

INDUSTRIAL HYGIENE PROGRAMME
FOR MONITORING
OCCUPATIONAL EXPOSURE TO ARSENIC

I. BACKGROUND: The Con Mine Case

Ore was roasted at the Con Mine in Yellowknife, Northwest Territories during the early years of operation (1938 - 1970). Arsenic trioxide dust formed in the baghouse of the roaster and accumulated into many tons of hazardous waste, over the thirty years of the roasting process. An arsenic reclamation plant was built as a means of extracting and removing arsenic from the mine site.

The Arsenic Reclamation Plant leached arsenic from the waste sludge, and marketed a refined arsenic trioxide product. Employees of the operation were exposed to particulates contaminated with arsenic. A comprehensive industrial hygiene programme was developed, of which urine monitoring was an essential element.

II. URINE MONITORING PROGRAMME FOR ARSENIC

Urine is the predominant route of elimination for occupationally-derived arsenic. A urine monitoring programme was established at the Con Mine, whereby employees supplied urine samples immediately prior to starting work in the Arsenic Plant, as well as at the end of the final working shift. Urine samples were also collected from employees before and after an activity presenting higher risks of exposure.

The urine sample at the start of the employment period was important in establishing a baseline arsenic level for the employee. Elevation in an employee's baseline, detected through comparison of urine arsenic levels at the end of equal and consecutive periods of absence from the exposure source, suggested "body burden" (Figure 1,2). Body burden was interpreted as the employee's declining ability to return to his pre-exposure urine arsenic level after each consecutive period of exposure to arsenic. Target levels were set, so that significant changes in the employee's urine arsenic baseline would trigger the removal of an employee from the exposure environment until his urine arsenic level returned to original pre-exposure levels.

Peak exposure limits were also set. Urine arsenic levels obtained during an exposure period were interpreted differently from those arsenic levels after a non-exposure period. Elevated urine arsenic levels obtained during an employment period were interpreted with a view for improving employee work habits, Plant engineering and ventilation, and all other aspects of the hygiene management programme.

Figure 1

ELIMINATION PATTERN FOR OCCUPATIONALLY EXPOSED WORKER

SUBJECT 4

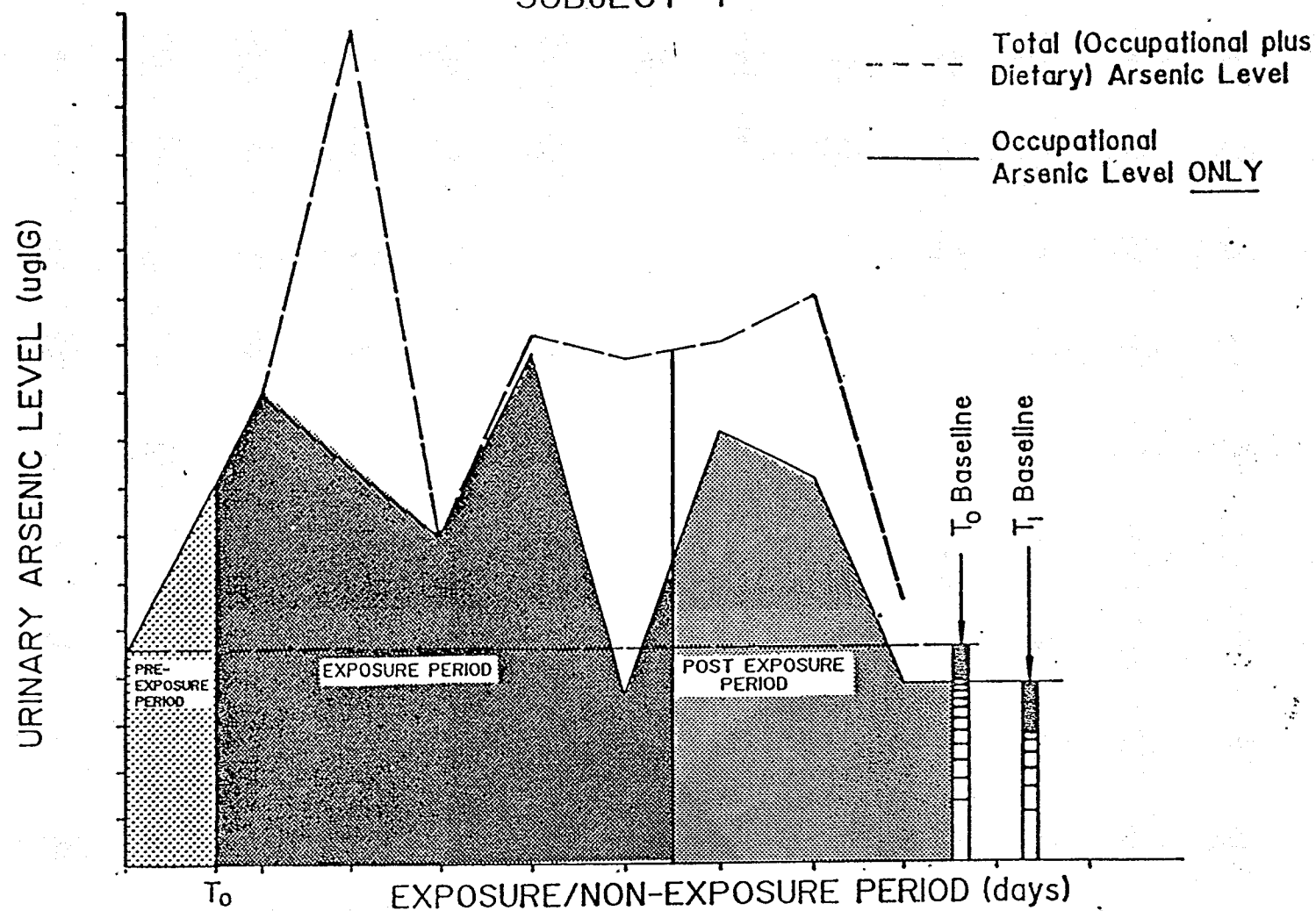
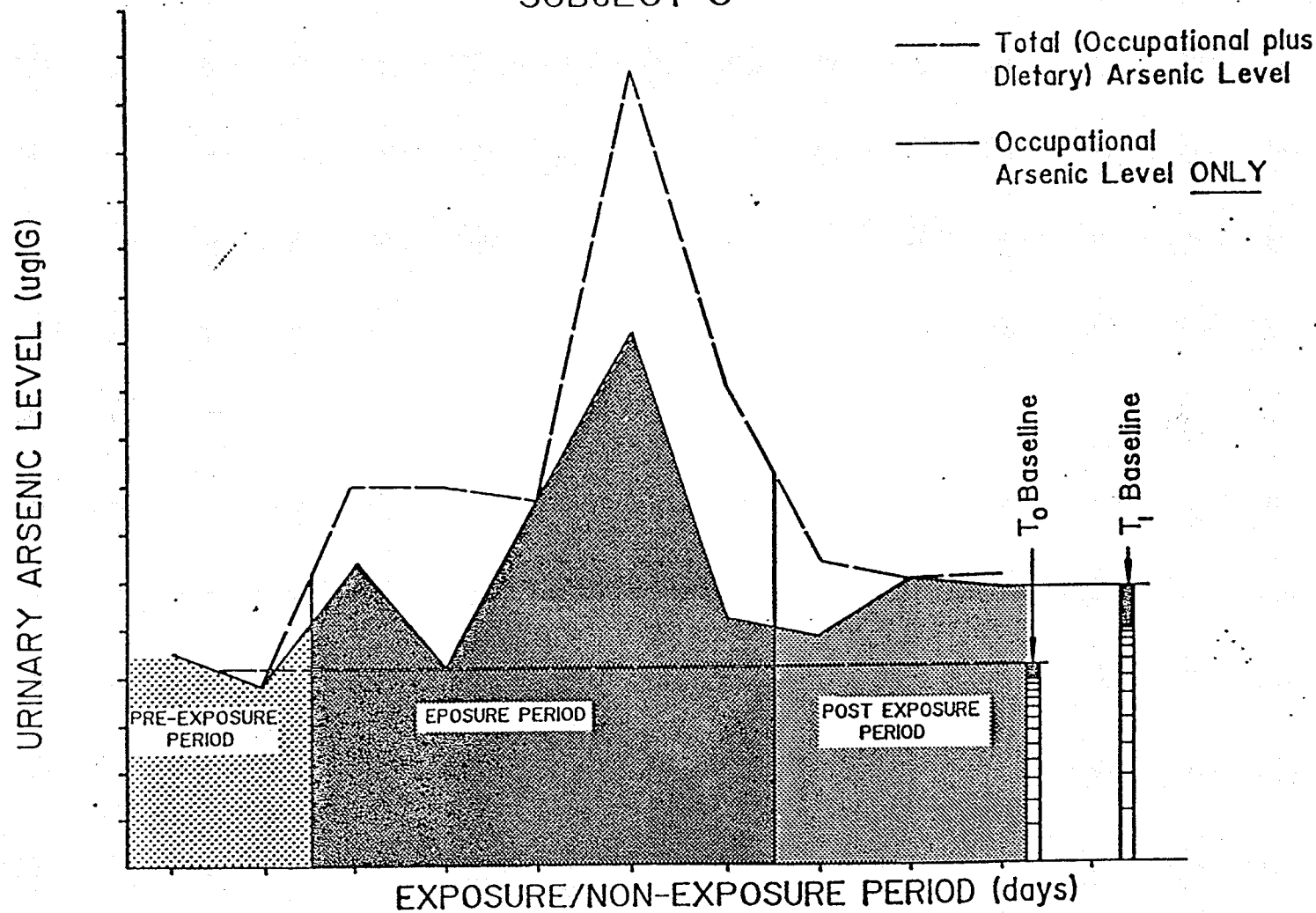


Figure 2

ELIMINATION PATTERN FOR OCCUPATIONALLY EXPOSED WORKER

SUBJECT 5



The programme guidelines were established by a committee including medical professionals, and Mining Inspection officials. The "target limits", established through this committee, were set as a means for triggering steps for the removal of further risk to the employee.

III. SOURCE OF ARSENIC IN THE URINE

There are many dietary sources of arsenic, all of which contribute to urine arsenic levels. Seafood (shellfish) is a significant contributor to urinary arsenic output. "Seafood arsenic" is metabolized differently and is chemically distinguishable in the urine, from occupationally derived arsenic.

IV. URINARY ARSENIC FRACTIONATION

Effective management of the urine monitoring program identified the need for urinary arsenic "speciation". The ability to differentiate occupational (or inorganic) arsenic from other sources, primarily seafood, was developed within the Environmental Services Laboratory.

Fractionation of the urinary arsenic clearly identified in the peak exposures whether the major contributions were dietary or occupational. As well, shifts in the employees baseline arsenic level could be clarified as health concerns or dietary arsenic consumption.

Fractionation of arsenic species provided a means for measuring the difference in "rates of elimination" of arsenic depending on the source: dietary or occupational. (Figure 3)

V. URINE OUTPUT AND KIDNEY FUNCTION (in the calculation of urinary arsenic output)

The collection of all urine from each employee is the most accurate method for measuring urinary arsenic output. This is not practical or convenient in most cases. Accurate methods for estimating the total daily output of urine from a single "grab sample" must be incorporated into any urinary monitoring programme.

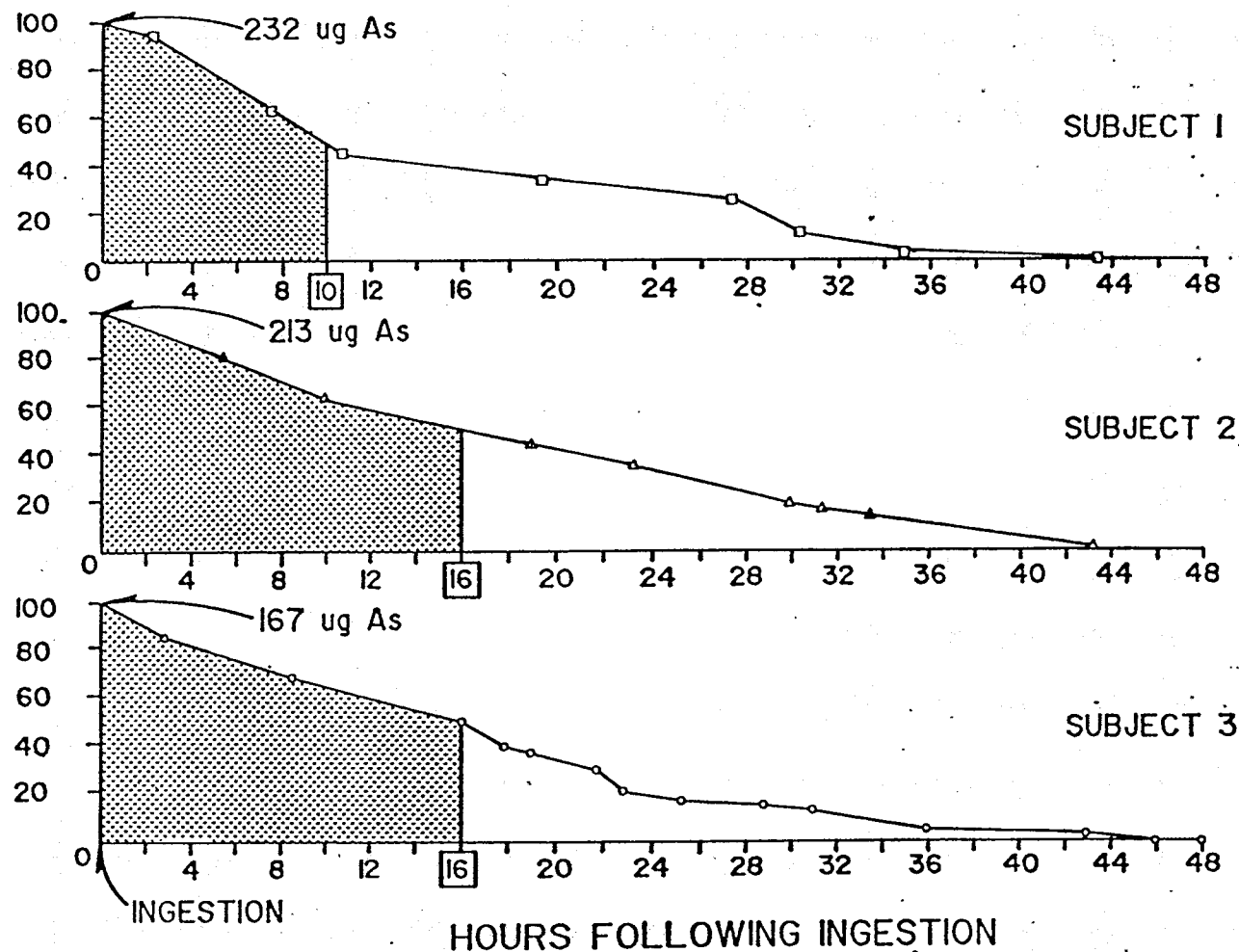
1) Specific Gravity Measurement

One method of correcting for kidney retention or representative urine volume is the measurement of specific gravity.

Figure 3

ARSENIC ELIMINATION AFTER SEAFOOD CONSUMPTION
DIETARY (SEAFOOD) ARSENIC
ELIMINATION PATTERNS
IN URINE

URINARY FRACTION OF TOTAL ARSENIC (INGESTED)
(%)



1) Specific Gravity Measurement (con't)

In very simple terms, a urine sample with a high specific gravity represents a small volume of urine, high in dissolved solids as a result of a longer retention time within the kidneys. A low specific gravity would then represent a large output of urine and a short kidney retention time. However, specific gravity is no longer considered to be the most reliable indicator of urine throughput, by many medical and industrial hygiene professionals.

2) Creatinine Output

Creatinine is a metabolite excreted from the kidneys in a reliable relationship with urinary throughput. A low creatinine value represents a small volume of urine with a long kidney retention time. Alternatively a high creatinine value represents a large volume of urine with a short retention period in the body. Fundamentally similar to the specific gravity means of estimating urine output, creatinine is preferred because of its stable elimination patterns between and amongst individuals.

The Con Mine has adopted the creatinine method for estimating urine output. Arsenic levels are reported in terms of creatinine output. Arsenic levels in a sample very low in creatinine (less than 0.5 grams creatinine/Liter), while potentially significant due to a large representation of urine, may be difficult to detect analytically. These samples are generally fractionated in order to best secure reliable arsenic exposure levels. "Normal" urinary output is between 1 to 3 liters per day, and "normal" creatinine output is between 1 and 2 grams per day. Great diversity is observed however, especially with large variation in daily liquid consumption.

VI. ANALYTICAL PROCEDURES

For the Determination of:

- (1) Total Urinary Arsenic (ug/L)
- (2) Occupational Arsenic ONLY (ug/L)
- (3) Creatinine (g/L)
- (4) Quality Control

Analytical procedures have been developed at the Con Mine in order to most effectively and accurately determine employee exposure to arsenic. Although many of these methods are technologically unique, extensive and comprehensive quality control provides the employees and management of the Mine with a high degree of confidence. This technology was recently presented at the PITTSBURGH CONFERENCE in Atlanta, Georgia (appendixed)

The methods currently employed at our analytical facility are listed.

(1) Total Urinary Arsenic Determination

(i) Direct: Total urinary arsenic levels are achieved directly through the use of "Zeeman" atomic absorption. The detection limit for this "direct" method is 30 ug/L.

(ii) Total Digest: A means of confirming the "direct" method has been developed. This involves a rigorous oxidative digestion followed by solvent extraction. As well as a means of confirmation, this method provides improved precision and accuracy, and detection limits over the "direct" method.

(2) Occupational (Inorganic) Arsenic Only

Partial Digest: The "hydrolyzable" arsenic fraction, representing occupational exposure, is differentiated from the "total" arsenic pool through an acid hydrolysis, reduction, solvent extraction and a concentrating step.

The dietary fraction, including arsenobetaine, is separated and removed at the extraction step.

The final concentrate is analyzed by Zeeman Flame AAS which results in a detection limit of 15 ug/L.

The arsenic values that are obtained from the Zeeman Flame AAS are reported as micrograms of arsenic per liter of urine (ug/L).

(3) Creatinine

Creatinine is analyzed on a Beckman Analyzer 2. The instrument is calibrated with commercially marketed creatinine standards. Creatinine is determined in grams per liter of urine.

(4) Quality Control

Extensive quality control and interlaboratory comparison for both "total" and "occupational" arsenic determinations have provided a high level of confidence for the Arsenic Plant employees, in our analytical performance and management.

Our quality control program includes both internal and external laboratory standardization. We participate in the Round Robin comparison program through the Toxicological Center at Laval University.

VII. SUMMARY

The urine monitoring programme has been successful in supplying employees with greater confidence and the Mine management useful tools for improving the working environment. Fractionation of urine arsenic has allowed more effective management of the programme in general, and has introduced methods for identifying individual elimination patterns. Health concerns such as peak exposure and body burden, through the establishment of target limits, have been systematically and effectively managed.