EPA's Metal Finishing Facility Risk Screening Tool (MFFRST)
Part 1: Status and Update

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Introduction

EPA unveiled the Metal Finishing Facility Risk Screening Tool, MFFRST, during last January's (1999) AESF/EPA Conference for Environmental Excellence (Lorber, et al., 1999; Schwartz and Lorber, 1999). This tool was to meet the objectives laid out during a March, 1998, meeting of the Common Sense Initiative Metal Finishing Subcommittee, Joint Risk Characterization and Research and Technology workgroup:

> To develop a screening methodology that will enable characterizations of risks to workers and neighbors from emissions of single or multiple chemicals from metal finishing operations. In the future, field monitoring may be used to supplement and/or field test the methodology.

> To develop a simple computer tool that will enable anyone without assistance to perform a screening characterization of the risks to workers and neighbors at metal finishing facilities.

One of our papers at last year's conference provided an overview of the concepts and approaches in MFFRST (Lorber, et al., 1999) and a second described the approach taken to characterize and model emissions both within individual metal finishing facilities and out of the stack into the ambient environment (Schwartz and Lorber, 1999). As well, a "shell" of MFFRST was available for display during the exhibition hours. This shell displayed a series of screens allowing users to set up a model run. The insides of the model were not completed, but one could see from last year's shell the intent of the model and the required input data.

We displayed a working version of MFFRST at last June's (1999) SURF/FIN® conference in Cincinnati. It was displayed during exhibition hours and interested individuals signed up to receive copies of MFFRST. As well, targeted individuals associated with industry, state and federal government agencies, and consultants were

asked to provide peer review comment on the tool and the accompanying documentation.

This paper reports on the results of the peer review, changes to MFFRST as a result of that review, and lays out plans to finalize MFFRST for final EPA publication and release. As well, this paper presents the full set of health risk benchmarks that are used in MFFRST (i.e., air concentrations used by regulatory Agencies to evaluate potential health impacts of exposure to contaminants in ambient and workplace environments) and an example of the application of MFFRST to hexavalent chromium.

Peer Review

A total of 62 copies of the MFFRST software plus accompanying documentation and review instructions were distributed, and 14 reviews were received.   From this total received, 4 were from EPA, 5 were from other government agencies (Department of the Army, Texas Natural Resources Council), 2 were from industry, and 3 were from consultants to industry. This was an informal review, and as such, any effort expended by individuals was on their own initiative and was helpful to EPA in finalizing this tool and document. The companion paper to this one reviews comments associated with the description of the metal finishing industry, and definition of the generic plating lines. Some of the more common and important comments on the tool in general include:

1) *General:* Most reviewers found the tool easy to use and potentially very useful. Except for one EPA reviewer, however, it was unclear whether any of the reviewers had specific uses for inhalation risk

assessments, despite being provided the following as a specific question in their review guidance package, "Who is likely to use the tool and for what purposes?"

2) *Software Ease of Use:* Many reviewers commented on the need for a "navigation" tool which could allow users to jump to different parts of MFFRST easily. A navigation bar has been added. One individual commented that, for the generic plating line, it would be preferable if users could easily deselect a default tank in a plating line. An initial default plating line screen has been added for just that purpose - the user can deselect any of the selected tanks in a plating line. Some users commented on the need for "help" screens, to provide definitions for terms used in the model and explanations for algorithms and approaches in general, which were not available for the Beta test release version - they are now part of MFFRST.

3) *Presentation of Results:* Some reviewers requested that more information be presented for the results, such as a tabular summary of the set of parameter inputs, discussions on interpretations, uncertainty, and variability of results, some way to highlight results which would be of interest to the user, such as when regulatory health benchmark concentrations are exceeded, and so on. Some improvements have been made to the results screen, and help screens will also prove useful. However, some comments on the results presentation were not acted upon. The tool will not highlight results of concern to the user, but the user should be able to use the tabular summaries to identify for him/herself which results are of interest. Being a screening tool, and also being a tool for general use and not for any specific regulatory office or Agency, we decided not to provide any biases or risk

assessment interpretations in the presentation of results. The help screens and the accompanying documentation are expected to provide the necessary discussions for using the tool and interpreting the results.

4) *Software bugs:* Some reviewers reported that, when arrowing backwards and forwards, changes made to parameters would not be retained. Specific parameter editing problems noted by reviewers, as well as others determined during our own testing, have been identified and rectified.

5) *Documentation:* Comments here were mainly on the need for documentation on loading and using the model. A user's guide will be an appendix to the completed documentation on MFFRST.

Health Risk Benchmarks

Our paper at last year's AESF/EPA conference (Lorber, et al., 1999) discussed the approach used to assess cancer and non-cancer risk. As described in Lorber, et al. (1999), estimation of cancer risk requires information on exposure including: air concentrations, duration of exposure, inhalation rate, body weight, and the chemical-specific unit risk value. EPA's principal approach to non-cancer inhalation risk assessment is to compare an appropriate air concentration to a "Reference Concentration", or RfC. Other benchmark concentration for residential exposures include the ATSDR Minimum Risk Levels (MRLs) and the EPA Risk-Based Concentrations (RBCs). For worker exposures, MFFRST compares the predicted workplace air concentrations to the OSHA Permissible Exposure Levels (PELs), the NIOSH Recommended Exposure Limits

(RELs), and the ACGIH Threshold Limit Values (TLVs). Table 1 displays the unit risk values for cancer risk, and all these other air concentration-based health benchmarks that are provided in MFFRST.

MFFRST also has the capability for a user to define his/her own unique concentration-based benchmark for resident and/or worker exposures. This feature may be useful if a user prefers to use a benchmark developed by a state regulatory agency, or has another air concentration level with which he/she wishes to compare with an air concentration predicted by MFFRST.

Following now are brief definitions and units for these benchmarks:

1) Unit Risk: the cancer potency factor associated with a lifetime of exposure. When the actual exposure is less than a lifetime, the concentration associated with the duration of exposure is averaged over a lifetime, $1/(mg/m^3)$, or an appropriate air concentration. Unit risk values can be obtained from EPA's Integrated Risk Information System (IRIS) (http://www.epa.gov/iris).

2) RfC: This benchmark has been developed for chronic and sub-chronic non-cancer effects. EPA considers the chronic RfC to be an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily inhalation exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime. EPA traditionally evaluates the potential for non-cancer effects for a particular exposure, as characterized by an air concentration, by dividing the air concentration by the RfC. The resulting

ratio is termed, the "Hazard Quotient", or HQ. MFFRST separately calculates the HQ for any chemical for which an RfC is available. For all other concentration-based benchmarks, MFFRST simply lists the concentration and the benchmark on a results table. RfCs can be obtained from IRIS.

RBC: These were developed by the Superfund Technical Support Section in EPA Region 3. RBCs are chemical concentrations corresponding to fixed levels of risk (i.e., a HQ of 1, or lifetime cancer risk of 1E-6, whichever occurs at a lower concentration) in water, ambient air, fish tissue, and soil. Only the RBCs for ambient air are utilized in MFFRST. The ambient air RBCs were derived by combining standard exposure scenarios with RfCs and Unit Risk values. RBCs can be obtained from EPA Region 3 at, http://www.epa.gov/reg3hwmd/risk/riskmenu.htm.

4) MRL: The Agency for Toxic Substances and Disease Registry (ATSDR) derives chemical-specific MRLs using a procedure similar to that used by EPA to derive RfCs. An MRL is an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. The MRLs used in MFFRST are "chronic" MRLs (i.e., for exposure durations of 365 days and longer). MRLs are based on noncancer health effects only and do not consider cancer effects. MRLs can be obtained from ATSDR at, http://www.atsdr.cdc.gov/mrls.html.

5) PELs: Permissible Exposure Limits (PELs) are regulatory standards promulgated by the Occupational Safety and Health Administration (OSHA) to control worker exposure to hazardous substances (including both cancer and noncancer causing substances). MFFRST uses the 8-hour time weighted average (TWA) PELs. In general, PELs are established assuming that workers are a relatively healthy cohort of the population and are only exposed to the substance during the working portion of their adult lives. PELs are issued as part of the OSHA General; General Industry Air Contaminants Standard (29 CFR 1910.1000) (see http://www.osha-slc.gov/OshStd_data/1910_1000_table_z-1.html).

6) RELs: The National Institute for Occupational Safety and Health (NIOSH) develops and periodically revises RELs for hazardous substances in the workplace. NIOSH evaluates all available medical and biological information relevant to a substance when developing a REL. The RELs used in MFFRST are TWA concentrations for up to a 10-hour workday during a 40-hour workweek. RELs can be accessed at http://www.cdc.gov/niosh/npg.

7) TLVs: The American Conference of Governmental Industrial Hygienists (ACGIH) develops TLVs as recommended air concentrations of substances to which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects (i.e., cancer and noncancer health effects). The TLVs used in MFFRST are the TWA concentrations for a conventional 8-hour workday and a 40-hour workweek. TLVs can be obtained from ACGIH (phone: 513-742-2020).

Chromium Example

   a. Predicted and observed air concentrations

   It might be fair to conclude that

hexavalent chromium is the constituent of most concern with regard to potential human health impacts for the metal finishing industry. This section will demonstrate the use of MFFRST to evaluate worker and residential exposures to this important constituent in the context of the default decorative and hard chromium metal finishing lines in MFFRST.

Before relying on any model such as MFFRST, however, it is always desirable to develop some confidence in the predictive capabilites of the model. All inhalation health risk assessments are driven by the air concentration to which individuals are exposed. It is always preferable to use appropriate measured air concentrations rather than modeled air concentrations to conduct inhalation risk assessments. MFFRST does allow users to directly input an air concentration for this purpose. Lacking an appropriate air concentration, however, one needs to be predicted. That is a principal function of MFFRST - to predict both indoor and ambient air concentrations of metal finishing facility constituents in order to assess inhalation exposures and potential health impacts to workers and nearby residents. The models used for this purpose were summarized in the earlier MFFRST paper (Lorber, et al., 1999), and in the documentation accompanying MFFRST.

We were unable to find data that was directly amenable to "model validation". Such data would include a comprehensive description of the industrial process such that we could duplicate it within the confines of the MFFRST. Specifically, we would need the configuration and description of all the chromium finishing tanks within the shop, the geometry of the workplace including the ventilation rate, pollution control technologies in place, and information on the location and conditions of air sampling. Lacking such detail, we were unable to set up MFFRST to duplicate a specific setting. That is what is required to do a rigorous "model validation". However, we were able to locate literature articles listing chromium air concentrations.

These articles provided us with air concentration data which we used to make a preliminary "ground truth" validation of the predictive capabilities of MFFRST. If the model were predicting concentrations that were orders of magnitude either higher or lower than measured, than we would have reason to be concerned that there is something fundamentally wrong with the model - either that the coding was incorrect or that the procedures for predicting air concentrations were incorrect. Predicted concentration within the range of observed concentrations would give us some confidence in the reasonableness of the predictive capabilities of MFFRST.

We were able to find several reports of air concentrations of chromium within chromium electroplating and other types of electroplating facilities. However, none of these reports were for facilities in the United States; they were in Italy (Gianello, 1998) and Taiwan (Kuo, et al, 1997; Lin, et al., 1994; Liu, et al., 1998). One issue for evaluation of these air studies was the form of chromium measured. Two studies were clear in that "total chromium" was being measured, not hexavalent chromium (Gianello, et al., 1998; Lin, et al., 1994). In fact, one of them (Gianello, et al., 1998) stated that the exposure risk was overestimated because total chromium, and not hexavalent chromium, was measured. On the other hand, two of the reports (Liu, et al, 1998; Kuo, et al, 1997), both conducted by the same group of scientists, clearly

reported hexavalent chromium air concentrations. These "hexavalent" chromium air concentrations reported by Liu, et al. (1998) and Kuo, et al. (199) were comparable to the air concentrations reported as "total" chromium by Gianello, et al. (1998) and Lin, et al. (1994).

The best evidence for the relationship between hexavalent and total chromium comes from a CARB study measuring both outdoors in the vicinity (< 1 km) of a chromium finishing facility (Grohse, et al. 1988). They found different relationships depending on whether the measurement was downwind within the plume or outside the plume. Downwind at 0.3 km, the ratios of hexavalent to total chromium for four measurements were 0.27, 0.35, 0.93, and 1.00. The two highest hexavalen chromium measurements at 110 and 316 ng/m^3 were also the ones with ratios above 0.90. In other measurements not downwind, the hexavalent to total chromium ratios ranged from <0.1 to 0.67 with a mean of 0.25 (n=10). This might suggest, for the tested facility at least, that emissions of chromium are initially Cr (+6), which then dissipates and/or transforms to other forms of Cr.

Others have investigated the relationship between total and hexavalent chromium. Falerios, et al. (1992) investigated the difference in concentrations between total and hexavalent chromium in indoor and outdoor environments associated contaminated soil chromite ore processing sites. With over 100 indoor and 100 outdoor air concentration samples at over 21 such sites, they generally found that hexavalent chromium was from below 10% to over 60% of total chromium (these were averages from each of the 21 sites). The overall average (for all 21 sites) for indoor and outdoor

environments was 21 and 25%, respectively. Paustenbach (1992) measured ambient outdoor and indoor total and hexavalent chromium, using different analytical methods, and showed that total chromium was, on average, 5 times higher than hexavalent chromium. The statewide toxic database of ambient air monitoring results developed and maintained by the California Air Resources Board (Redgrave, 1999) suggests that the ratio of Cr (+6) to total Cr is much lower than 20% in ambient environments not near industrial air sources. From that database, Cr (+6) outdoor concentrations ranged from 0.11 to 0.27 ng/m^3, while total Cr measurements ranged from 3.9 to 5.1 ng/m^3, suggesting a ratio less than 5%. Since none of these studies were in plating facilities, their results cannot be extrapolated for current purposes. In ambient environments, however, it would appear that hexavalent chromium is 20% or less of total chromium.

Table 2 shows a comparison of the measured air concentrations of chromium within metal finishing facilities and in ambient environments near sources and in background settings, and the MFFRST predicted workplace and ambient concentrations for the decorative and hard chromium default plating lines.

Two major trends in workplace environments apparent from these studies are:

1) Much higher concentrations are found near chromium electoplating tanks as compared to other locations in chromium electroplating facilities: Two of the studies evaluated this question specifically and found differences of about a factor of 10. Chromium concentrations near tanks ranged as high as 230 µg/m^3, with averages in two

studies of 89 and 63 $\mu g/m^3$. Concentrations within the workplace but not near tanks were in the low single digit to sub $\mu g/m^3$. Concentrations in administrative office space was in the sub $\mu g/m^3$ range.

2) *Much higher chromium concentrations are found in dedicated chromium electroplating facilities as compared to other facilities such as nickel chrome or aluminum electroplating facilities.* Three of the four studies also looked at chromium concentrations within a zinc electroplating factory, an aluminum anode-oxidation plant, an aluminum electroplating facility, and a nickel-chromium facility. Chromium concentrations in these facilities mostly averaged less than 1 $\mu g/m^3$.

Table 2 also displays the concentrations of chromium predicted for the hard chrome and decorative chrome generic lines. As seen there, the predicted air concentrations for the "process worker" and "non-process" worker were 3.6 and 0.7 $\mu g/m^3$ for the hard chromium generic plating line, and 1.0 and 0.5 $\mu g/m^3$ for the decorative line, respectively. The principal difference between the two types of workers was that the "process worker" was assumed to be exposed a small percentage of the time to the very high concentrations of the small release of fugitive emissions from the baths into the workplace, while most of the time they would be exposed to average air concentrations within the workplace (which were calculated from fugitive emissions using a simple box model approach). This fraction of time was preset to 0.05 (5% of the time). The second critical model parameter was the fraction of total emissions that were assumed to be released into the open environment. The default value for this parameter was 0.01 (1%). The

concentrations of hexavalent chromium in these fugitive emissions above the electroplating bath for the hard chrome generic line was 5400 $\mu g/m^3$ and was 1800 $\mu g/m^3$ for the decorative chrome line.

At least as a preliminary validation, it would appear from Table 2 that MFFRST is predicting hexavalent chromium air concentrations that are within the realm of observations in the working environment (assuming the four articles found are a reasonable representation of US workplace hexavalent chromium concentrations; see earlier paragraph). Also, MFFRST does have the framework to be able to capture differences in concentrations to which process and non-process workers are exposed. If anything, some of the data suggests that air concentrations to which workers who typically work near tanks are higher than might be predicted by MFFRST.

The data most amenable to model validation of impacts to residences near facilities comes from Grohse, et al. (1988). They measured hexavalent and total chromium at four locations within 1 km of an operating chromium plating facility. For the immediate downwind direction at 300 meters, they found measurements of 0.026, 0.033, 0.110, and 0.316 $\mu g/m^3$. This compares to the MFFRST prediction of 0.026 $\mu g/m^3$ for the hard chrome plating line, which drops to 0.019 $\mu g/m^3$ at 300 meters. Further downwind at about 800 meters, the found measurements of 0.004, 0.008, ND (<0.0005), and 0.014 $\mu g/m^3$. MFFRST predicts 0.005 $\mu g/m^3$ at 800 meters.

SCREEN3 is actually designed to predict 1-hr maximum downwind concentrations. For its application in MFFRST, the 1-hr maximum predictions are

multipled by a "conversion factor" of 0.08 which converts 1-hr maximum concentrations to annual average concentrations. Therefore, the prediction of 0.026 $\mu g/m^3$ actually translates to a maximum 1-hr prediction of 0.325 $\mu g/m^3$, which possibly not ironically looks like the high measured concentration of 0.316 $\mu g/m^3$ (although this measurement was over about a 6 hour period, so it is not exactly a 1-hr maximum).

Of course, these data are not optimal for model validation, mainly because there is no information on the release rate of Cr (+6) from this actual facility.

Data on hexavalent chromium in ambient background environments suggest concentrations near 0.010 $\mu g/m^3$, much less than these impacted air samples at 0.100 $\mu g/m^3$ and higher. Falerios, et al. (1992) and Paustenbach, et al. (1991) present extensive data (and other analysis) of total and hexavalent chromium in ambient air associated with chromite-ore processing soil contamination sites in New Jersey. Most of their data is near the contaminated soil sites, both indoor and outdoor, but they did take indoor samples at 15 residences that represented background conditions. As seen by the summary of their data on Table 2, essentially all the data suggests airborne concentrations of Cr (+6) to be less than 0.010 $\mu g/m^3$ (<10 ng/m^3).

Ambient air monitoring in California conducted by the California Air Resources Board (Redgrave, 1999) in areas not near industrial air sources shows Cr (+6) to be very low. An average of monthly means during a year, from years 1992 to 1998, showed Cr (+6) concentrations to range from 0.00011 to 0.00027 $\mu g/m^3$.

For true validation of the air concentration prediction algorithms of MFFRST, more complete site-specific data for one or more actual facilities, most importantly measurements of both fugitive indoor emissions and emissions out of the stack, are needed.

b. Health Impact Assessment

Table 3 summarizes exposure assumptions for the adult resident, process worker, and non-process worker, and then presents a summary of the key health risk assessment results for these individuals for the generic hard chrome plating line. These results are typical of those one can obtain from MFFRST.

Of note is the fact that there are no qualitative judgements or observations made with results provided by MFFRST. Some observations that can be made from this table, however, include:

1) The exposure scenarios are typical of what EPA would term "high end", or possibly even "worst case". There are no preset scenarios, per se, in EPA; the general intent is to capture the upper 10 percent (90-100th) percentile of individuals in an actual population assumed to be exposed. Assumptions such as 30 years of exposure, 250 days at the workplace per year, and so on, are often part of scenarios that EPA uses in regulatory decision making.

2) The "percent of time near processing tanks" is critical for calculation of the air concentration to which the two kinds of workers are exposed. As seen here, an assumption of 5% time near processing tanks resulted in concentrations that were 5 times higher than the average air concentration modeled to be in workplace.

A default assignment of 5% to the process worker was made on the basis of expert judgement, and not on any data. Like all parameters, a user can change this assumption in MFFRST.

3) The modeled cancer risk for the adult resident is just below 10^{-4}, and for the two types of workers is in the 10^{-4} to 10^{-3} risk. Typically, modeled cancer risk estimates in this range have often been used as a partial basis for decisions on health hazards posed by chemical exposures (Alavanja, et al., 1990; Paustenbach, 1990; Travis, et al, 1987). The long durations of exposure for both the worker and resident have something to do with this - also the proximity of the resident (100 meters in a downwind direction) leads to relatively high predicted air concentrations.

4) An air concentrations of 3.55 μg/m^3 for the process worker exceeds the NIOSH REL of 1.0 μg/m^3. The ambient air concentrations at the residence of 0.026 μg/m^3 exceeds both the RfC (0.008) and RBCs (0.00015) for ambient exposures. As a screening tool, MFFRST will identify such exceedances and then the user needs to decide what steps are necessary, ranging from a refinement of models and/or modeling assumptions to a regulatory response.

Next Steps

As of the drafting of this manuscript, the code of MFFRST is substantially complete and the document is being completed. Document chapters include: 1) Introduction, 2) Identification of Major Contaminants and Generation of Source Release Estimates, 3) Modeling the Fate of Contaminants From Source to Receptor, 4) Development of Exposure Scenarios and Risk Estimation, 5) Demonstration of Methodology, 6) Monitoring for Key Contaminants, and 7) Uncertainties and Other Special Topics. There will be an Appendix providing a User's Guide to MFFRST.

Prior to finalization of MFFRST and release as an EPA document, a second and final targeted round of Peer Review will occur. Specific individuals will be sought for this round, and they will be provided specific issues to address in their field of expertise. These may be individuals who have already provided comment or individuals uniquely sought for this second round. Once their comments are addressed, EPA will seek to publish MFFRST as a formal, final document with accompanying software. Both these products will also be posted on appropriate web sites for download and distribution. This activity is expected to occur during the year 2000, with finalization and distribution before next year's AESF/EPA Conference for Environmental Excellence.

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Table 1. Toxicity data and benchmark concentrations for the metal finishing chemicals in MFFRST

Constituents	CAS Number	Inhalation Chronic RfC (mg/m^3)	Ref	Inhalation Unit Risk (mg/m^3)$^{-1}$	Ref	ATSDR Chronic MRLs (see footnote c) (mg/m^3)	Region 3 Air RBCs (see footnote g) (mg/m^3)	ACGIH 8-hr TWA TLV (see footnote h) (mg/m^3)	NIOSH 8-hr TWA REL (see footnote j) (mg/m^3)	OSHA 8-hr TWA PEL (see footnote k) (mg/m^3)
1,1-Dichloro-1-fluoroethane	1717006									
1,1,1 Trichloroethane (TCA)	71556	2.2e+00	e				1.0e+00	1900	1900	1900
2-Ethoxyethanol	110805	2e-01	a				2.1e-01	18	1.8	740
2-Methoxyethanol	109864	2e-02	a					16	0.3	80
Ammonia	7664417	1e-01	a			2.1e-01	1.0e-01	18	18	35
Arsenic	7440382			4.3e+00	a		4.1e-07	0.01		0.01
Boric Acid	10043353									
Cadmium	7440439	2e-04	e	1.8e+00	a		9.9e-07	0.01		0.005
Chlorine	7782505	2e-04	e				3.7e-01	1.45	1.45	3
Chloroform	67663			2.3e-02	a	1e-01	7.7e-05	50		240
Chromic Acid	7738945							0.05	0.001	
Chromium	7440473	8e-06	d	1.2e+01	d			0.05	0.5	1
Chromium (Cr+3)	16065831							0.5	0.5	0.5
Chromium (Cr+6)	18540299	8e-06	a	1.2e+01	a		1.5e-07	0.05	0.001	
Copper	7440508							1	1	1
Cyanide	57125	7e-02	i				7.3e-02			
Ethylbenzene	100414	1e+00	a				1.1e+00	435	435	435
Ethylene glycol	107211	7e+00	i				7.3e+00			
Ferric chloride	7705080									
Fluoboric acid	16872110									
Formaldehye	50000			1.3e-02	a	3.7e-03	1.4e-04		0.02	0.92
Formic acid	64186	7e+00	i				7.3e+00	9	9	9
Gold	7440575									
Hydrochloric Acid	7647010	2e-02	a				2.1e-02		7	7
Hydrofluoric Acid	7664393								2.5	2.5
Isopropyl alcohol	67630							980	980	980
Lead	7439921							0.05	0.1	0.05
Manganese	7439965	5e-05	a			4e-05	5.2e-05	0.2	1	5
Mercury	7439976	3e-04	a			2e-04	3.1e-04	0.025	0.05	0.1
Methanol	67561	2e+00	i				1.8e+00	260	260	260

Table 1. (con't)

Methyl Ethyl Ketone (MEK)	78933	1e+00	a				1.0e+00	590	590	590
Methyl Isobutyl Ketone	108101	8e-02	b				7.3e-02	205	205	410
Methylene Chloride	75092	3e+00	b	4.7e-04		1e+00	3.8e-03	174		87
n-Butyl alcohol	71363	4e-01	i				3.7e-01		150	300
Nickel	7440020					2e-04		0.1	0.015	1
Nitric Acid	7697372							5	5	5
N-Methyl-2-pyrrolidone	872504									
N,N-Dimethylformamide	68122	3e-02	a					30	30	30
Perchloroethylene (PCE)	127184	4e-02	i			3e-01	3.1e-03	170		678
Phosphoric Acid	7664382	1e-02	a				1.1e-02	1	1	1
Selenium	7782492							0.2	0.2	0.2
Silver	7440224							0.01	0.01	0.01
Sodium Hydroxide	1310732									2
Sodium Hypophosphite	7681530									
Sodium Metasilicate	6834920									
Sodium Phosphate	7558807									
Sulfuric Acid	7664939							1	1	1
Toluene	108883	4e-01	a			1.5e+00	4.2e-01	188	375	750
Trichloroethylene (TCE)	79016						1.0e-03	269	134	537
Xylene (mixed isomers)	1330207	7e+00	i			4.4e-01	7.3e+00	435	435	435
Zinc	7440666									

Notes:

a - IRIS (EPA, 1999)   b - HEAST (EPA, 1997)   c - ATSDR (1999)
d - As a conservative assumption, toxicity data for hexavalent chromium are used for releases reported as "chromium."
e - Peer-reviewed provisional value of EPA/ORD Superfund Technical Support Center (STSC).
f - Non-peer-reviewed provisional value of EPA/ORD/STSC.
g - Region 3 RBCs (U.S. EPA, 1998c) are presented only for chemicals with EPA RFCs or Unit Risk Values.
h - ACGIH (1998)
i - RfCs extrapolated from oral RfDs by multiplying the RfD by 70 kg and then dividing the result by 20 m^3 air/day. For these constituents, it was assumed that there were no portal-of-entry effects and route-specific solubilities. These assumptions were recommended by EPA/ORD/STSC.
j - NIOSH (1999)
k - OSHA (1999)
* - Carcinogenic Weight of Evidence Group for Chromium VI is A for inhalation and D for oral.

Table 2. Table of observed and predicted chromium air concentrations.

Concentration (range; mean), $\mu g/m^3$	Reference, Description	
I. Observed Literature Concentrations of Total and Hexavalent Air Concentrations		
0.02-1.5; 0.43	Gianello, et al. 1998. Total chromium measurements; aircraft construction factory in Italy, 4 hr samples from 16 workers using personal samplers.	
0.7-168.3; 89.7	CE near electroplating tanks; n = 23	San-Chi Lin, et al. 1994. Sampling in a chromium electroplating facility (CE), three different locations, compared with an aluminum electroplating (AE) facility in Taiwan; 4-6 hr samples of total chromium; did not say whether this was Cr (+6); means are geometric means
0.5-39.7; 11.2	CE other process locations, n = 25	
0.3-4.4;1.5	CE office and outdoors, n = 14	
0.04-0.2; 0.1	AE, n = 15	
0.4-182.6; 4.20	HCPP	Liu, C., et al. 1998. Sampling in hard chrome plating plants (HCPP), nickel chrome electroplating plants (NCEP), and aluminum anode-oxidation plants (AAOP) in Taiwan, using personal air samplers at 1.0-1.4 m, for 4 hours randomly selected during work week; measurements as "air chromium" assumed to be total chromium
0.3-2.3; 0.58	NCEP	
0.1-2.2; 0.43	AAOP	
0.5, 6.0 0.3	Cr; area; NT; n=2 Cr ; area; OP; n=1	Kuo, et al., 1997. Sampling in chromium (Cr), nickel-chromium (Cr-Ni), and zinc (Zn) electroplating factories in Taiwan. Samplers included area and personal samplers. Two personal sampling events tested 81 and 37 mm filters (latter noted as w/37 mm). Areas sampled include, near tank (NT), other processes (OT), and administrative office (AO). Sampling time was 6 hours; air concentration of chromium claimed to hexavalent chromium.
0.6 0.2	Cr-Ni; area; NT; n=1 Cr-Ni ; area; OP; n=1	
0.2-230.0; 63.2 0.1-0.6; 0.3 0.1, 0.4	Cr; personal; NT; n=12 Cr; personal; OP; n=6 Cr; personal; AO; n=2	
0.2, 0.7 0.6-0.9, 0.7 0.7	Cr-Ni; personal; NT; n=2 Cr-Ni; personal; OP; n=4 Cr-Ni; personal; AO; n=1	
ND ND ND	Zn; personal; NT; n=2 Zn; personal; OP; n=1 Zn; personal; AO; n=1	
0.1-40.0; 8.0 0.1-4.0; 1.9	Cr; personal w/37 mm; NT; n=6 Cr; personal w/37 mm; OP; n=4	

Table 2 (cont'd).

0.3-5.0; 2.8 0.7-4.0; 1.9	Cr-Ni; personal w/37 mm; NT; n=3 Cr-Ni; personal w/37 mm; OP; n=3	
ND ND	Zn ; personal w/37 mm; NT; n=3 Zn ; personal w/37 mm; OP; n=1	
0.026-0.316; 0.121 ND - 0.014; 0.006 ND - 0.010; 0.004 ND - 0.014; 0.005 0.0019-0.0027; 0.0024	Cr (+6); downwind 0.3 km; n=4 Cr (+6); downwind 0.8 km; n=4 Cr (+6); east of source; n=3 Cr (+6); north of source, n=3 Cr (+6); upwind of source, n=4	Grohse, et al. (1988). Field test measuring Cr (+6) and total chromium in vicinity of operating chromium metal finishing facility.
0.004-0.130; 0.013 0.0006-0.027; 0.0025	Total Cr; above soil; n=24 Cr (+6); above soil; n=22 Means are geometric means	Paustenbach, et al. (1991). Sampling conducted above contaminated soil chromate ore processing residue site in New Jersey.
0.003 0.023 <0.002 0.005 0.001 0.007	Cr (+6), indoor, cont. sites, n=106 Tot Cr, indoor, cont. sites, n=103 Cr (+6), outdoor, cont. sites, n=119 Tot Cr, outdoor, cont. sites, n=88 Cr (+6), indoor, backgrnd site, n=43 Tot Cr, indoor, backgrnd site, n=49 All results are normal means	Falerios, et al. (1992). Sampling conducted in 21 sites in Hudson County, NJ, at chromate ore processing residue sites. Sampling conducted indoors and outdoors at the contaminated sites, and also including indoor at 15 residences as background
0.00011-0.00027 0.0039 - 0.0051	Cr (+6); ambient bckgrnd, 1992-98 Tot Cr, ambient bckgrnd, 1992-98	Redgrave, (1999). Range of annual average of monthly means from 1992 to 1998 in the CARB toxic data base of ambient air concentrations
II. Predicted MFFRST Results		
3.6	Process Worker	Hard Chrome Generic Line, all defaults
0.7	Non-Process Worker	
0.026	Outdoor Residence 100 meters away	
1.0	Process Worker	Decorative Chrome Generic Line, all defaults
0.5	Non-Process Worker	
0.017	Outdoor Residence 100 meters away	

Table 3. Summary of exposure assumptions for the adult resident and workers, and summary of hexavalent chromium health risk assessment quantities generated by MFFRST for the decorative and hard chromium plating lines.

I. Exposure Assumptions					
Process worker	8-hour workdays, 250 days/yr, 30 yrs, 5% of time near processing tanks				
Non-Process worker	8-hour workdays, 250 days/yr, 30 yrs, 0% of time near processing tanks				
Adult resident	16-hours/day at home; 350 days/yr, 30 yrs, 100 meters from facility				
II. Cancer and Non-cancer Risk					
Individual	Cancer Risk	Individual	Conc., $\mu g/m^3$	RFC	HQ
Process worker	$2.1 * 10^{-3}$	Process Worker	3.55	0.008	443.8
Non-Process worker	$5.5 * 10^{-4}$	Non-Process Worker	0.70	0.008	88.1
Adult resident	$8.6 * 10^{-5}$	Adult Resident	0.0260	0.008	3.27
III. Comparison of predicted air concentrations, $\mu g/m^3$ with concentration-based health risk benchmarks, $\mu g/m^3$					
Individual	Conc, $\mu g/m^3$	RfC	RBC	MRL	
Resident	0.026	0.008	0.00015	NA	
Individual	Conc, $\mu g/m^3$	PEL	REL	TLV	
Process worker	3.55	NA	1	50	
Non-process worker	0.70	NA	1	50	