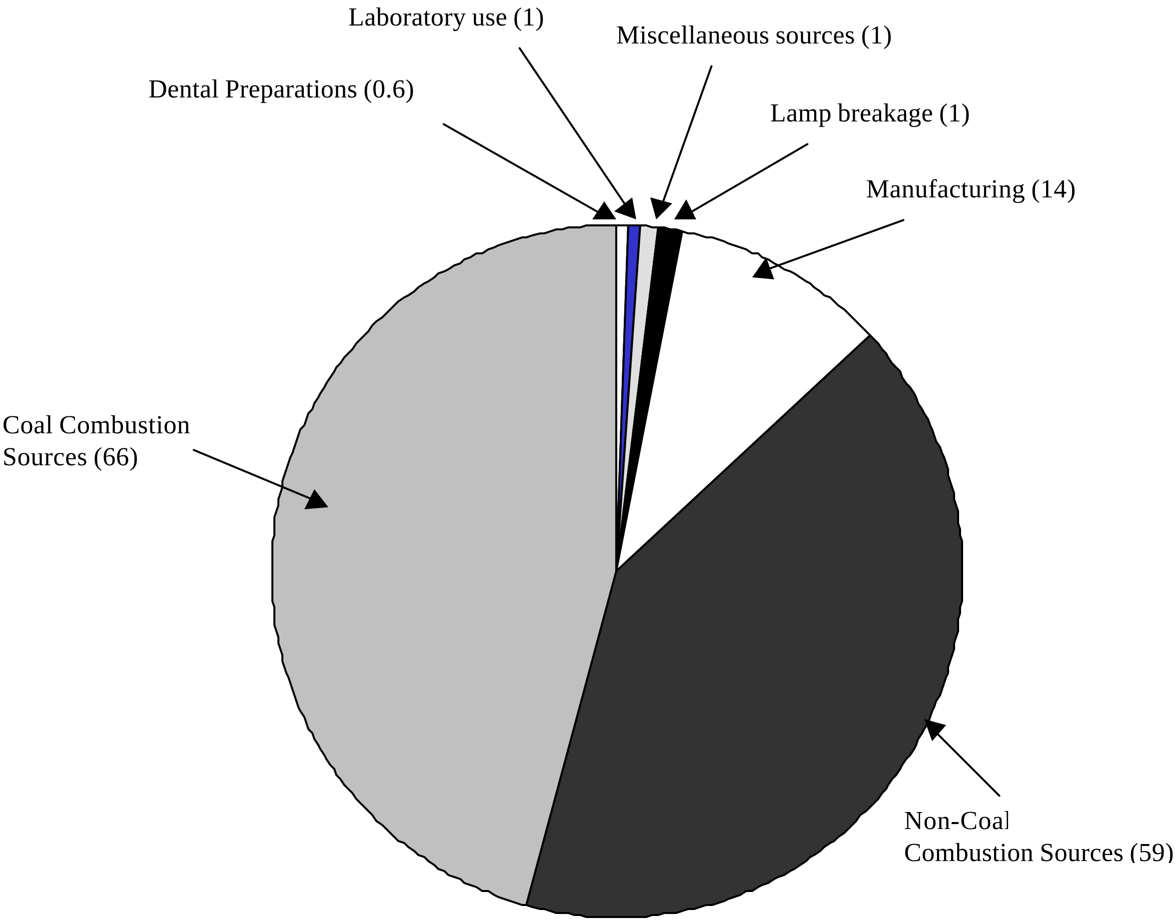

Figure 3. U.S Emissions of mercury by source in tons (EPA, 1997)

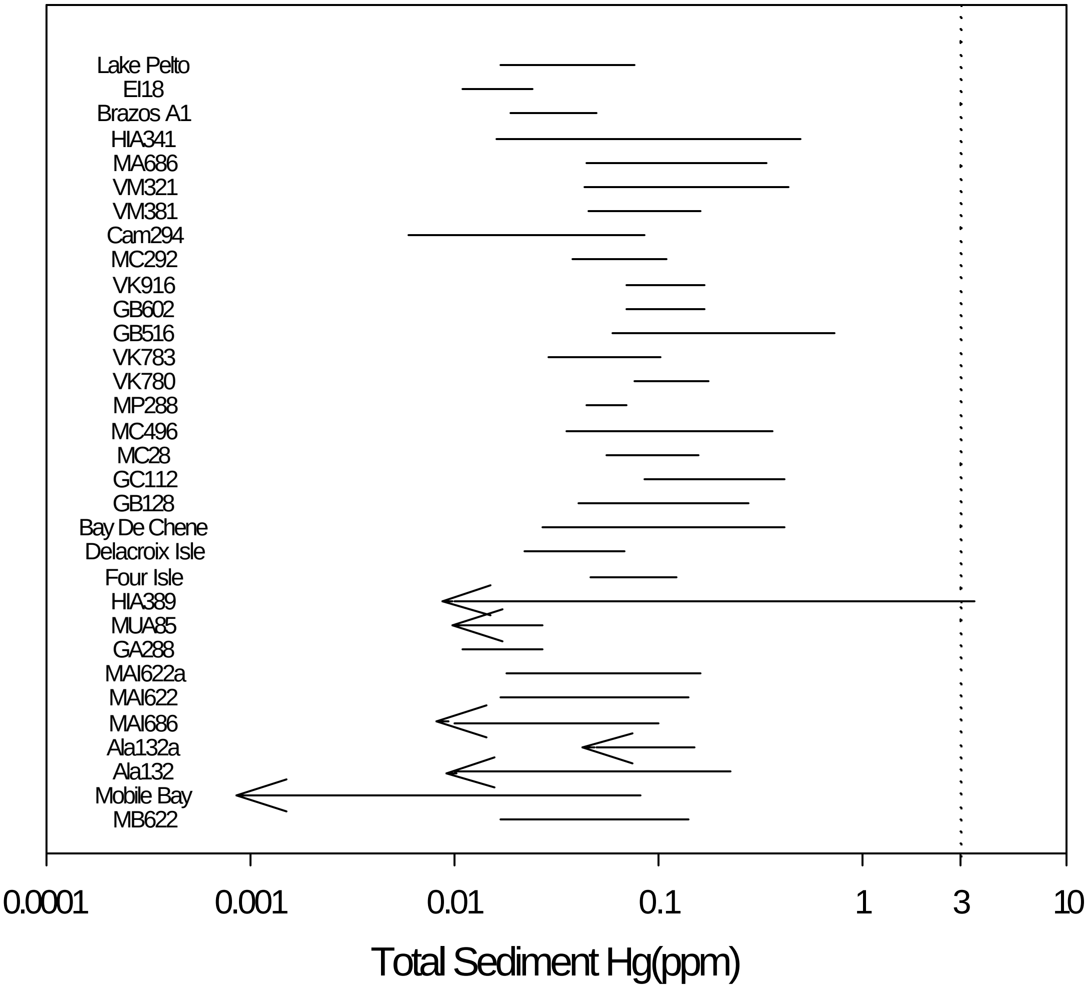

Figure 4. Ranges on mercury concentrations for sediments near offshore Gulf of Mexico platforms and drilling sites. Arrow indicates non-detect values in data set. (Trefry, 2002)

Component	Low Density Drilling Fluid	High Density Drilling Fluid
Barite	15%	62%
Low Gravity Solids	6%	6%
Treatment Chemicals	3%	3%
Liquid Phase	76%	29%

Table 1.Make-up of typical drilling fluids (Adapted from NRC, 1985)

Barite Source	Mercury (ppm)
Various Unspecified	<0.05 - 31
Vein Deposits - measured	0.8 - 28
Vein Deposits - literature	0.06 - 14
Bedded Deposits - measured	0.13 - -0.26
Bedded Deposits - literature	0.06 - 0.19
Continental Crust	0.04

Table 2. Ranges of concentrations of mercury in barite ore (Trefry, 2002)

Specie	Near Platform (ppm)	Away from Platform (ppm)
Grouper	0.10	0.20
Red Snapper	0.09	0.02
Sheepshead	0.06	0.24

Table 3. Ranges of mercury in fish tissue near and away from offshore platforms (Adapted from Neff, 2002 and Ache, 2000)