Final Report

Volume 2
Human Health Risk Assessment

Prepared for

Papua, Indonesia

Prepared by

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August 2002
555-3359-003

ACKNOWLEDGMENTS

This report reflects the contribution of many individuals and would not have been undertaken without the support of PT Freeport Indonesia's management. We are particularly grateful to Dr. Wisnu Susetyo, Dr. Jim Miller, Mr. Kent Hortle, Mr. Gesang Setyadi, and Mr. Joe Garrison for their support of the many data collection activities that supported the analysis presented in this report. The ERA Review Panel Team RPT), chaired by Professor Retno Soetaryono of the University of Indonesia, provided valuable comments, information and perspectives as part of their reviews of interim findings and the final reports. The members of the Review Panel Team and of their support team from the University of Indonesia are identified in the tables below.

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ACKNOWLEDGMENTS (continued)

The on-site data collections were critical to achieving a risk assessment based on site-specific data. We would like to recognize the efforts of the many staff from PTFI's Tailings and Coastal Division, Tailings and Biodiversity Division, and Timika Environmental Laboratory. The respective leadership of Dr. Yahya Husin and Messrs. Gesang Setyadi and Dedi Mahdar of PTFI were critical in carrying out the on-site studies. We would also like to acknowledge the many contributions made by Bogor Agricultural Institute (IPB) and Cenderawasih University staff in their coordination and conduct of the resource use studies by local people that supported this analysis.

The performance of staff with the analytical and testing laboratories is recognized and appreciated: Timika Environmental Laboratory, Australian Governmental Analytical Laboratory (AGAL, Sydney, AU), CSIRO (Sydney, AU), DPI (Brisbane, AU), Battelle Pacific Northwest Division - Marine Sciences Laboratory (Sequim, WA, USA) and EVS Environment (Vancouver, BC, CA). They had to deal with large sample volumes, ultra-trace analyses, and swift turn-around times.

Sue Robinson, James Keithly, and David Mayfield of Parametrix, Inc. prepared this report with peer review and technical support provided by Dr. Joyce Tsuji of Exponent, Inc. Dr. Rick Cardwell was the overall ERA project manager. Analysis and QA/QC of study data and the preparation of Study Data Reports was performed by the following Parametrix staff: Brandon Ball, Angie Coyner, Stuart Currie, Ken Fellows, Pete Lawson, Chip Maney, Terry Phipps, and Todd Pollard. Lucinda Tear provided advice on all statistical matters and Dr. John Toll provided peer review of the probabilistic modeling and parameter distributions. Rick Rosario and Lisa Allen provided database and GIS support. Document coordination and production by Barbara Mullen with support from Lorena Dinger and Debbie Fetherston also is gratefully acknowledged.

We also wish to thank the following scientists for their reviews, advice, and wisdom: Dr. Herb Allen (University of Delaware), Dr. Dominic Di Toro (HydroQual, Inc.), Dr. Elaine Dorward-King (Rio Tinto Borax), Mr. Gordon Moore (formerly with PTFI), Dr. David Norriss (Crescent Technology) and Mr. C.J. Doiron (Crescent Technology).

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ACRONYMS AND ABBREVIATIONS

Modified ADA	Ajkwa Deposition Area
AMDAL	Analysis Concerning Environmental Impact (translated from Analisis Mengenai Dampak Lingkungan)
ANC	Acid-Neutralizing Capacity
ANDAL	Analysis of Environmental Impact (translated from Analisis Dampak Lingkungan)
ANOVA	Analysis of Variance
ANZFA	Australian and New Zealand Food Authority
ARD	Acid Rock Drainage
ATSDR	Agency for Toxic Substances and Disease Registry
CDI	Chronic Daily Intake
CDF	Cumulative Distribution Functions
COW	Contract of Work
CSIRO	Australia's Commonwealth Scientific and Industrial Research Organization
US EPA	United States Environmental Protection Agency
FDA	Food and Drug Administration
GBT	Indonesian acronym for "East Ore Mountain"
GI	Gastrointestinal
HCI	Hydrologic Consultants, Inc.
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
LD50	Lethal Dose 50 percent
MPA	Maximum Potential Acidity
MRL	Minimum Risk Level
MRT	Molecular Recognition Technology
NRC	National Research Council
PM10	Particulate matter in the aerodynamic diameter range of 10 micrometers and less
ppm	Part(s) Per Million
PTFI	PT Freeport Indonesia
RAF	Relative Absorption Factor
RBC	Risk-Based Concentration
RDA	Recommended Dietary Allowance
RfC	Reference Concentration

ACRONYMS AND ABBREVIATIONS (continued)

RfD	Reference Dose
SF	Slope Factor
SLRA	Screening-Level Risk Assessment
SQ	Screening Quotient
TDI	Tolerable Daily Intake
TERA	Toxicology Excellence for Risk Assessment
TRMP	Tailings River Management Project of PTFI
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
UL	Tolerable Upper Intake Level
WHO	World Health Organization

EXECUTIVE SUMMARY

Background

PT Freeport Indonesia (PTFI) operates a copper-gold mining facility in the Highlands near Timika, Mimika Regency, Papua. The PTFI Contract of Work (COW) Mining and Project Area covers approximately 3,000 km^2, from the Grasberg mine at near 4,000 m above sea level to the Arafura Sea (Figure 1-1). For the past 11 years, PTFI has been conducting assessments of the potential environmental impacts associated with expansion of the Grasberg mine. The most recent of those assessments was an environmental analysis (AMDAL[1]) which addressed expansion of the mine operation up to 300,000 tons per day. This AMDAL led to the initiation of this Risk Assessment in 1998. A Tier 1 Screening Level Risk Assessment (SLRA) (Parametrix Project Team 1999a) was the basis for this Human Health Risk Assessment (HHRA). The objective of the HHRA is to determine the potential impact of the approved tailings management on the dry land and mangrove ecosystems and on the people that inhabit them. This report represents the second of three comprehensive assessments of the risks posed to aquatic life (Volume 1), human health (Volume 2; this report volume), and plants and wildlife (Volume 3) by tailings and other mine releases including any acid rock drainage (ARD) component (hereafter referred to collectively as tailings in this report).

Summary of Approach

This risk assessment includes a second-tier (Tier 2) SLRA and a HHRA. The Tier 2 SLRA was conducted to analyze a significant amount of additional data that were collected based on the recommendations in the Tier 1 analysis (Parametrix Project Team 1999a) and other studies. The purpose of the Tier 2 SLRA was to focus the HHRA on those substances and exposure pathways that potentially posed risk to the people living in the COW Area. Media evaluated in the Tier 2 SLRA included: surface water, deposited tailings/sediment, air concentrations of organic milling reagents, air concentrations of dust containing tailings, groundwater, and many different types of foods (plant and animal). The Tier 2 SLRA also screened estimated future concentrations of substances in surface water, groundwater, deposited tailings/sediments, and dust containing tailings[2]. There were instances where large samples of some media could not be collected and analyzed for metals (e.g., Cd analyzed

[1] AMDAL is a Government of Indonesia environmental impact analysis process that stands for *Analisis Mengenai Dampak Lingkungan*. It translates to *Analysis Concerning Environmental Impact*.

ANDAL means *Analisis Dampak Lingkungan* and directly translates to *Analysis of Environmental Impact*. This risk assessment is one of the documents generated by the ANDAL process.

[2] These concentrations were determined stoichiometrically (i.e., using fixed ratios) between empirical data on mill tailings data for ore bodies identified by PTFI for future mining and current concentrations of tailings substances. Future concentrations in foods were estimated qualitatively.

in one sample of a specific type of snail). Low sample sizes sometimes are unavoidable for several reasons. These include suboptimal habitat, high species diversity that results in lower densities of species, and reduced numbers of organisms due to harvest by local people. The aquatic ecological risk assessment and plant and wildlife risk assessments (Parametrix 2002a,b) comprehensively address risks to different types of aquatic life and wildlife.Metal concentrations in the various samples were compared to a variety of criteria to determine potential risk and thus did not rely on any particular sample, species, effect or response—including biomarkers—to evaluate risk. Rather, *multiple lines of evidence* were used to support determinations of potential risk to humans from possible exposure to tailings. These included sampling many types of media and foods in many locations and analyzing them for the substances of interest, surveying activities associated with actual exposures, and evaluating the nature and incidence of health indicators through medical surveys and monitoring.

The Tier 2 SLRA was comprised of a three-step analysis:

1. Concentrations of tailings substances in environmental media were statistically compared with reference (background) media concentrations and substances eliminated that were below background levels.

2. For media and substances exceeding background concentrations from Step 1, conservative media concentrations of that substance were compared with available Indonesian Government[3] standards.

3. For all remaining media and substances exceeding government standards, conservative media concentrations were then compared with risk-based concentrations (RBCs) developed based on site-specific (Amungme[4] and Kamoro) use rate and frequency data for each of three age groups: adult, adolescent and child.

Screening quotients (SQ values) then were estimated as the ratio of each substance's concentration to its RBC value. Only where similar modes of toxic action were indicated was the potential for substance additivity considered and only for non-cancer health effects (US EPA 2000). Substance

[3] Indonesian Government standards, when available, were considered first. Australia-New Zealand and World Health Organization standards were used only when Indonesian standards were unavailable.

[4] Amungme are the indigenous people of the Highlands, while the Kamoro people are the largest group of indigenous people of the lowland and estuary regions. Other indigenous groups also are present in the COW Area, but the Amungme and Kamoro represent the majority of indigenous people.

additivity was considered for all carcinogenic endpoints. Substances with SQ values above benchmark levels were identified for further probabilistic evaluation in the HHRA. Probabilistic refers to a computational procedure that determines the likelihood of a potential risk rather than just the magnitude of that risk.

Exposure was quantified probabilistically in the HHRA using the same exposure and media concentration studies used in the Tier 2 SLRA. However, because the toxicity reference values are based on longer-term exposures, the HHRA focused on potential lifetime exposures rather than exposure of specific age groups as in the Tier 2 SLRA. This is consistent with the state of practice for risk assessments of chronic exposures[5]. Additionally, the HHRA analyses used a range of media contact rates (ingestion, inhalation), exposure frequencies, media concentrations, and toxicity data rather than point estimates (Tier 2 SLRA) to compute cumulative probabilities of risk occurrence.

In the HHRA, health risks for non-cancer toxicity endpoints were quantified probabilistically as Hazard Quotients (HQs)—defined as a ratio of the exposure dose to the non-cancer toxicity reference value (TRV). Cancer risk was quantified probabilistically for cancer-causing substances as the product of the TRV for a cancer endpoint (i.e., the cancer slope factor) and the exposure dose. HQ values greater than 1.0 (i.e., the threshold limit for determining non-carcinogenic risk potential) indicate the exposure dose exceeds the non-cancer TRV. Consequently, these substances were identified as being of potential concern (US EPA 1989a). Potential cancer risks falling below the range of one excess cancer risk per ten thousand exposed people (0.0001 or 10^{-4}) to one excess cancer risk per one million exposed people (0.000001 or 10^{-6}) were identified as being of potential concern for a cancer endpoint (US EPA 1989a). The lower end of this range (i.e., 10^{-6}) is considered a conservative indicator of acceptable cancer risk. The probability of HQ values or cancer risks exceeding these threshold or benchmark limits was then identified. Additivity of potential risk across carcinogenic and non-carcinogenic substances was considered in the analysis.

Potential risks to the food supply were summarized based on the results from the Aquatic Ecological Risk Assessment (AERA) and the Plant & Wildlife Risk Assessment (P&WERA) (Parametrix 2002a,b).

[5] Though age group-specific risks were evaluated, for screening purposes,in the Tier 1 and 2 SLRAs, the toxicity reference values (TRVs) for chronic exposure used in the HHRA are generally developed for long-term exposures (often lifetime) and not for specific age groups. Use of chronic TRVs in assessing risk potential for children exposed subchronically will overstate risk potential; thus exposures over a lifetime were evaluated in the HHRA.

Findings

Concentrations of the majority of tailings substances in food, water, and deposited tailings posed negligible risks based on comparisons with reference concentrations, Indonesian standards, and/or RBCs in the Tier 2 SLRA (see Section 5.1.2). Of the many substances and exposure pathways evaluated in the Tier 2 SLRA, only three substances (arsenic, cadmium, and manganese) and five potential exposure pathways were further evaluated quantitatively in the HHRA. The Tier 2 SLRA results indicated that the large majority of people within and outside of the COW Area are at negligible risk from exposure to media potentially containing copper, though copper-sensitive people may be at potential risk of some liver effects. Copper-sensitive people are defined as those rare individuals, typically infants or young children, that have a genetic pre-disposition to developing liver cirrhosis following exposure to elevated levels of copper in the environment. Medical monitoring has not identified any of these rare individuals in or outside of the COW Area (Effendi et al. 2000, Appendix A Data Report #19 [*Status Gizi Dan Kesehatan Masyarakat Yang Tinggal Di Proyek Penambangan PT Freeport Indonesia]*). Due to the limitations in the available toxicity data for copper-sensitive people, copper was evaluated only qualitatively in the HHRA.

The exposure pathways identified from the Tier 2 SLRA as warranting a more detailed evaluation were:

- Incidental ingestion of deposited tailings.
- Consumption of certain mangrove mollusk species (e.g., the wood-boring mollusk [Tambelo], snails, mud clams, and prawns from areas containing tailings.
- Consumption of wild sweet potato leaves grown in areas near the east modified ADA that contain historic tailings.
- Incidental ingestion of tailings in surface water from recreational or subsistence activities.
- Inhalation of dust containing tailings in lowland settlements.

Excepting consumption of certain mangrove mollusks and crustaceans (cadmium and copper), and inhalation of dust (arsenic and manganese), all potential risk were associated with cancer risks from inorganic arsenic. These potential risks are described in more detail below.

Inorganic Arsenic

Inorganic arsenic is a substance known to cause cancer in humans based on certain ingestion and inhalation studies (Wilson 1996; TERA 1999; US EPA 2001). A prediction of potential cancer risk from exposure to inorganic arsenic (or any carcinogenic substance) from either of these exposure

routes (discussed further below) does not indicate that a person will contract cancer, since the development of cancer depends on several factors that can reduce or eliminate the risk. These factors include (but are not limited to) the degree (amount and length[6]) of exposure and the body's immune capabilities (i.e., ability to kill cancerous cells and initiate repair).

Current risk assessment practice for substances that cause cancer assumes there is no "safe" dose. This is why any exposure to a carcinogenic substance is assumed to be associated with some probability of contracting cancer. Therefore, an important question for interpreting cancer risks for inorganic arsenic and other carcinogenic substances (e.g., nickel) from this risk assessment is what cancer risk probability level is considered "acceptable"? The definition of what constitutes an acceptable cancer risk is a policy question. In the U.S., it has been addressed by the United States Environmental Protection Agency (US EPA 1990) and other regulatory agencies. The US EPA has defined as *acceptable* those cancer risks that range from one additional cancer per ten thousand exposed people (expressed numerically as 0.0001 or 10^{-4}) to one additional cancer per one million exposed people (expressed numerically as 0.000001 or 10^{-6}) (US EPA 1990). Thus, the risk range of 10^{-4} to 10^{-6} commonly is used in the United States to provide a benchmark for interpreting cancer risk. Levels below 10^{-4} generally are not of concern. Indonesian regulatory guidance defining acceptable levels of cancer risk were not identified from the scientific literature, and therefore the United States acceptable risk range was used in the HHRA.

Findings for potential inorganic arsenic cancer risk from the HHRA, discussed below, indicated all predicted cancer risk levels were at or below 10^{-4}, and thus within the acceptable cancer risk range previously discussed. Though not directly comparable with potential cancer risks, measures of inorganic arsenic concentrations in hair and nails frequently are used as an indicator of the degree of exposure (though not risk) in populations where arsenic intakes are a potential concern. With the exception of one individual in the highland settlement of Banti[7], ranges of inorganic arsenic in hair samples collected from people in settlements potentially affected by tailings and those from reference settlements (Parametrix Project Team 1999a) were shown to be below a level of one part per million (ppm). This level is considered "normal" (ATSDR 1998) for hair and nails and reflective of background levels of exposure from all sources. Thus, the hair arsenic data generally indicate that people are not being exposed at levels outside a normal range. Nail concentration data were not collected.

[6] Current scientific theory on the development of cancer is that it occurs over a lifetime.

[7] There is no evidence indicating that the arsenic exposure of this individual is related to tailings.

Potential cancer risks for inorganic arsenic in various reference (non-tailings) media, though variable, exceed the conservative end of the reference cancer risk range (i.e., 10^{-6}). These levels reflect naturally occurring arsenic in the environment. For example, the current Indonesian drinking water standard for arsenic of 0.05 mg/L, a concentration assumed safe for drinking water exposures in the United States, represents a cancer risk of 10^{-3} (one additional cancer per 1,000 exposed people). This cancer risk level is higher than the "acceptable" cancer risk range, which is more stringent. Soil and sediment concentrations of inorganic arsenic also can be naturally elevated in areas without anthropogenic (caused by human activities) contributions as a result of mineral enrichment from volcanic and other geological processes, such as occurs in Indonesia. The potential cancer risk levels associated with the concentrations in these media can range from 10^{-4} to 10^{-5}, depending on actual concentration, which is within the acceptable risk range.

As previously stated, potential cancer risks across all inorganic arsenic exposure pathways were within or below a 10^{-4} cancer risk level. The probability of cancer risks occurring at levels higher than this varied by pathway and region of the COW Area, but was always very low (<1 percent at the 99th percentile). Potential cancer risks were within a 10^{-4} risk level for incidental ingestion of historic tailings containing arsenic from freshwater swamps (e.g., Mapiamara, Fainaua; see Figure 1-1) situated along the old Ajkwa River channel. The results for the latter exposure pathway appear in the Tier 2 SLRA. Low sample size precluded further evaluation in the HHRA[8]. However, potential cancer risks in the HHRA for incidentally ingesting deposited tailings from other locations on a regular basis over a long period (i.e., lifetime), including the Mile 21 Tailings Reclamation Research Center, were lower at 10^{-5}. The probability of higher cancer risk levels occurring from this pathway generally was very low (<1 percent at the 99th percentile).

Potential cancer risks associated with the inhalation of inorganic arsenic in dust containing tailings varied by settlement location, but typically were within the range of 10^{-5} to 10^{-6} and low probability (<1 percent) of a higher cancer risk. These levels are within the acceptable risk range identified in this analysis.

Ingesting leaves from sweet potatoes grown in historic tailings near the east modified ADA sheet flow areas near Kali Kopi had potential cancer risks for inorganic arsenic. These ranged from 10^{-4} to 10^{-5} and had a low probability (<1 percent) of being higher. Non-cancer (skin) health effects from sweet

[8] The potential arsenic cancer risks was associated with two samples (total arsenic range = 40 to 200 ppm) of sediment containing historic tailings collected in Mapiamara and Fainaua freshwater swamps.

potato leaf consumption were not identified (see Section 5.2.2). It is unclear whether the sweet potato gardens in this area could sustain more than a few individuals given the conservative assumptions used concerning site-specific consumption sweet potato leaves from gardens in areas with tailings.

Incidental ingestion of tailings in surface water from recreational exposures such as swimming or playing was predicted to have a potential cancer risk for inorganic arsenic of 10^{-5}, with a low probability (<1 percent at the 99th percentile) of higher cancer risks occurring.

As indicated above, the potential cancer risk levels estimated for all of the exposure pathways were within or below a 10^{-4} cancer risk level, which is within the acceptable range assumed in this analysis. Potential cancer risk levels from exposure to reference media concentrations of inorganic arsenic are frequently within this range and can sometimes be higher, as previously mentioned. In a determination of what constitutes acceptable cancer risk in the United States, Travis et al. (1987) evaluated the risk levels associated with 132 United States federal regulatory decisions and found that most defined acceptable risk as being around 10^{-4}. This 10^{-4} cancer risk level represents the high end of the range of potential risks predicted for tailings-containing media exposures in the COW Area. However, potential cancer risks for inorganic arsenic for many exposure pathways were within a 10^{-5} to 10^{-6} range.

With the exception of arsenic from non-tailings sources, which occurred in foods and deposited historical tailings, levels of potential cancer risk are expected to decline in the future. This is supported by a comparative analysis of current and future tailings characteristics (i.e., Grasberg underground at the end of mine life), which suggested that future total arsenic concentrations may be reduced by an average of 50 percent (Appendix A Data Report #1 [*Analysis of Future Metals Concentrations in Tailings and Tailings-Affected Environmental Media*]).

Total dietary intakes of arsenic measured during the Human Use and Dietary Survey indicate that arsenic exposures exceeding benchmark levels occur at all settlements near tailings as well as in reference settlements without tailings. Higher levels of arsenic intake were identified in lowland and estuarine settlements (including their paired reference settlements), likely reflecting the high fish and mollusk consumption patterns in these regions. The high levels of arsenic in these organisms are known to be largely inert organic arsenic rather than inorganic arsenic (known to cause cancer), based on measurements in fish and invertebrates from a variety of locations within the COW Area. As such, these estimates are extremely conservative and overpredict actual risks.

Copper

Copper is an essential nutrient that is homeostatically regulated in the human body (see Section 4.1), although there are some rare individuals, typically infants or very young children, that are genetically predisposed to certain health effects associated with the liver. This rare condition is known as idiopathic copper toxicosis[9]. These rare individuals (typically infants or very young children) were the focus of the risk evaluations for copper in the Tier 2 SLRA and HHRA because the general population will be at negligible risk from all copper exposure pathways due to their ability to physiologically regulate this metal. However, a potential risk of liver cirrhosis was identified for children with idiopathic copper toxicosis if they consumed certain mollusk species from certain areas (i.e., Tambelo [*Bactronophorus thoracites*], mud clam, murex snails). These species from the Ajkwa and Minajerwi estuaries may pose this potential risk; however, murex snails are rare if not absent from these two areas. The screening quotients (SQs) for consumption of certain mangrove mollusk species by these sensitive children ranged from 1 to 7 times the toxicity threshold thought to be protective of these individuals. Medical monitoring conducted in seven settlements near tailings and three reference settlements has not specifically identified any individuals that may have this affliction (Effendi et al. 2000, Appendix A Data Report #19 [*Status Gizi Dan Kesehatan Masyarakat Yang Tinggal Di Proyek Penambangan PT Freeport Indonesia*]). The Tier 2 analysis assumed that 100 percent of all mollusks were collected and consumed from areas containing tailings. This is a very conservative assumption for most people living in the COW Area based on site-specific mollusk consumption data (IPB Bogor et al. 1999, Appendix A Data Report #21 [*Study on Mollusk Consumption in Estuary and Mimika Coastal Area*]) and abundance data (Setyadi and Hortle 1999; Pribadi and Parametrix 2001).

The Aquatic Ecological and Plant and Wildlife Risk Assessments indicate that certain mollusk species and populations (specifically certain types of snails) have been affected by tailings in the Ajkwa estuary (Parametrix 2002a,b). This group of predatory snails is rare to absent in the estuaries with tailings (Setyadi and Hortle 1999; Pribadi and Parametrix 2001), which indicates they could not be consumed at the levels assumed in this analysis. Additionally, the murex snail *Chicoreus capucinus*

[9] Idiopathic copper toxicosis, also termed Indian Childhood Cirrhosis or Tyrolian Childhood Cirrhosis, is not to be confused with Wilson's Disease. The latter is a disorder in which copper cannot be properly metabolized in the body. Wilson's Disease *is not* addressed in this risk assessment because people with this affliction require careful medical monitoring to avoid life-threatening copper exposures from even normal (background) levels of copper in the environment.

was not reported among the snail species consumed by people in lowland and estuarine settlements (IPB Bogor et al. 1999). Therefore estimates of risk based on murex snail consumption may not reflect actual exposures. Further, it is likely that the screening risk estimates for copper-sensitive people consuming any of these mollusk species could be overstated since the analysis assumes people will consume organisms with high levels of copper in their tissues despite the unpleasant (reportedly bitter) taste. This unpleasant taste apparently precludes many individuals from consuming these mollusks at the high rates of consumption (i.e., absent taste and appearance concerns, as well as apparent low abundance) assumed in the analysis[10]. Based on the foregoing, the Tier 2 estimates concerning potential copper risks appear to have overpredicted exposure based on consumption of certain Ajkwa mollusks.

The potential risks identified in the Tier 2 SLRA for copper-sensitive people consuming mollusks were not evaluated quantitatively in the HHRA. This is because definitive dose-response data from the scientific literature for establishing a protective TRV were not available and the TRV used in the Tier 2 SLRA (NRC 2000) is too uncertain. However, the actual exposure of these sensitive individuals, should they even occur in the COW Area, is expected to be less than that assumed in the Tier 2 SLRA, given the very conservative exposure assumptions used in the screening assessment[11]. As previously mentioned, there is no specific information indicating that people (young children) with such sensitivities occur within the general population in the COW Area based on medical monitoring and health surveys conducted by medical personnel and their contractors (Effendi et al. 2000). Data from Effendi et al. (2000, Appendix A Data Report #19 [*Status Gizi Dan Kesehatan Masyarakat Yang Tinggal Di Proyek Penambangan PT Freeport Indonesia*]) indicated one child (age 7 years) from Banti with liver function measurements well above the normal range. There is no evidence, however, that this anomalous reading is indicative of a copper-sensitive child, especially because recent (October 2001) clinical measurements taken from the same child indicate normal liver function (Madar 2001). Additionally, information from the scientific literature does not suggest that idiopathic liver toxicosis occurs in this population. Moore et al. (1997) indicate that they probably are very rare

[10] Flavor change (reportedly bitterness) and discoloration of mollusks by copper may occur at high copper concentrations. For example, striping and mottling of tissues has been reported in Tambelo and mud clams (respectively) by local people (IPB Bogor et al 1999). Concentrations of copper were analyzed by PTFI in organisms with discoloration and subsequently evaluated in the Tier 2 SLRA and HHRA. However, specific data correlating flavor preference and discoloration with measured copper concentrations were not available.

[11] Examples of these conservative assumptions include (1) 100 percent of the mollusks are harvested from the COW Area; and (2) the tissue concentration is adequately represented by a single, conservative value. In reality, people get their mollusks from a variety of locations based on site-specific data (IPB Bogor et al. 1999) and the concentrations occurring in the tissues of these organisms will vary significantly, encompassing a range of low and high concentrations.

in a population. Thus, the likelihood of all of the exposure and toxicity factors occurring together for copper-sensitive people is likely to be extremely low.

Serum and urinary copper data from a cross-section of individuals of all age groups were relatively consistent across settlements, although urinary copper was more variable (Appendix A Data Report #20 [*Exposure Characterization in Fish and Shellfish Harvesting Camps*]). Variable copper levels in urine likely reflect individual variation in copper excretion. The stable levels in serum are consistent with what is expected for a homeostatically regulated nutrient. Total dietary intake levels of copper also were shown to be below threshold toxicity values established for copper-sensitive people, lending more support that the Tier 2 SLRA predictions for this subgroup may overstate risk potential.

In the future, potential risks to copper-sensitive individuals from consumption of certain mangrove mollusk species would likely be similar to those predicted under current mine conditions (i.e., low since their abundance is expected to be rare) until enough natural sediment (i.e., post-mine closure) has accumulated to attenuate copper to reference levels.

Cadmium

Consumption of a predatory murex snail was identified as posing a potential risk of cadmium effects to the kidney cortex. Consumption of *Chicoreus capucinus* containing cadmium in their tissues was identified for both the Ajkwa and Minajerwi estuaries. However, with only one sample from each estuary, this pathway could not be evaluated further in the HHRA. Murex snails are either rare or absent in the Ajkwa and Minajerwi estuaries (Setyadi and Hortle 1999; Pribadi and Parametrix 2001). This likely indicates they could not be consumed at the levels assumed in this analysis and thus would not present a risk potential. Cadmium screening quotient values (SQs) from the Tier 2 SLRA for consumption of *C. capucinus* were low and ranged from 2 to 3 for people living in estuarine settlements. As stated previously, *C. capucinus* consumption is not documented as being one of the species of snails consumed by people in lowland and estuarine settlements. Therefore, the Tier 2 SLRA probably overstates the actual exposure and risk potential for this pathway.

Clinical measurements of kidney function made during a recent health survey of people in the COW Area settlements did not detect any abnormalities (e.g., blood urea nitrogen, creatinine) indicative of kidney damage (Effendi et al. 2000, Appendix A Data Report #19 [*Status Gizi Dan Kesehatan Masyarakat Yang Tinggal Di Proyek Penambangan Pt Freeport Indonesia*]). Further, measurements of cadmium dietary intake from a total diet study indicated that cadmium intakes typically were higher at reference settlements than at those near tailings areas.

Manganese

In the Tier 2 SLRA, manganese was identified as potentially posing a risk of neuro-behavioral effects for children, adolescents and adults living in lowland settlements that regularly inhale dust containing tailings. However, these potential risks were very low with SQ values just slightly above 1.0 (i.e., 1.4 – 1.8) and considered quite conservative since the TRV values applied to each age-group are actually most appropriately used with chronic, long-term exposures. Potential exposures from this pathway were further evaluated for lifetime weighted average exposures in the HHRA and indicated less exposure than was predicted in the Tier 2 SLRA because less conservative assumptions were used. The HQ values predicted in the HHRA for the dust inhalation pathway were all well below 1.0 (maximum predicted HQ = 0.2). There was a very low probability (<1 percent at the 99th percentile) of higher HQ values. Therefore, inhalation of manganese in dust containing tailings was predicted to pose a negligible risk to people living in lowland settlements.

Biomarker data for urine and blood indicate that people living in settlements near tailings experience manganese exposures that are comparable to people living in reference settlements. Further, total dietary intakes of manganese were shown to be higher in reference settlements than in settlements located near tailings.

Future risks from inhalation of manganese in dust containing tailings also are expected to be negligible since data (see Appendix A, Data Report #3 [*Levee Road Dust Monitoring Study*]) indicate that future tailings concentrations of manganese are expected to be similar in concentration to those of current tailings.

Organic Milling Reagents

A screening analysis of milling reagent risk potential was conducted using conservative exposure assumptions. Volatilization of milling reagents from surface water to air was predicted to be negligible based on conservative fate modeling (Appendix A Data Report #6 [*Screening-Level Evaluation of Milling Reagents in Water and Air Downstream of the Freeport Mill*]). Therefore, negligible exposures and potential health risks were predicted for people living in any highland, lowland or estuary settlement who might inhale the very low predicted air concentrations of these substances. Similarly, negligible exposures and risks were predicted for people that might incidentally ingest surface water due to milling reagents at all settlements. Measurement of surface water concentrations of these constituents above and below the highland settlement of Banti (where concentrations would be expected to be highest), and measurement of Henry's Law Constants would be necessary to verify the accuracy of predicted water and air concentrations. Additionally, toxicity

data used to evaluate the milling reagents were extremely limited, thus creating a high degree of uncertainty to the screening analysis[12].

All other substances posed negligible potential health risks based on the results of the Tier 1 SLRA (Parametrix Project Team 1999a) and the Tier 2 SLRA and HHRA (the present document).

Impacts to Food Supply

Potential effects of tailings on aquatic organisms, some of which represent key food items in the diet of local people, are being evaluated as part of the aquatic ecological risk assessment (Parametrix 2002a).

The Plant and Wildlife Risk Assessment (Parametrix 2002b) found that garden plants do not grow well in 100% tailings. Most of the garden plants tested had a germination rate of less than 10 percent in coarse tailings, and only up to 50 percent in medium to fine tailings. Results indicate nutrient deficiencies and moisture were the limiting factors for seed germination, and not associated with metal effects. Additionally, some species of small birds and rats in the Ajkwa River estuary were identified as having potentially reduced reproductive success due to the copper concentrations in the tailings. However, neither of these groups of organisms was identified as an important food source in the Human Use and Dietary Survey (Bogor Agricultural and Cenderawasih Universities et al. 2000, Appendix A Data Report #10 [*Human Use and Dietary Survey: A Dietary and Exposure Survey of Peoples within and near PT Freeport's COW Area*]). A loss of freshwater swamps at the mouth of the estuary, and the mangrove forest in the upper Ajkwa River estuary (above the confluence with the West Minajerwi) also could affect the abundance of some of the aquatic organisms that currently are harvested. However, the Plant and Wildlife Risk Assessment suggests that significant new mangrove stands will be created in the estuary (Parametrix 2002b). This Plant and Wildlife Risk Assessment also projected losses of sago palm within the modified ADA due to flooding, though sago palm outside of the modified ADA will be unaffected and safe for consumptive uses. As new freshwater habitat is created within the modified ADA, sago and other associated vegetation will colonize these areas and they will be safe for consumption.

[12] The use of uncertainty factors of up to 10,000 in deriving TRV values from some studies suggests that risks could be over- rather than under predicted.

Summary of Findings

The Tier 2 SLRA found that concentrations of most substances in food, water, and tailings were not of concern based on comparisons to reference concentrations, Indonesian Government standards, and RBCs. Arsenic, cadmium, copper, and manganese were identified for further evaluation in the HHRA for a small set of potential exposure pathways. Due to insufficient dose-response data in the scientific literature, potential risks to copper-sensitive people could not be evaluated quantitatively in the HHRA.

A potential cancer risk from inorganic arsenic that was within an acceptable cancer risk level was identified for all of the pathways evaluated, including: incidental ingestion of deposited tailings, ingestion of tailings surface water while swimming, consumption of sweet potato leaves grown in some historic tailings areas, and inhalation of dust containing tailings transported to lowland settlements (see Section 5.2.2). The majority of potential arsenic risks identified were associated with background concentrations and not related to tailings.

Consumption of prawns containing cadmium from freshwater swamps was associated with negligible risk. Cadmium in dust containing tailings was not identified as being of concern, with potential cancer risks typically below the range of risk assumed in this analysis. Additionally, a low level of risk was predicted in the Tier 2 SLRA for people consuming certain snails containing cadmium in their tissues. These risks could not be further evaluated in the HHRA due to limited sample size. However, available monitoring data indicate that the murex snails, all of which are predators upon other snails and locally comprise three species (*Chicoreus capucinus, Naquetia capucina,* and *Stramonita gradata*), are rare if not absent from the Ajkwa and Minajerwi estuaries (Setyadi and Hortle 1999; and Pribadi and Parametrix 2001). Consequently, they could not be consumed at the levels associated with the potential risks identified in the Tier 2 SLRA. Therefore, predicted risks from the Tier 2 SLRA likely overstate the actual exposure and risk potential associated with snail consumption.

The vast majority of people exposed to copper will not be at risk of any health effects because of their ability to physiologically regulate this essential metal (see Section 4.1). However, a subgroup of potential consumers (i.e., infants or very young children with a rare, genetic predisposition for liver cirrhosis), could be at risk if they ingested elevated levels of copper occurring in some mollusk species of the Ajkwa and Minajerwi estuaries. Whether these copper-sensitive people occur in the COW Area populations is unknown, but appears to be rare. Medical monitoring conducted in most

COW Area settlements have not identified any individuals with this rare genetic pre-disposition, though only a subsample of each settlement's inhabitants have been evaluated.

Manganese inhaled in dust containing tailings was evaluated further in the HHRA and shown to have a negligible risk potential. Therefore inhalation of dust containing tailings in lowland settlements was not of concern. Negligible health risks were predicted from ingestion of or inhalation of organic milling reagents in surface water or air, respectively.

Future risks were predicted to be lower for some of the pathways because metal concentrations are expected to decline. Otherwise, future risks are likely to be similar to current risk predictions until enough natural sediment accumulates to reduce metal concentrations to reference levels.

Thus, in summary, the HHRA found that under current and future mine conditions, consumption of foods (e.g., fruits, vegetables, sago, fish, Tambelo, mollusks, crustaceans), groundwater (Timika and other lowland locations) and surface water (Kwamki Lakes, Kopi River) are safe for the general population since the probabilities of potential cancer and other health effects were very low and within acceptable risk benchmarks.

Some limited impacts to food supply were identified in the Plant and Wildlife Risk Assessment and Aquatic ecological Risk Assessment (Parametrix 2002a,b).

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APPENDICES

Study Descriptions for Key Studies Performed to Support HHRA

1. **Study Title**: Analysis of Future Metal Concentrations in Tailings and Tailings-Affected Environmental Media. PTFI and Parametrix. 2001.

   Affiliation of Authors:

   PT Freeport Indonesia
   Parametrix Inc.

   Study Description:

   A data report prepared by Parametrix using data collected by PT Freeport Indonesia. It summarized the methods used to estimate future tailings concentrations in environmental media as well as the predicted concentrations in each medium. The Parametrix team conducted a comparative analysis of current tailings characteristics with those of future tailings projected to be discharged between 2014 and 2035, based on milling of cores extracted by PTFI from portions of the ore body to be mined during this period. Column leach tests with these tailings were also conducted to estimate geochemical behavior. Statistical comparisons of the current and future tailings concentrations served as the basis for predicting changes in concentrations of tailings substances in environmental media in the highlands, lowlands, and estuary. Media included surface water, groundwater, deposited tailings, and dust.

2. **Study Title**: Characterization of Metal Residues in Biota Harvested from Tailings-Associated and Reference Areas. PTFI and Parametrix, Inc. 2001

   Affiliation of Authors:

   PT Freeport Indonesia
   Parametrix Inc.

   Study Description:

   PTFI routinely collects fish tissue from a variety of locations (freshwater, estuarine) in rivers within the Ajkwa Deposition Area as well as from reference rivers as part of the environmental monitoring program. This program also collects sediment. Parametrix designed a supplemental survey of metal residues in sediment and tissues of fish and invertebrate (e.g., snails, prawns) species that were known to be consumed by local people. Organic and inorganic species of arsenic were determined in many of the fish and invertebrates sampled from rivers within the COW Area and from reference rivers. This data report summarizes all of the fish and invertebrate tissue data used to evaluate potential consumption exposures including concentrations in tissues from reference areas. It compares residues with Indonesian or other regulatory standards for food.

3. **Study Title**: Levee Road Dust Monitoring Study. PTFI and Parametrix, Inc. 2001.

   Affiliation of Authors:

PT Freeport Indonesia
Parametrix Inc.
The National Atomic Energy Agency (BATAN)

Study Description:

The National Atomic Energy Agency (BATAN), in coordination with PTFI collected data on airborne dust and associated metal concentrations at different locations within the Ajkwa Deposition Area during peak truck traffic periods. Dust and metal concentrations were measured on both the east and west levee roads in the fall/winter of 2000 and used as input to air dispersion modeling performed by Parametrix. Dispersion modeling utilized meteorological data (windspeed, direction, annual average precipitation) and information on the quantity of daily truck traffic to estimate metal concentrations in breathable (i.e., 10 micrometer particulate matter or PM_{10}) dust that could be transported via the wind to lowland settlements adjacent to the ADA. Predicted dispersal concentrations at lowland settlements were also a function of linear distance from the levee roads. The data and modeling methods used to predict potential dust inhalation exposures (current and future) in lowland settlements are contained in this data report, and compared with airbore dust standards.

4. **Study Title**: Low-Level Mercury Analyses in Surface Water. PTFI and Parametrix Inc. 2001.

   Affiliation of Authors:

   PT Freeport Indonesia
   Parametrix Inc.

   Study Description:

   The Parametrix team designed this study with data collected by PTFI. The study sought to determine the presence or absence of mercury in tailings and reference rivers. Clean sampling techniques were used to minimize cross-contamination of samples, and ultra-low analytical detection limits were used. Both dissolved and total concentrations were measured in the Ajkwa and reference rivers. The data report describes the data and compares it to Indonesian and other regulatory surface water standards.

5. **Study Title**: Mangrove Invertebrate Study. 2001. PTFI and Parametrix, Inc.

   Affiliation of Authors:

   PT Freeport Indonesia
   Parametrix Inc.

   Study Description:

   PTFI designed and conducted a sampling program for mollusks from several mangrove locations and analyzed the tissues for a variety of metals. Sediment associated with the organisms was also collected. Organisms in the sampling program included Tambelo worm, mud crabs, snails, and mud clams. The data report summarizes the tissue data from this program and compares the data with Indonesian and other regulatory standards for food.

6. **Study Title**: Screening-Level Evaluation of Milling Reagents in Water and Air Downstream of the Freeport Mill. Parametrix and Exponent. 2001.

   Affiliation of Authors:

   Parametrix Inc.
   Exponent Inc.

   Study Description:

   PTFI uses known proportions of organic reagents in a physical ore flotation process. This information was supplied to Parametrix and Exponent for use in a milling reagent screening analysis to determine if further evaluation of milling reagents in the HHRA was warranted. Concentrations of milling reagents were conservatively estimated using dispersion modeling to estimate concentrations in surface water and air in highland, lowland, estuarine locations along the tailings rivers: Aghawagon, Otomona, and Ajkwa. These modeled data were then used to screen potential human health risks from inhalation of air and incidental ingestion of water. The data and methods used are described in this report.

7. **Study Title**: Highland, Lowland and Estuary Sediment and Tailings (HH4) Data: Years 1998, 1999, 2000. PTFI and Parametrix. 2001.

   Affiliation of Authors:

   PT Freeport Indonesia
   Parametrix Inc.

   Study Description:

   The Parametrix team designed and estimated concentrations of substances in the ADA in 1999. Samples of tailings were collected in a series of east-west trending transects situated throughout the ADA (north to south). Samples were taken along each transect.

8. **Study Title**: Analysis of Sweet Potatoes from Gardens at Banti. PTFI and Parametrix. 2001.

   Affiliation of Authors:

   PT Freeport Indonesia
   Parametrix Inc.

   Study Description:

   The objective of this survey, conducted by Cenderawasih University, was to estimate concentrations of metals in sweet potatoes grown adjacent to the Aghawagon River near the highland village of Banti and from a reference area. Tuber and leaf samples were sampled and analyzed after washing and preparation in the same manner employed by Banti residents.

9 **Study Title**: Tier 2 Plant Metal Uptake Study Data Report and Screening Assessment. Parametrix, Inc.. 2002. Tier 2 Plant Metal Uptake Study Data Report and Screening Assessment. Parametrix Inc., Kirkland, WA. 222 pg. + attachments.

Affiliations of Authors:

[1]Parametrix, Inc.

Study Description:

The Plant Metal Uptake Study was conducted to evaluate the potential effects of tailings on plants within and near the ADA. This report (1) evaluated metals concentrations in plants that were grown under controlled conditions and comprising species that are consumed by humans and potentially by wildlife. A second objective was to evaluate metal concentrations in plants used for human food and by wildlife that were grown in the project area. Metal concentrations were measured and uptake rates were estimated for each metal and plant combination.

10. **Study Title**: Human Use and Dietary Survey: A Dietary and Exposure Survey of Peoples within and near PT Freeport's COW Area. Bogor Agricultural University, Cenderawasih University, PT Freeport Indonesia, Parametrix Inc, and Exponent Inc.

    Affiliation of Authors:

    Bogor Agricultural University
    Cenderawasih University
    PT Freeport Indonesia
    Parametrix, Inc.
    Exponent, Inc.

    Study Description:

    This survey evaluated recreational and subsistence activities that bring people into potential contact with tailings. The survey was conducted in 1998 and involved 160 children, adolescents, and adults from lowland, highland and estuarine settlements. Seven settlements within the COW area and three reference villages were surveyed. Survey work was conducted by Bogor Agricultural and Cenderawasih universities. A key aspect was measurement of foods and liquids consumed over a 6-day period to estimate consumption rates. Additionally, participants completed a questionnaire documenting their typical rates of consumption for a variety of food types and beverages, seasonal aspects of food consumption, and time spent in various activities (e.g., gardening, swimming, playing) that might define tailing exposure. Measurements of metals in the five foods commonly eaten in each settlement were quantified. Estimates were made of total daily metal intake based on sampling the food and water consumed by participants comprising each age group over a one-day period (referred to as Total Diet). Additionally, metals in hair, urine, and blood were also measured participants, as were concentrations of metals in settlement soils, drinking water, and recreational/bathing water. The methods and findings of the Human Use and Dietary Survey are summarized in this data report.

11. **Study Title**: Biomarker Data for Human Use and Dietary Survey Participants. PTFI, Parametrix, Inc. and Exponent Inc. 1999.

    Affiliation of Authors:

    PT Freeport Indonesia
    Parametrix, Inc.

Exponent, Inc.

Study Description:

This report contains data on concentrations of metals in hair, urine and blood from participants in the Human Use and Dietary Survey (see Study Description above). These measurements were termed biomarkers of exposure, and results were included in the Tier 1 Screening-Level Risk Assessment.

12. **Study Title**: Total Diet Calculations for Human Use and Dietary Survey Participants. PTFI, Parametrix, Inc. and Exponent, Inc. 1999.

    Affiliation of Authors:

    PT Freeport Indonesia
    Parametrix, Inc.
    Exponent, Inc.

    Study Description:

    This report contains data on concentrations of substances measured from a one-day sampling of all food and beverages consumed by participants in the Human Use and Dietary Survey (see Study Description above). This report contains the total diet data as well as estimates of intake for substances potentially associated with tailings. It compares estimated intakes with those recommended by the United States Environmental Protection Agency, World Health Organization, etc. This report contains the total diet data as used in the Tier 1 Screening-Level Risk Assessment.

13. **Study Title**: Summary of Nutritional and Public Health Status in Freeport Contract of Work Area. Bogor Agricultural University, Cenderawasih University and PT Freeport Indonesia. 2001.

    Affiliation of Authors:

    Bogor Agricultural University
    Cenderawasih University
    PT Freeport Indonesia

    Study Description:

    This report contains an English summary of the key findings of the 2000 report: *Status Gizi Dan Kesehatan Masyarakat Yang Tinggal Di Proyek Penambangan PT Freeport Indonesia – Jurusan Gizi Masyarakat Dan Sumberdaya Keluarga, Institut Pertainian Bogor, Universitas Cenderawasih.* (see Study Description #19)

14. **Study Title**: Ajkwa Deposition Area Groundwater Modeling. University of Gadja Mada, ITB and URS, Inc. 2001.

    Affiliation of Authors:

    University of Gadja Mada

Institute of Technology, Bandung
URS Consultants, Inc.

Study Description:

This modeling study, conducted by ITB, URS and University of Gadjah Mada, evaluated the rate of recharge between groundwater underlying the ADA and adjacent lakes and streams. Data from this study was also used to support evaluations of future concentrations in groundwater.

15. **Study Title**: Tailing Hydraulic Testing and Characterization for Groundwater Modeling – Geotechnical Engineering Laboratory, Inter University Center for Engineering Sciences, Institut Tecknologi Bandung (ITB). 2000.

Affiliation of Authors:

Institute of Technology, Bandung

Study Description:

This report contains the data and engineering evaluations developed by ITB in support of the groundwater modeling in the ADA described in Study Description #14 above.

16. **Study Title**: Further Evaluation of Water and Soil Use by Local Populations in the Contract of Work Area of PT Freeport Indonesia – Universitas Cenderawasih and PT Freeport Indonesia. 1999.

Affiliation of Authors:

Cenderawasih University
PT Freeport Indonesia

Study Description:

This is a sequel to the Human Use and Dietary Survey (see Study Description # 10) initially conducted by Bogor Agricultural and Cenderawasih Universities et al. to support the Tier 1 Screening-Level Risk Assessment. The follow-up survey provides additional information for highland, lowland, and estuary settlements concerning the frequency of contact or use of rivers within the COW (water and deposited tailings), lakes, and groundwater. The type of contact or use and the amount and frequency of time spent were evaluated.

17. **Study Title**: Clinical Laboratory Data from Health Survey. Prepared for PT Freeport Indonesia.

Affiliation of Authors:

AEA Laboratories (Dr. Lili Soehartono)
Bogor Agricultural University
Cenderawasih University

Study Description:

This data report contains data tables summarizing the results of analyses of blood, urine and fecal parasite levels of participants in a health and nutritional survey conducted as part of the biomarker study (see Study Description #11). These results are discussed in detail in the Health Survey Report prepared by Bogor Agricultural University and Cenderawasih University (see Study Description #18).

18. **Study Title**: Status Gizi Dan Kesehatan Masyarakat Yang Tinggal Di Proyek Penambangan PT Freeport Indonesia – Jurusan Gizi Masyarakat Dan Sumberdaya Keluarga, Institut Pertainian Bogor, Universitas Cenderawasih

    Affiliation of Authors:

    Bogor Agricultural University
    Cenderawasih University

    Study Description:

    This report contains the methods and findings of a health and nutritional survey. It was conducted in seven settlements within the COW and three reference settlements. Questionnaire findings and clinical results from blood, urine and fecal sampling are presented and discussed for each settlement.

19. **Study Title**: Exposure Characterization in Fish and Shellfish Harvesting Camps. Cenderawasih University. 2000.

    Affiliation of Authors:

    Cenderawasih University

    Study Description:

    This report documents the methods and findings of a survey conducted in temporary fishing camps in a lowland reach of the Kamora River. The survey identified and estimated the length of residence in the camps and the types and quantities of foods and liquids consumed by different age groups while residing at the camps.

20. **Study Title**: Study on Mollusk Consumption in Estuary and Mimika Coastal Area. 1999.

    Affiliation of Authors:

    Bogor Agricultural University,
    Cenderawasih University,
    Indonesia Environmental Foundation (YALI)
    Legal Aid Institute of Timika

    Study Description:

This study summarizes methods and results of a mollusk consumption survey of local populations conducted in lowland and estuary settlements. The survey collected information on the types of mollusk species consumed, typical collection locations, and opinions concerning mollusk taste and availability. It discussed the social and cultural significance of consumed species. The types of mollusks addressed in the survey include mud clams, Tambelo worm and a variety of snails. Consumption was examined for young and older children and adults.

21. **Study Title**: Memorandum on the Potential Connection Between Springs at Banti and the Grasberg Mine. HCI. 2001.

    Affiliation of Authors:

    Hydrologic Consultants, Inc.

    Study Description:

    The purpose of this report was to investigate the potential of hydraulic connections between the groundwater near Banti and mine operations..

22. **Study Title**: Sago Palm Study Data Report. 2001. Parametrix, Inc.

    Affiliation of Authors:

    Parametrix Inc. (Sago and Sago Grub Study; Sago Palm Study Data Report)
    Cenderawasih University (Sago Starch Report)

    Study Description:

    This report contains a combined evaluation of data from two separate studies. The first study, *Physical-chemical Characteristics and Metal Concentrations Sago Starch from Sago Palm Trees Growing in Natural and Tailings Habitats in Timika, Papua (Cenderawasih University)* represents the findings of metal concentrations measured in sago starch collected from locations containing tailings and a reference location. Iwaka was the reference village chosen as an area of natural sago habitat. The area near MP 18 was chosen as an area where historical tailings deposition had occurred. Sago were felled and starch extracted and analyzed for metals and other parameters at the Timika Environmental Laboratory of PTFI in Timika.

    The second study, *Sago and Sago Grub Study*, sought to supplement the data from the Cenderawasih sago starch study. This second study provides data on metal concentrations in sago starch in areas where historical tailings deposition occurred, as well as on the concentration of metals in beetle grubs inhabiting the felled sago palms. These grubs are a food used by local populations and wildlife.

23. **Study Title**: PTFI Groundwater Monitoring Program, Years 1998, 1999, 2000. 2001.

    Affiliation of Authors:

    PT Freeport Indonesia
    Parametrix, Inc.

Study Description:

This report summarizes the methods and findings from routine groundwater monitoring performed by PT Freeport Indonesia over the years 1998, 1999 and 2000. It summarizes groundwater concentrations of tailings substances sampled from a variety of monitoring wells in the lowland area and compares them with available Indonesian drinking water standards.

24. **Study Title**: PTFI Surface Water Monitoring Program, Years 1998, 1999, 2000. 2001.

Affiliation of Authors:

PT Freeport Indonesia
Parametrix, Inc.

Study Description:

This report summarizes the methods and findings from routine surface water monitoring performed by PT Freeport Indonesia for 1998, 1999 and 2000. It summarizes concentrations of tailings substances sampled from the tailings and reference rivers and a lake (Kwamki Lake) in the lowland region. The report contains a summary of these data and compares them with reference concentrations and available Indonesian surface water standards for drinking water and recreational use.

25. **Study Title**: Evaluation of Arsenic and Copper Bioaccessibility from Deposited Tailings, Suspended Sediments and Tissue Samples. Exponent Inc. and Parametrix, Inc.

Affiliation of Authors:

Exponent, Inc.
Parametrix, Inc.

Study Description:

The Parametrix team designed and conducted an *in vitro* evaluation simulating the potential gastrointestinal absorption of arsenic and copper that could occur following ingestion of tailings. Additionally, gastrointestinal absorption of copper was also simulated for ingestion of two invertebrate species: Tambelo worm (*Bactronophorus*) and mud clam (*Geloina*) harvested from the Ajkwa estuary. Samples of suspended solids and sediments from the Ajkwa River were collected from highland, lowland, and estuarine locations. Deposited and suspended tailings samples were analyzed for several other substances in addition to copper and arsenic. Results provided data on gastrointestinal absorption from the indicated pathways for copper and arsenic.

26. **Appendix Title**: Appendix B: Tier 2 Human Health Screening-Level Risk Assessment. Parametrix, Inc. 2001.

Affiliation of Authors:

Parametrix, Inc.

Study Description:

This appendix describes the exposure pathways assessed in the Tier 2 SLRA. It describes methods for accomplishing the following analyses:

1) comparison of substances with regulatory standards;
2) comparison with risk-based concentrations, the toxicity values used in developing risk-based concentrations;
3) results of the Tier 2 screening process. This screening identified the exposure pathways and tailings substances that were further evaluated in the HHRA.

27. **Appendix Title**: Appendix C: Probabilistic Risk Assessment Model Description.

Affiliation of Authors:

Parametrix, Inc.

Study Description:

This appendix contains a complete discussion of the probabilistic evaluation of exposure pathways and tailings substances that were identified following the Tier 2 Screening-Level Risk Assessment (see Study Description #27). It includes the following:

1) discussion of the model used;
2) the exposure pathway parameter distributions used to estimate risk potential;
3) potential risk results for each exposure pathway evaluated;
4) a sensitivity analysis;
5) overall discussion;
6) graphical and tabular summaries of the HHRA evaluations