

**ASSESSMENT OF GEOTECHNICAL REUSE POTENTIAL AND
SUSTAINABLE MANAGEMENT OF LEGACY WASTE: A COMPREHENSIVE
STUDY FROM TWO INDIAN DUMPSITES**

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INDIAN INSTITUTE OF TECHNOLOGY DELHI**

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by

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Department of Civil Engineering

Submitted

in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the



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NOVEMBER 2024

DEDICATED TO
MY BELOVED FATHER
Mr. Abhaya Kumar Parida

CERTIFICATE

This is to certify that the thesis entitled “ASSESSMENT OF GEOTECHNICAL REUSE POTENTIAL AND SUSTAINABLE MANAGEMENT OF LEGACY WASTE: A COMPREHENSIVE STUDY FROM TWO INDIAN DUMPSITES” being submitted by Mr. Debaprakash Parida to the Indian Institute of Technology Delhi is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard fulfilling the requirements of DOCTOR OF PHILOSOPHY degree. The research report and results presented in this thesis have not been submitted, in part or full, to any University or Institute for the award of any degree or diploma.

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JAY JAGANNATH

ABSTRACT

Open dumps pose significant environmental and health risks due to uncontrolled solid waste disposal. Enhanced landfill mining (ELFM) repurposes old dumps, recovering materials and energy while mitigating environmental impacts. This study explores the geotechnical reuse potential of segregated legacy waste (SLW) from two major municipal solid waste (MSW) dumps in Delhi, India. The samples aged 10 – 20 years of MLW, -30 mm (entire trommeled fraction, ETF), 30 to 6 mm (coarse fraction, CF) and -6 mm (fine fraction, FF) generated during landfill mining (LFM) operation at the site were obtained. The present study has meticulously designed the following experimental program to assess the reuse potential of SLW:

- a) Physico-chemical characteristics such as physical composition, moisture content (M.C), organic content (O.C), mineralogical composition and chemical constituents.
- b) Geoenvironmental characteristics to identify the contaminants of concern (CoC) such as pH, electrical conductivity (EC), release of colored leachate, dissolved solids and heavy metals.
- c) Geotechnical characteristics such as grain size distribution (GSD), specific gravity, consistency limits, unit weight, compaction characteristics and permeability.
- d) The impact of heavy metal contamination on human health has also been assessed.

Additionally, for assessing a sustainable management practice of legacy waste, life cycle sustainability assessment (LCSA) has been carried out by suggesting four alternative scenarios of legacy waste management. The suitability of SLW for disposal in engineered landfills (ELF) has also been reviewed against the threshold limits prescribed in regulatory guidelines.

The 10-20 years old mixed legacy waste (MLW) is a heterogeneous mix of many components, which makes it challenging to segregate and repurpose as individual usable materials. The analysis of MLW revealed that the SLM (-20 mm fraction) constitutes more than 60% in MLW, that indicates the potential of legacy waste for bulk reuse as the replacement of natural soil. The SLW fraction has elevated M.C up to 30% that aligns with the observations from the previous studies. The high M.C of SLW results adherence of FF on the surface of the CF resulting inefficient removal of FF during trommeling of freshly excavated legacy waste (ELW) without sufficient drying and pre-processing. The O.C up to 12% in the SLW was found to be significantly higher than the local soil (background level). High O.C limits the use of SLW in earthwork applications without any control measures. While high O.C is generally not deemed a contaminant, its impact on the structural stability and serviceability of construction projects cannot be overlooked. The mineralogical composition revealed the major components of SLW as quartz, calcite and feldspar which can be evident from the results of chemical constituents where major components being Si, Ca, Fe and Al. Substantial presence of inorganic constituents was observed by x-ray fluorescence (XRF) analysis of SLW.

The concentration of total heavy metals determined by acid digestion revealed a significant contamination potential when compared to the background levels. The results of toxicity characteristics leaching procedure (TCLP) concluded that the SLW fractions do not pose hazardous to the environment and thus, can be disposed of in non-hazardous landfills with appropriate treatment and design measures. The effect of particle size and liquid to solid (L/S) ratio was studied by single-stage batch leaching (SBL) and up-flow column leaching (UCL) tests. A significant effect of particle size and L/S ratio was observed from the study. It revealed that the FF holds higher contaminant concentration compared to the CF and ETF across all categories of contaminants. Moreover, the UCL

test revealed gradual reduction in contaminant concentration in the water extracts of SLW over a range of L/S ratio from 0.1 L/kg to 10.0 L/kg. Release of colored leachate, a less studied parameter in the literature, was studied in both SBL and UCL tests. High color intensity was observed to be leached from FF in SBL test apparently disappeared at a L/S ratio of 10.0 L/kg in UCL test.

The contamination indices determined based on the concentration of total available heavy metals in SLW and background levels revealed that the heavy metals do not present any threat to the environment and human health. However, indiscriminate dumping of SLW in open areas can affect the human health and coloration of water sources.

The field study conducted to minimize the contaminant concentration by repeated trommeling (RT) of CF revealed a proportionate reduction in both the M.C and O.C with the reduction in FF from the CF. A progressive decline in overall FF removal efficiency was observed with the advancement of RT phases during field repeated trommeling (FRT) process. In first RT, 15-16.7% of FF removal was observed which reduced to 3.3-3.8% at the third RT during the FRT process. The leaching parameters such as dissolved solids, EC, color intensity, trace metals were notably influenced by both the L/S ratio and FRT process.

The geotechnical characteristics of ETF was evaluated, and the results were benchmarked against the properties of local soil. The test of compaction characteristics yielded an optimum moisture content (OMC) of 12.5-15% and maximum dry density (MDD) of 16-18 kN/m³. The permeability of ETF was observed to be in the range of 1.3×10^{-7} to 3.2×10^{-7} m/s aligns with the local soil (5.7×10^{-7} m/s). The analysis suggests the potential suitability of SLW for replacing local soil in various field applications. This

assessment highlights the importance of sustainable waste management practices in reducing the reliance on natural soil resources.

The comparative assessment of characteristics of SLW revealed that the parameters such as O.C, color intensity, total available heavy metals (except As), dissolved solids are multi-fold beyond the background levels and highly elevated for unrestricted use as soil. The leachable trace metals do not constrain the unrestricted and open reuse of SLW. However, this parameter should not be studied in isolation and appropriate design measure should be considered to constrain the mobility of concerned contaminants.

The LCSA of legacy waste management revealed that the current scenario of indiscriminate dumping of SLW in unregulated areas pose severe environmental and public health risks. In addressing the cumulative toxicity impacts, the prospective scenario involving the implementation of an engineered cover system (ECS) to both existing and future filling of ETF emerged as the most favourable option among the three scenarios. While the prospective scenario involving complete containment of the fill area may appear resource intensive and time consuming, it can serve as prudent engineering decision, particularly in locations where the groundwater table is shallow, adjacent to the base of the deep pits and dead mines.

सारांश

खुले कूड़ेदान (डंपसाइट) अनियंत्रित ठोस अपशिष्ट निपटान के कारण महत्वपूर्ण पर्यावरणीय और स्वास्थ्य जोखिम पैदा करते हैं। एनहांसड लैंडफिल माइनिंग (एलएफएम) पुराने डंपसाइट्स को पुनःप्रयोजित करता है, जिससे सामग्री और ऊर्जा की पुनःप्राप्ति होती है और पर्यावरणीय प्रभावों को कम किया जाता है। यह अध्ययन दिल्ली, भारत के दो प्रमुख नगर निगम सॉलिड वेस्ट (एमएसडब्ल्यू) डंपसाइट्स से प्राप्त सेग्रीगेटेड लिगेसी वेस्ट (असअलडब्ल्यू) के जियोटेक्निकल पुनःप्रयोग क्षमता का अन्वेषण करता है। इन नमूनों की उम्र 10 से 20 वर्ष है और ये लैंडफिल माइनिंग संचालन के दौरान साइट पर उत्पन्न किए गए थे, जिनमें -30 मिमी (पूरा ट्रॉमल्ड अंश, इटीएफ़), 30 से 6 मिमी (मोटा अंश, सीएफ़) और -6 मिमी (सूक्ष्म अंश, एफ़एफ़) शामिल हैं। वर्तमान अध्ययन ने सावधानीपूर्वक निम्नलिखित प्रयोगात्मक कार्यक्रम को डिजाइन किया है ताकि असअलडब्ल्यू के पुनःप्रयोग क्षमता का मूल्यांकन किया जा सके:

- a) भौतिक-रासायनिक विशेषताएँ जैसे की भौतिक संरचना, नमी सामग्री (एमसी), जैविक सामग्री (औसी), खनिज संरचना और रासायनिक घटकों का विश्लेषण किया जाएगा।
- b) जीओएनवायरमेंटल विशेषताएँ का अध्ययन कंटामिनांतस (सीओसी) की पहचान करने के लिए, जैसे की pH, विद्युत चालकता (इसी), रंगीन लीचेट का उत्सर्जन, घुले हुए ठोस और भारी धातुएं।
- c) जियोटेक्निकल **विशेषताएँ** जैसे की कण आकार वितरण (जीअसडी), विशिष्ट गुरुत्व, सुसंगतता सीमाएं, इकाई वजन, संपीड़न विशेषताएं और पारगम्यता।
- d) **भारी धातु संदूषण का मानव स्वास्थ्य पर प्रभाव** भी आकलित किया जाएगा।

इसके अतिरिक्त, पुराने कचरे के स्थायी प्रबंधन अभ्यास का आकलन करने के लिए, लाइफ साइकिल असेसमेंट (एलसीए) किया गया है जिसमें पुराने कचरे के प्रबंधन के चार वैकल्पिक

परिदृश्य जांचे गए हैं। इंजीनियर्ड लैंडफिल (इएलएँफ़) में असअलडब्ल्यू के निपटान की उपयुक्तता को भी नियामक दिशानिर्देशों में निर्दिष्ट सीमा मूल्यों के खिलाफ समीक्षा की गई है।

10-20 वर्षों पुराना एमएलडब्ल्यू कई घटकों का विषम मिश्रण है, जिससे इसे अलग करना और व्यक्तिगत उपयोगी सामग्रियों के रूप में पुनः उपयोग करना चुनौतीपूर्ण हो जाता है। एमएलडब्ल्यू के विश्लेषण से पता चला कि असअलएम (-20 मिमी अंश) एमएलडब्ल्यू में 60% से अधिक होता है, जो प्राकृतिक मिट्टी के प्रतिस्थापन के रूप में पुराने कचरे के थोक पुनः उपयोग की संभावना को इंगित करता है। असअलडब्ल्यू अंश में 30% तक उच्च नमी सामग्री (ऍमसी) होती है जो पिछले अध्ययनों से प्राप्त अवलोकनों के साथ मेल खाती है। असअलडब्ल्यू की उच्च नमी सामग्री का परिणाम यह होता है कि सीएँफ़ की सतह पर ऍफ़ऍफ़ चिपक जाता है, जिससे पर्याप्त सुखाने और पूर्व-प्रसंस्करण के बिना ताजे खुदाई किए गए पुराने कचरे (ईअलडब्ल्यू) की ट्रॉमलिंग के दौरान ऍफ़ऍफ़ को कुशलतापूर्वक हटाना मुश्किल हो जाता है। असअलडब्ल्यू में 12% तक का औसी स्थानीय मिट्टी (पृष्ठभूमि स्तर) की तुलना में काफी अधिक पाया गया। उच्च औसी बिना किसी नियंत्रण उपायों के असअलडब्ल्यू का भू-कार्य अनुप्रयोगों में उपयोग सीमित करता है। हालांकि उच्च औसी को आमतौर पर प्रदूषक नहीं माना जाता है, इसका निर्माण परियोजनाओं की संरचनात्मक स्थिरता और सेवा योग्यता पर प्रभाव को नजरअंदाज नहीं किया जा सकता। खनिज संरचना से पता चला कि असअलडब्ल्यू के प्रमुख घटक कार्बज, कैल्साइट और फेल्डस्पार हैं, जो रासायनिक घटकों के परिणामों से स्पष्ट हो सकते हैं, जहां प्रमुख घटक Si, Ca, Fe और Al पाए गए। असअलडब्ल्यू के अंश में अकार्बनिक घटकों की पर्याप्त उपस्थिति अक्स-रे फ्लोरेसेंस (अक्सआरऍफ़) विश्लेषण द्वारा देखी गई।

एसिड डाइजेशन द्वारा निर्धारित कुल भारी धातुओं की सांद्रता ने पृष्ठभूमि स्तरों की तुलना में महत्वपूर्ण प्रदूषण क्षमता का खुलासा किया। विषाक्तता विशेषताओं लीचिंग प्रक्रिया (टीसीएलपी)

के परिणामों ने निष्कर्ष निकाला कि असअलडब्ल्यू अंश पर्यावरण के लिए खतरनाक नहीं हैं और इस प्रकार, उपयुक्त उपचार और डिज़ाइन उपायों के साथ गैर-खतरनाक लैंडफिल में निपटान किया जा सकता है। एसबीएल और यूसीएल परीक्षणों द्वारा कण आकार और तरल से ठोस (एल/एस) अनुपात का प्रभाव अध्ययन किया गया। अध्ययन से कण आकार और एल/एस अनुपात का महत्वपूर्ण प्रभाव देखा गया। इसने यह खुलासा किया कि सभी प्रदूषक श्रेणियों में एफएफ में सीएफ और ईटीएफ की तुलना में अधिक प्रदूषक सांद्रता होती है। इसके अलावा, यूसीएल परीक्षण ने 0.1 एल/किग्रा से 10.0 एल/किग्रा की एल/एस अनुपात सीमा में एसएलडब्ल्यू के पानी के अर्क में प्रदूषक सांद्रता में क्रमिक कमी का खुलासा किया। रंगीन लीचेट का रिलीज, जो साहित्य में कम अध्ययन किया गया पैरामीटर है, का अध्ययन एसबीएल और यूसीएल दोनों परीक्षणों में किया गया। एसबीएल परीक्षण में एफएफ से उच्च रंग तीव्रता का लीच होना देखा गया, जो यूसीएल परीक्षण में 10.0 एल/किग्रा के एल/एस अनुपात पर स्पष्ट रूप से गायब हो गई।

असअलडब्ल्यू में कुल उपलब्ध भारी धातुओं की सांद्रता और पृष्ठभूमि स्तरों के आधार पर निर्धारित प्रदूषण सूचकांकों से पता चला कि भारी धातुएं पर्यावरण और मानव स्वास्थ्य के लिए कोई खतरा पैदा नहीं करती हैं। हालांकि, एसएलडब्ल्यू का खुले क्षेत्रों में अनियंत्रित डंपिंग मानव स्वास्थ्य को प्रभावित कर सकती है और जल स्रोतों के रंग को बदल सकती है।

क्षेत्रीय अध्ययन में यह पाया गया कि सीएफ के बार-बार ट्रोमेलिंग (आरटी) के माध्यम से संदूषक सांद्रता को कम करने से एमसी और औसी में अनुपातिक कमी आई, साथ ही सीएफ से एफएफ की मात्रा में भी कमी आई। फील्ड रिपीटेड ट्रोमेलिंग (एफआरटी) प्रक्रिया के दौरान आरटी चरणों की प्रगति के साथ कुल एफएफ हटाने की दक्षता में क्रमिक गिरावट देखी गई। पहले आरटी में 15-16.7% एफएफ हटाने का अवलोकन किया गया, जो तीसरे आरटी में घटकर 3.3-3.8% रह

गया। लीचिंग मापदंडों जैसे घुले ठोस पदार्थ, इसी, रंग तीव्रता, ट्रेस मेटल्स पर एल/एस अनुपात और ऍफ़आरटी प्रक्रिया का उल्लेखनीय प्रभाव पड़ा।

इटीऍफ़ की जियोटेक्निकल विशेषताओं का मूल्यांकन किया गया, और परिणामों की तुलना स्थानीय मिट्टी की गुणधर्मों से की गई। संकुचन विशेषताओं के परीक्षण में 12.5-15% का आदर्श आर्द्रता सामग्री (ओऍमसी) और 16-18 kN/m³ का अधिकतम शुष्क घनत्व (ऍमडीडी) प्राप्त हुआ। इटीऍफ़ की पारगम्यता 1.3×10^{-7} से 3.2×10^{-7} मी/सेक के बीच पाई गई, जो स्थानीय मिट्टी (5.7×10^{-7} मी/सेक) के समान है। विश्लेषण से पता चलता है कि असअलडब्ल्यू को विभिन्न क्षेत्रीय अनुप्रयोगों में स्थानीय मिट्टी के स्थान पर उपयोग करने की संभाव्यता है। यह मूल्यांकन प्राकृतिक मिट्टी संसाधनों पर निर्भरता को कम करने में सतत अपशिष्ट प्रबंधन प्रथाओं के महत्व को रेखांकित करता है।

असअलडब्ल्यू की विशेषताओं का तुलनात्मक मूल्यांकन ने यह प्रकट किया कि पैरामीटर्स जैसे औसी, रंगता, कुल उपलब्ध भारी धातु (अर्थात As को छोड़कर), विलीन ठोस, पृथक्करणीय ट्रेस धातु मूल स्तर से अनुमान से अधिक गुना उच्च हैं और असीमित उपयोग के रूप में मिट्टी के रूप में उपयोग के लिए उचित नहीं हैं। लीचेबल ट्रेस धातुओं को असीमित और खुले रूप में असअलडब्ल्यू के पुनः उपयोग को निर्बंधित नहीं करना चाहिए। हालांकि, इस पैरामीटर को अलग अध्ययन में नहीं देखना चाहिए और चिंतित कंटेमिनेंट्स की चलनीयता को नियंत्रित करने के लिए उपयुक्त डिज़ाइन उपायों को विचार में लेना चाहिए।

लीगेसी वेस्ट प्रबंधन की एलसीए ने यह दर्शाया कि वर्तमान स्थिति में असअलडब्ल्यू को बिना विनियमित क्षेत्रों में अनियंत्रित ढालना वातावरण और सार्वजनिक स्वास्थ्य पर गंभीर जोखिम पैदा करता है। समुल्य विषाणुता प्रभावों का सामना करते हुए, इटीऍफ़ की मौजूदा और भविष्य में भराई गई जगहों पर इंजीनियर्ड कवर प्रणाली (इटीअस) के लागू होने वाले संभावित स्थिति तीन

स्थितियों में सबसे अधिक पसंदीदा विकल्प साबित हुआ। हालांकि, भराई गई क्षेत्र का पूर्ण संयमन वाला संभावित स्थिति संसाधन उपयोग और समय खपती प्रतीत हो सकता है, यह विशेष इंजीनियरिंग निर्णय के रूप में कारगर साबित हो सकता है, विशेष रूप से उन स्थानों में जहां भूजल स्तर गहरा है, गहरे गड्ढों और मृत खानों के आधे के पास।

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LIST OF ABBREVIATIONS

LF	Landfill
LFM	Landfill Mining
ELFM	Enhanced Landfill Mining
WtM	Waste to Material
WtE	Waste to Energy
MSW	Municipal Solid Waste
SLW	Segregated Legacy Waste
ELF	Engineered Landfill
ELW	Excavated Legacy Waste
ETF	Entire Trommeled Fraction
CF	Coarse Fraction
FF	Fine Fraction
CoC	Contaminants of Concern
LLA	Low Lying Areas
RH	Research Hypotheses
ULW	Unsegregated Legacy Waste
LCSA	Life Cycle Sustainability Assessment
MLW	Mixed Legacy Waste
GSD	Grain Size Distribution
SBL	Single-Stage Batch Leaching
UCL	Up-Flow Column Leaching
SLM	Soil-Like Material
C&D	Construction and Demolition
NGT	National Green Tribunal
SBM-U	Swachh Bharat Mission-Urban
LWM	Legacy Waste Management
RDF	Refuse Derived Fuel
MT	Metric Tonne
LMT	Lakh Metric Tonne

XRF	X-Ray Fluorescence
XRD	X-Ray Diffraction
EDX	Energy Dispersive X-ray Spectroscopy
M.C	Moisture Content
O.C	Organic Content
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
EC	Electrical conductivity
WAC	Waste Acceptance Criteria
LF	Landfill
NHW	Non-Hazardous Waste
HW	Hazardous Waste
PLI	Pollution Load Index
DoC	Degree of Contamination
EF	Enrichment Factor
LCR	Lifetime Cancer Risk
NCR	Non-Carcinogenic Risks
ADI	Average Daily Intake
E _{Fr}	Exposure Frequency
ED	Exposure Duration
BW	Body Weight
AT	Average Time
C _{nF}	Conversion Factor
SA	Surface Area
ABS	Skin Absorption Factor
PEF	Particle Emission Factor
AF	Soil Adhesion Factor
HQ	Hazard Quotient
R _{fD}	Reference Dose
HI	Hazard Index

SF	Slope Factor
AM	Adult Male
AF	Adult Female
CH	Children
CR	Carcinogenic Risk
LCA	Life Cycle Assessment
ISO	International Organization for Standardization
FU	Functional Unit
LCI	Life Cycle Inventory
DS	Dumpsite
NCT	National Capital Territory
IS	Indian Standard
LOI	Loss on Ignition
DI	Deionized
TDS	Total Dissolved Solids
PCU	Platinum Cobalt Units
LR	Leaching Ratio
TCLP	Toxicity Characteristic Leaching Procedure
EU	European Union
FRT	Field Repeated Trommeling
TR	Trommeling
RT	Repeated Trommeling
MOHUA	Ministry of Housing And Urban Affairs
CPCB	Central Pollution Control Board
ECS	Engineered Cover System
IMD	Meteorological Department of India
GW	Global warming
SOD	Stratospheric ozone depletion
IR	Ionizing radiation
OFH	Ozone formation, Human health

FPM	Fine particulate matter formation
OFT	Ozone formation, Terrestrial ecosystems
TA	Terrestrial acidification
Feu	Freshwater eutrophication
MEu	Marine eutrophication
TE	Terrestrial ecotoxicity
FE	Freshwater ecotoxicity
ME	Marine ecotoxicity
HCT	Human carcinogenic toxicity
HnCT	Human non-carcinogenic toxicity
LU	Land use
MRS	Mineral resource scarcity
FRS	Fossil resource scarcity
WC	Water consumption

LIST OF SYMBOLS AND NOTATIONS

Pb	Lead
Cd	Cadmium
Cr	Chromium
Zn	Zinc
Al	Aluminium
Fe	Iron
K	Potassium
Mg	Magnesium
Cu	Copper
SiO ₂	Silicon Dioxide/Quartz
CaCO ₃	Calcium Carbonate/Calcite
NaAlSi ₃ O ₈	Albite
CaMg(CO ₃) ₂	Calcium Magnesium Carbonate/Dolomite
Al ₂ Si ₂ O ₅ (OH) ₄	Kaolinite
FeCO ₃	Ferrous Carbonate/Siderite
CaSO ₄ ·2H ₂ O	Calcium Sulphate Dihydrate/Gypsum
Al ₂ O ₃	Aluminium Oxide
Fe ₂ O ₃	Iron Oxide
Cr ₂ O ₃	Chromium Oxide
MnO	Manganese Oxide
TiO ₂	Titanium Dioxide
V ₂ O ₅	Vanadium Oxide
P ₂ O ₅	Phosphorus Pentoxide
CaO	Calcium Oxide
MgO	Magnesium Oxide
K ₂ O	Potassium Oxide
Na ₂ O	Sodium Oxide
SO ₃	Sulfur Trioxide
ZrO ₂	Zirconium Dioxide

NiO	Nickel Oxide
CuO	Copper/Cupric Oxide
ZnO	Zinc Oxide
Rb ₂ O	Rubidium Oxide
SrO	Strontium Oxide
BaO	Barium Oxide
As	Arsenic
Ni	Nickel
Gs	Specific Gravity
kd	Distribution Coefficient
C ₀	Initial Concentration of Leachate at L/S of 0.1 L/kg
C _f	Contamination Factor
I _{geo}	Geo-accumulation Index
C _i	Concentration of Metal 'i'
C _{bi}	Concentration of Metal 'i' in Background Soil
Mn	Manganese
Sc	Scandium
Ti	Titanium
C _{ref}	Concentration of the Reference Element
ADI _{ing}	Average Daily Intake Through Ingestion
ADI _{inh}	Average Daily Intake Through Inhalation
ADI _{der}	Average Daily Intake Through Dermal Absorption
R _{ing}	Rate of Intake Through Ingestion
R _{inh}	Rate of Intake Through Inhalation
C _s	Concentration of Heavy Metal in ETF
RfD	Reference Dose
SF _{ing}	Slope Factor for Ingestion
SF _{inh}	Slope Factor for Inhalation
SF _{der}	Slope Factor For Dermal Absorption
Hg	Mercury

HNO_3	Nitric Acid
HCl	Hydrochloric Acid
Na	Sodium
Ca	Calcium
2θ	Diffraction Angle
Si	Silicon
Cl	Chlorine
$(\text{L/S})_{\text{field}}$	Anticipated Site Specific L/S Ratio
inf	Rate of Infiltration
t_{year}	Time Period in Year
ρ	Density of Fill
H_{fill}	Thickness of Fill

