Cairo Air Improvement Project

Lead Pollution Abatement Component

Preliminary Assessment: Awadallah Secondary Lead Smelter in Shoubra El Kheima

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LEAD ABATEMENT PROGRAM

PRELIMINARY ASSESSMENT:
Awadallah Secondary Lead Smelter at
Shoubra El Kheima

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USAID-Cairo Air Improvement Project
Lead Abatement Program

PRELIMINARY ASSESSMENT FACT SHEET:
AWADALLAH SECONDARY LEAD SMELTER AT SHOUBRA EL KHEIMA

JANUARY 29, 2002

Through the Egyptian Environmental Affairs Agency (EEAA), the Government of Egypt has developed a comprehensive plan for lead abatement in Cairo. The EEAA Lead Exposure Abatement Plan (LEAP) addresses all sources, exposure pathways, and remedial actions associated with lead pollution in the Greater Cairo Area. As part of this plan, secondary lead smelters located in densely populated areas have come under increased scrutiny. As a result, the Egyptian government has developed the Lead Smelter Action Plan (LSAP) to reduce the impact of lead smelters on the environment.

Under LSAP, the Cairo Air Improvement Project (CAIP) is currently working with the Awadallah family's company, a major lead producer in Cairo, to consolidate its operations and move them to a new, modern plant site located at the Abu Zaabal industrial park. CAIP is also helping develop a long-term solution to remediate the Shoubra El Kheima smelter site to further reduce environmental and human health risks.

APPROACH

In developing a remediation program for the Awadallah secondary lead smelter at Shoubra El Kheima, a preliminary assessment was carried out to determine:

- Existing environmental site conditions
- Environmental and human health hazards at the site
- Remaining contaminant pathways to the environment
- Potential remedial technologies and associated costs
- Need for further evaluation to select a cost-effective method for remediating the site according to specific standards

THE SMELTER

The Awadallah secondary smelter at Shoubra El Kheima began operations in 1979 and ceased smelting in August 2001. The main raw material for the plant was used batteries. Approximately 20,000 tonnes of batteries were recycled per year, producing 11,000 tonnes of lead ingots.

The smelter covers an area of approximately 1,550 m^2, with a total volume of building material of about 553 m^3. When the smelting process stopped, the plant was only used to refine and manufacture lead products. Few environmental controls were in place to prevent dust and molten lead from coating the smelter's floors and walls.

Extrusion Room

THE ENVIRONMENTAL SETTING

The site is located within the flood plain of the Nile River. The topography of the area is almost flat, with an average altitude of 17 m above mean sea level. The climate at the site is arid, with rainfall at about 25 mm/year. Wind direction is primarily from the north.

The smelter lies within a mixed industrial and residential area. It is located approximately 40 m north of a soccer field, and about 30 m east of a housing block. Underlying the smelter, there are two hydrogeologic units, an upper silt and clay layer, and a major alluvial aquifer used for industrial water supply. The water table is between 5 to 6 m below the ground surface. Two hundred meters to the south of the site is the Ismailia Canal, a source of recharge to the aquifer.

Data Collection

CAIP and IWACO Egypt conducted a field investigation of the smelter site to identify potential hazards to human health and the environment. Using quality assurance/ quality control (QA/QC) protocols, the investigation focused on the following:

- Preliminary estimate of the size and volume of building material and equipment that may need to be removed or remediated
- Extent to which dust and soils have been contaminated due to activities at the site
- Extent to which groundwater or surface water has been contaminated
- Existence of other sources of contamination that may have contributed to water and air pollution

Hazard Assessment

The Awadallah smelter in Shoubra El Kheima poses a multitude of health and safety hazards to workers, nearby residents, and the environment. Exposure to toxic elements such as lead, cadmium, arsenic, antimony, and selenium can have a profound effect on long-term human health. Children and young adults playing near or within smelter grounds can be exposed to lead by inhaling or ingesting high levels of contaminated fugitive dust. Fugitive dust from the smelter can be blown and deposited on agricultural products, the Ismailia Canal, and the Amiriya water treatment plant located about 300 m downwind. Workers and children playing within site boundaries also face a number of safety hazards.

Of the contaminants found at the site, lead is of most concern. Lead exposure affects many organ systems, including cardiovascular, renal, and hepatic. The most sensitive is the central nervous system, particularly in children. Lead also damages kidneys and the immune system. Unborn children can be exposed to lead through their mothers. Harmful effects include premature births, smaller babies, decreased mental ability in the infant, learning difficulties, and reduced growth in young children.

Lead and other metals were found at high levels in dust, soil, and water samples taken at the site. Lead concentration in dust samples from the site's floor was up to 33 percent. Soil samples showed up to 2.4 percent lead in the upper 0.5 m and above-ground levels to below the water table. Lead in groundwater below the site (>0.5 mg/l) exceeds Egyptian and international drinking water standards.

Pathways to the Environment

There are three potential pathways by which contaminants such as lead can reach potential receptors:

1. Air, through the dispersion of fugitive dust
2. Water, through stormwater runoff, fugitive dust depositing on waterway, and migration of leacheate to groundwater
3. Direct contact with contaminated dust and soil

A preliminary evaluation of each pathway was conducted as part of this assessment.

Findings

1. Lead, cadmium, antimony, selenium, and arsenic from former smelting operations have contaminated dust, soil, and surfaces at the site.
2. Through atmospheric dispersion and direct contact, air is the principal pathway to the environment for these contaminants.
3. Contaminated dust, soil, and waste within the smelter site pose a significant health and safety threat to workers, nearby residents, and the environment.
4. Surface water and groundwater pose little risk as pathways for contaminants because: (a) they are used for industrial purposes, and (b) the Ismailia Canal and groundwater is already severely contaminated.

Based on these findings, the site's remediation plan should include the following actions at a minimum:

- Remove contaminated dust from the site's floors, walls, and ceiling
- Clean salvageable material and remove it from the site, including the corregated steel roof of the building, stack, and machinery
- Remove all contaminated material to a secured landfill or encapsulate the building site in concrete

- Remove exposed contaminated soil down to at least 1 m below ground surface and place it in a secured landfill
- Control access to the site, whether the smelter is demolished or not
- Control fugitive dust and direct contact with contaminants at the site
- Develop a monitoring plan for groundwater and surface water, though remediation is not recommended at this time

REMEDIATION ALTERNATIVES

Our team evaluated the following remediation alternatives and estimated costs for each option:

1. Doing nothing
2. Limiting access to the building
3. Demolition of the building and salvage
4. Demolition of the building and acid washing salvage material
5. Demolition of the building, acid washing salvage material, and placement of clay cap
6. Demolition of the building, acid washing salvage material, and placement of three-layer clay cap
7. Demolition of the building, acid washing salvage material, and haulage of contaminated equipment to secured landfill
8. Demolition of the building, acid washing salvage material, and encapsulation of the site in concrete
9. Demolition of the building, acid washing salvage material, rinsing of soil, rinsing of unsalvaged building material, and hauling material to a secured landfill

Selection of the preferred action should be based on future land use, site standards, and an economic evaluation.

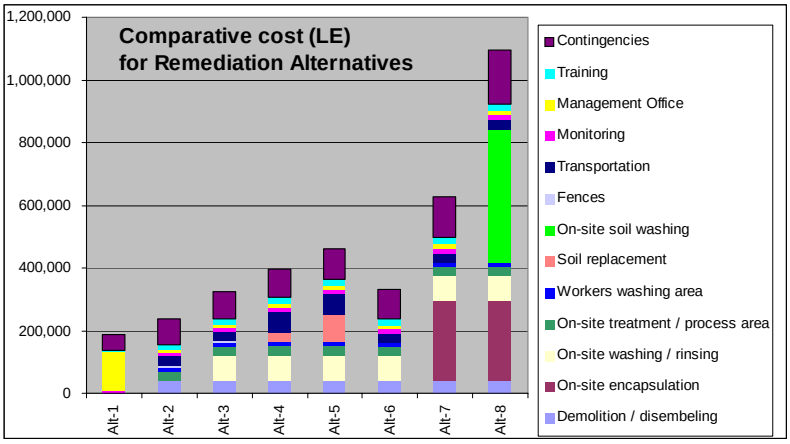
REMEDIATION PLANNING

The preliminary assessment identifies potential hazards at the smelter and contaminant pathways to the environment. However, no recommendations have been made as to the most economically feasible way to remediate the site and reduce the level of risk to nearby residents. To meet this shortcoming, CAIP has developed a plan for the selection of an appropriate remediation alternative.

The plan is based on the U.S. Environmental Protection Agency's CERCLA (Superfund) process. It consists of three basic steps:

1. *Remedial investigation/feasibility study.* This step requires collecting additional environmental data, further analyzing pathways to potential receptors, evaluating exposure rates, completing a risk assessment, developing site clean-up standards, and defining specific remediation alternatives. A feasibility study will be conducted for each remediation alternative.
2. *Economic evaluation.* Based on the feasibility study, an economic evaluation will be carried out to determine the most cost-effective method of remediating the site.
3. *Remediation plan.* Based on the steps above, a final remediation plan will be developed.

This process is intended as a guide for the EEAA. CAIP will work with the smelter owner, the governorate, the municipality, and the EEAA to secure agreements on issues such as funding, final land use, procurement of land for staging operations, and other factors.



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1.0 INTRODUCTION

1.1 Purpose and Scope

Through the Egyptian Environmental Affairs Agency (EEAA), the Government of Egypt (GOE) has developed a comprehensive plan for lead abatement in Cairo. This Lead Exposure Abatement Plan (LEAP) addresses all sources, exposure pathways, and remedial actions associated with lead pollution in the Greater Cairo Area. As a result, secondary lead smelters located in densely populated areas have come under increased scrutiny. These smelters have been a major source of lead in the environment for many years. With this in mind, the GOE developed the Lead Smelter Action Plan (LSAP) to reduce the impact of lead smelters on the environment. The LSAP focuses on reducing airborne and lead emissions from lead smelters, and on relocating the smelters to industrial zones. However, contaminated soils, building materials, machinery, and other items still remain at the former smelter sites. Therefore, steps are being taken under LSAP to develop a remedial program for at least one secondary lead smelter site that could be replicated at other smelter sites throughout Egypt.

1.2 Background

Production of lead in the Greater Cairo Area (GCA) is estimated to be between 35,000 and 45,000 tons/year. The demand for lead for batteries and other products is expected to steadily increase over at least the next decade. Until 1999, there were two companies in the GCA that dominated secondary lead production. These were General Metals, a publicly owned company in Helwan that produced 5% of lead products, and a private sector company owned by the Awadallah family producing 56% of the lead. A number of small, independent private smelters produced the remaining 39%. In November 1999, the General Metals smelter was shut down, leaving the remaining smelters to meet the lead needs of Cairo. Each of these smelters uses antiquated technology for lead refining and smelting, causing severe air, soil, and water pollution.

To develop a remediation program to reduce lead pollution in the GCA, a significant amount of work has been completed to quantify the environmental and health effects of the secondary lead smelting industry in Egypt. As part of this work, a baseline study of the private sector secondary lead smelters in Egypt was completed in February 1996 by the EEAA's Technical Cooperation Office for the Environment (TCOE). In 1994-1995, Datex, Inc. completed a technical analysis of the lead smelter industry as a part of its technical support to develop the design of the Cairo Air Improvement Project (CAIP). In addition, two studies were completed by the World Bank — one in 1993 and the other in 1995. Finally, a number of studies and research activities have been reported in the literature that served as background for the development of the Lead Smelter Action Plan (LSAP). Key documents that helped develop the plan are listed in Section 8, "References." Based on this work, the LSAP defined three major objectives:

- Objective 1: Upgrade the operation of large lead smelters

- Objective 2: Provide technical assistance to cooperative, licensed, small and medium-sized lead smelters

- Objective 3: Establish and enforce a comprehensive, country-wide, long-term solution to the lead pollution problem

As part of Objective 1, CAIP is currently working with the Awadallah company to consolidate its operations and move them to a new, more modern plant site located at the Abu Zaabal industrial park. This move has brought about the closing down of three of its four smelters, including the smelter at Shoubra El Kheima, significantly reducing air lead emissions. CAIP is also working with the Awadallah family to develop a long-term solution to remediate the Shoubra El Kheima smelter site to further reduce environmental and human health risks posed by the site. This preliminary assessment is a first step toward remediating the site and ultimately meeting Objective 3 outlined above.

1.3 Approach

As part of the process of developing a remediation program for the Shoubra El Kheima secondary lead smelter, this preliminary assessment aims to provide the reader with an understanding of:

- Existing environmental site conditions
- Environmental and human health hazards still existing at the site
- Pathways to the environment for contaminants such as lead and other trace metals
- A preliminary assessment of potential remedial technologies and their costs
- A conceptual plan to further evaluate the site so it can be remediated in a cost-effective manner

This report presents the results of an eight-month investigation of the Shoubra El Kheima secondary lead smelter performed by Phillip E. Brown and IWACO Egypt for CAIP under the guidance of Dr. Zeinab Safar. It outlines the approach taken toward data collection and site investigation. The report is preliminary because, prior to the selection of a final remediation alternative, additional information is required to develop a cost-effective program to remediate the site in a safe manner.

1.4 Intended Results

The intended results of this preliminary assessment of the Awadallah smelter in Shoubra El Kheima are the following:

- Compare the site to international remedial standards

- Present preliminary costs for various remedial activities, including but not limited to doing nothing, demolition and leaving material in place with a suitable cap, and hauling material to an acceptable landfill

- Develop a scope assessment for more detailed site-specific studies, including:

    1. Determination of the extent of contamination
    2. Exposure/risk assessment
    3. Definition of clean-up standards
    4. Economic analysis of various remedial alternatives
    5. Recommendation of final remediation approach

On a national level, this assessment aims to assist the EEAA in developing a support program for remediation planning at other sites.

2.0 SITE SELECTION AND SMELTER DESCRIPTION

2.1 Site Selection

CAIP is taking the lead in developing a remediation program for secondary smelters in the Greater Cairo Area under the Lead Smelter Action Plan (LSAP). Many smelters have been shut down and are in the process of being relocated to new industrial areas. With the shutting down of existing smelters, action must be taken to remediate these former sites to further reduce risks to human health and the environment. In selecting a demonstration site for this remediation action, several criteria had to be met, including:

- *Availability*. The site must be available for remediation studies.
- *Cooperation with the owner*. The owner must be willing to cooperate with the project and allow field studies on the site.
- *Location*. The site must be located in the Greater Cairo Area.
- *Accessibility*. The site should be accessible for equipment such a drilling equipment.
- *Future*. Future land use of the site should be defined.

Meeting each of these criteria was a challenging task. In the Qalyubia Governorate, CAIP is working with a large smelter owner, Awadallah, to remediate at least one smelter in Shoubra El Kheima. For this process, CAIP has selected Awadallah's secondary lead smelter on Magari Street near the Ismailia Canal in Shoubra El Kheima (Figure 2-1).

This smelter meets all the criteria presented above and was selected with the owner's approval. It is one of the largest smelters in the area, with a production of more than 11,000 tonnes of lead product annually. Of Awadallah's smelters, it is also believed to pose the most risk to the environment.

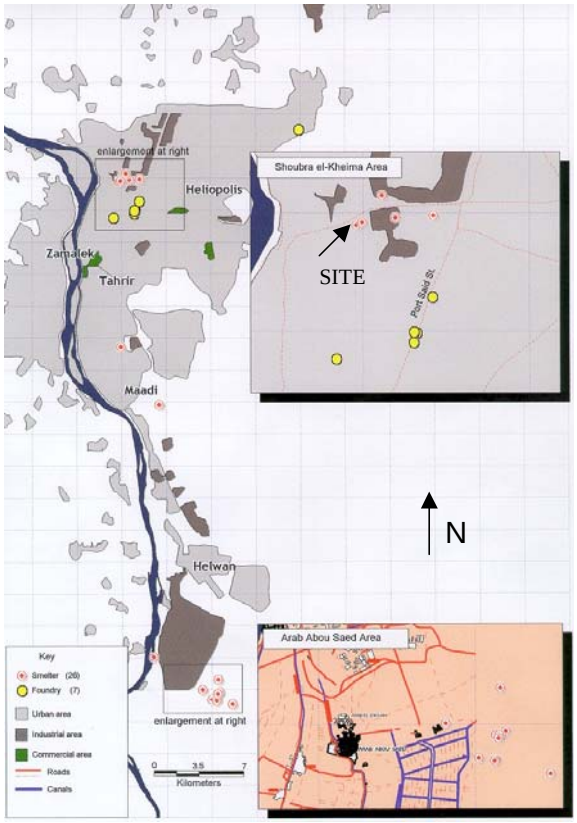


Figure 2-1. Site Location

2.2 The Smelter: Site Description and History

The Awadallah smelter at Shoubra El Kheima operated between 1979 and August 2001. Currently, some refining operations are still ongoing. The smelter covers an area of approximately 1550 m^2. The walls consist of 50 mm-thick bricks and poured concrete. About two-thirds of the plant has a 50-100 mm-thick concrete floor. The total volume of concrete has been calculated at about 553 m^3. The main raw material for the plant was used batteries. Approximately 20,000 tonnes of batteries were recycled per year, producing 11,000 tonnes of lead ingots. For the most part, the batteries were broken at another plant, and only the lead plates and nodes were processed at this smelter.

There were two rotary furnaces in the plant, both used for smelting until August 2001. After that date, the smelting process was abandoned and the plant was used only to refine and manufacture lead products. Refining and alloying of lead ingots is done in kettles. At the smelter, the refined lead is used to produce pipe, lead sheets, and lead oxides.

A wet scrubber was installed in 1994 to reduce lead emissions, but its filtration efficiency was less than 20%. The filtration system was modified in 1998 and a small bag house was added to the system. This reduced emissions, but caused difficulties with the operation of the furnaces, resulting in greater emissions inside the workplace.

It was observed during site visits that lead dust coats most of the site's concrete floor and brick walls, and virtually lines the duct work and bag house. A 20 m tunnel underlies part of the site, routing dust and smoke from the furnace to the 40 m-high brick stack. This stack has been subsequently removed and replaced with a stack made of steel.

As shown in Figure 2-2, a photograph of the extrusion room, no environmental controls have been in place at the workplace to prohibit the dust and molten lead from coating the floors or walls of the smelter. There is a tank used to collect condensate, and a 30 m-deep groundwater supply well for cooling. An above-surface storage tank is used to store light diesel fuel (Solar) for the furnaces. Other site photos are included in Appendix A.

Figure 2-2. Extrusion Room

2.3 Environmental Setting

One of the important aspects of any remedial investigation is the development of a thorough understanding of the site's environmental setting. As part of this preliminary assessment, studies were performed at the Awadallah smelter site by the consulting firm IWACO Egypt. From these studies, much was learned about the geology and hydrology of the site. These studies are presented in detail in Appendix B of this report. The following summarizes findings related to the environmental setting of the site.

2.3.1 Topography and Relief

The topography of the area is almost flat, with an average altitude of 17 m above mean sea level (m amsl).

2.3.2 Climate

The climate of the site is considered arid. Annual rainfall is low, with a long-term average of about 25 mm/year. Average daily air temperatures range between 28 °C in the summer and 13 °C in winter. Potential evapotranspiration is more than 4,000 mm/year, with a maximum occurring in the summer at more than 15 mm/day.

2.3.3 Land Use

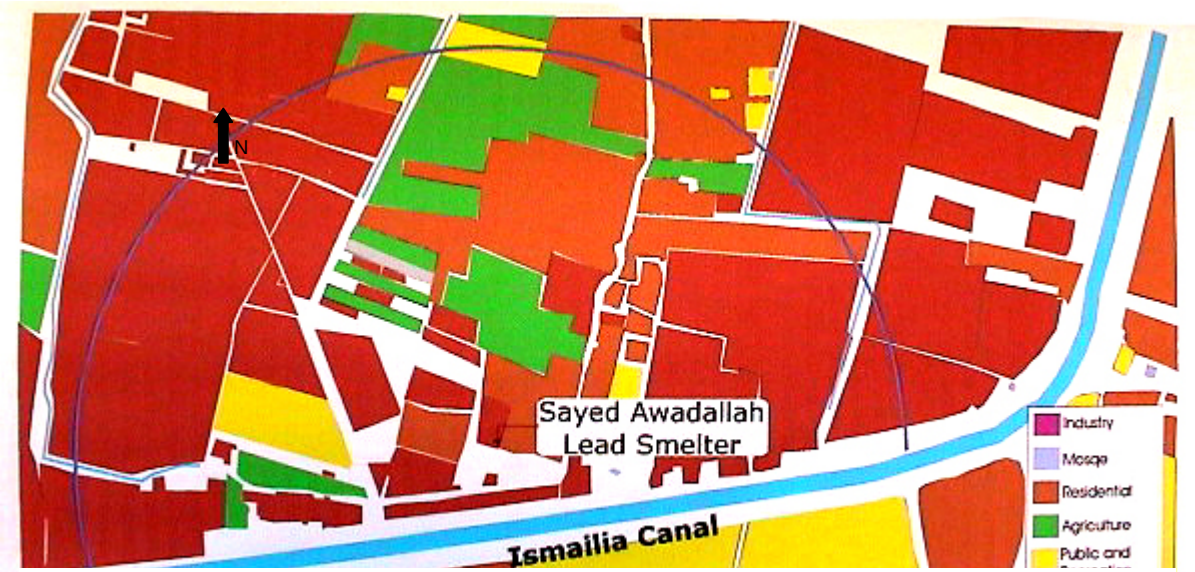


Figure 2-3. Land Use in the Vicinity of the Awadallah Lead Smelter

As illustrated in Figure 2-3, the Awadallah smelter lies within a mixed industrial and residential area with scattered agricultural plots near the Ismailia Canal. Prior to the 1970s, the area was entirely agricultural. In the 1970s, small industries including the smelter, small workshops, foundries, and other smelters were located in the area in a largely unplanned manner. The site is approximately 40 m north of a soccer field and playground, and about 30 m east of a housing block. A variety of industrial and

housing areas lie further to the west and north of the smelter. There is an iron foundry about 1 km west of the site.

2.3.4 Geologic and Hydrologic Setting

The smelter was constructed within the flood plain of the Nile River. The site lies approximately 200 m north of the Ismailia Canal, with the water table between 5-6 m below the ground surface. Underlying the smelter, there are two hydrogeologic units, an upper aquitard, and a major alluvial aquifer.

The upper unit lies directly below the site and consists of Holocene fluvial deposits. The unit is composed of a semi-pervious silty clay. Its thickness is quite variable, ranging between 0 and 35 m in the valley. The upper silty clay acts as an aquitard and limits recharge from precipitation to the lower aquifer unit below.

The lower unit is composed of Pleistocene, graded sands, and gravels, and is considered to be the major productive aquifer in the Nile River valley. With a thickness of more than 200 m, the hydraulic conductivity of the aquifer is around 50 m/d, and transmissivity ranges from 5,000 to 15,000 m^2/day.

The Ismailia Canal is the most controlling hydrologic feature near the site. It acts as a point of recharge for the upper and lower hydrologic units. The upper unit, although relatively impermeable, is saturated to some degree and is recharged by the canal. It is uncertain if perched zones exist or if there is a shallow groundwater table. The lower aquifer, which is also recharged by the Ismailia Canal, is more regional and is the major supplier of groundwater to the area. The well at the smelter is approximately 30 m deep and is most likely completed in this unit. A well survey presented in Appendix B indicates that there are 92 wells in the area at 72 locations. These wells abstract about 3 million m^3/year, mainly for industrial use.

3.0 DATA COLLECTION (FIELD STUDIES)

3.1 General

Under Egyptian environmental laws and regulations, there are no fixed guidelines for data collection at potentially hazardous waste sites. However, guidelines from the U.S. Environmental Protection Agency (EPA) and other worldwide institutions call for preliminary assessments of a site before detailed scientific, engineering, and feasibility studies are conducted and remedial actions taken. These assessments should be performed using quality assurance/quality control (QA/QC) protocols to ensure that the data collected is accurate.

In the United States, preliminary assessments of former and existing industrial sites are usually phased. The first phase typically consists of a site visit and an evaluation of public records, available maps, aerial photographs, and other information to determine whether potentially hazardous materials exist at the site. If a Phase I investigation determines that hazards do exist, a second phase evaluation takes place. This phase generally consists of limited geologic and hydrologic sampling at the site. For both Phase I and Phase II investigations, strict guidelines and QA/QC protocols have been developed. If the results of these indicate that environmental and human health risks are high, more detailed remediation studies and programs may be required.

As part of this preliminary assessment, a field investigation of the smelter site was deemed necessary to gain an understanding of the nature of potential hazards to human health and the environment. This investigation was designed to do the following:

- Provide a preliminary estimate as to the size and volume of building material and equipment that may have to be removed or remediated
- Determine the extent of dust and soil contamination due to activities at the site
- Determine whether groundwater or surface water has been contaminated due to activities at the site
- Identify other sources of contamination in the area that may have contributed to air and water pollution

The following presents a summary of the field study conducted by CAIP personnel and the consulting firm IWACO Egypt. Study methods are discussed in further detail in Appendix B. The findings were used to evaluate the site in terms of potential risks to human health and the environment, as discussed in subsequent sections of this report.

3.2 Site Survey

The site survey was designed to estimate the size and volume of materials that may have to be removed from the site during remedial activities. Blueprints and maps of the site were examined, and a CADD drawing developed. Estimates of building volumes were based on the average thickness of the walls, floors, and other structures.

3.2.1 Geochemical Sampling: Dust and Soil

Because of the high potential for contaminated soils at the site, dust and soil samples were taken. These were analyzed for specific metals and other potential contaminants related to the secondary lead smelting and battery manufacturing industries, including:

- Lead (Pb)
- Antimony (Sb)
- Cadmium (Cd)
- Selenium (Se)
- Arsenic (As)

The risks posed by these elements are discussed in Section 3 of this report. Methods used for sampling and analysis are presented below.

Dust. During the smelting and manufacturing process, contaminated dust was deposited on the floors, ceiling, and walls of the facility, as well as in the direct vicinity of the complex. This dust can be dispersed via various pathways to the environment, including air, water, and human contact. For this assessment, dust samples were taken from within and just outside the plant on May 6, 2001. These samples were collected in the field using a clean stainless steel garden troll, and placed in a plastic bag for analysis. As illustrated in Figure 3-1, the locations of these dust samples were as follows:

- S-1 – Surface sample taken in front of eastern rotary furnace
- S-2 –Surface sample taken half-way between rotary furnaces
- S-3 – Sample take 50 mm below S-2 sample above the concrete floor
- S-4 – Open storage area in the southern portion of the plant
- S-5 – Northeast corner of soccer field
- S-6 – Brick taken from the eastern wall of the smelter near the furnace

The samples were placed on ice and taken to the EGSMA laboratory, where they were analyzed under the supervision of Dr. Mahamed Sabry for lead, chromium, arsenic, selenium, and antimony. In the laboratory, the dust samples were digested with repeated additions of nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) in accordance with U.S. EPA method 3050B, with the digestate being prepared for analysis using a flame atomic absorption spectrometer.

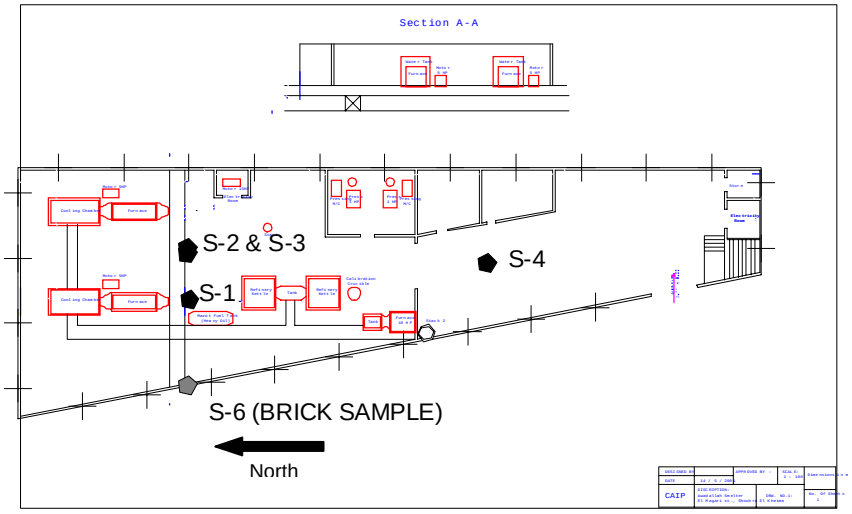


Figure 3-1. Dust Sample Locations

Soil. To collect soil samples, four (4) boreholes were drilled on October 13, 2001, inside the smelter to below the water table at locations presented in Figure 3-2 below.

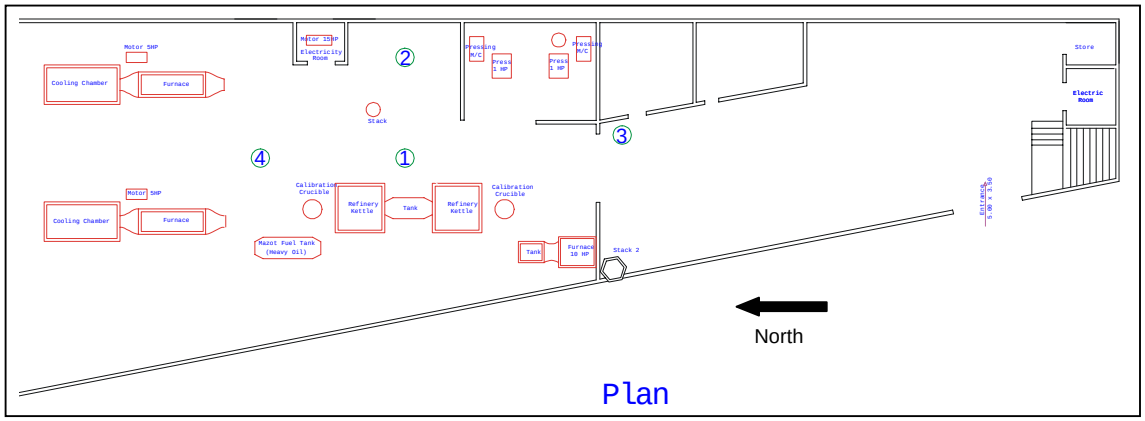


Figure 3-2. Borehole Locations

The boreholes were drilled using a manually driven 150 mm i.d. auger. As presented in Table 3-1, a total of 19 soil samples were collected from the boreholes at depths ranging from 0.5 to 8 m below the ground surface, depending on the depth of the water table.

Table 3-1. Soil Samples

SN	Label	Borehole Number	Depth(s)	Remarks
1	0101	1	0.5	Single depth
2	0102	1	2.0, 2.5	Composite
3	0103	1	3.5, 4.0	Composite
4	0104	1	4.5, 5.0, 5.5	Composite
5	0201	2	0.5	Single depth
6	0202	2	1.0, 2.0	Composite
7	0203	2	4.0, 5.0	Composite
8	0204	2	5.5, 6.0	Composite
9	0205	2	7.0, 8.0	Composite
10	0301	3	0.5	Single depth
11	0302	3	1.0, 2.0	Composite
12	0303	3	4.0, 5.0	Composite
13	0304	3	5.5, 6.0	Composite
14	0305	3	7.0, 8.0	Composite
15	0401	4	1.0	Single depth
16	0402	4	2.0, 3.0	Composite
17	0403	4	4.0, 5.0	Composite
18	0404	4	5.5, 6.0	Composite
19	0405	4	7.0, 8.0	Composite

As with dust samples, the soil samples were placed on ice and taken to the EGSMA laboratory, where they were analyzed under the supervision of Dr. Mahamed Sabry for lead, zinc, chromium, arsenic, selenium, and antimony. In the laboratory, the soil samples were digested with repeated additions of nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) in accordance with U.S EPA method 3050B, with the digestate being prepared for analysis using a flame atomic absorption spectrometer.

3.2.2 Hydrologic Investigation

As described below, the hydrologic site investigation consisted of three components: (1) a literature review and desk study, (2) surface and groundwater sampling, and (3) installation and sampling of monitoring wells.

Literature review and desk study. As a first step, a literature review was performed to examine studies already conducted in the area, particularly with regard to water quality analyses, the location of groundwater extraction wells, and the location of other potential polluters.

Surface and groundwater sampling. Surface and groundwater samples were collected from nearby wells and the Ismailia Canal upstream and downstream from the site. Water samples were taken from nine (9) different locations surrounding the smelter, including the water well of the smelter, two (2) points on the Ismailia Canal, and six (6) other existing wells. A total of 22 samples was collected from these points, including raw water, filtered water, and duplicate samples. Table 3-2 presents the location of the selected points.

Table 3-2. Water Sample Locations

Well No.	Name of Company (Type of Sample)	Sample Label	Well Depth (m)
12	**Abdel Gabbar Dyeing Co.**		
	(Raw)	1201	45 m
	(Raw Duplicate)	1202	45 m
	(Filtered)	1203	45 m
16	**Mobil Fuel Station**		
	(Raw)	1601	40 m
	(Filtered)	1603	40 m
	(Filtered Duplicate)	1604	40 m
17	**El Ahram Foundry**		
	(Raw)	1701	Unknown
	(Filtered)	1703	Unknown
22	**El Fottouh Cotton Factory**		
	(Raw)	2201	25 m
	(Filtered)	2203	25 m
24	**Noval Factory**		
	(Raw)	2401	24 m
	(Filtered)	2403	24 m
35	**El Salam Dyeing Co.**		
	(Raw)	3501	45 m
	(Filtered)	3503	45 m
93	**Sayed Awadallah Lead Smelter**		
	(Raw)	9301	Unknown
	(Raw Duplicate)	9302	Unknown
	(Filtered)	9303	Unknown
	(Filtered Duplicate)	9304	Unknown
94	**Ismailia Canal 200 m U.S.**		
	(Raw)	9401	n/a
	(Filtered)	9403	n/a
95	**Ismailia Canal 200 m D.S.**		
	(Raw)	9501	n/a
	(Filtered)	9503	n/a

All samples were preserved, placed on ice, and sent to a qualified laboratory for analysis in accordance with the Sampling and Analysis Plan (SAP) presented in Appendix B. Samples in the field were analyzed for pH, specific conductance, temperature, and salinity, using calibrated field instruments. In the laboratory, the samples were analyzed for selected trace metals using approved methodologies, as described in Appendix B.

Installation and sampling of monitoring wells. For the site investigation, five (5) monitoring wells were drilled. One deep well and one shallow well were drilled and completed inside the smelter, with the remaining three wells located outside the smelter, not far from its boundaries. Figure 3-3 illustrates the locations of these wells. The wells were drilled and completed according to the SAP in Appendix B. All samples were preserved, placed on ice, and sent to a qualified laboratory for analysis. Samples in the field were analyzed for pH, specific conductance,

temperature, and salinity using calibrated field instruments. In the laboratory, the samples were analyzed for selected trace metals using approved methodologies, as described in Appendix B.

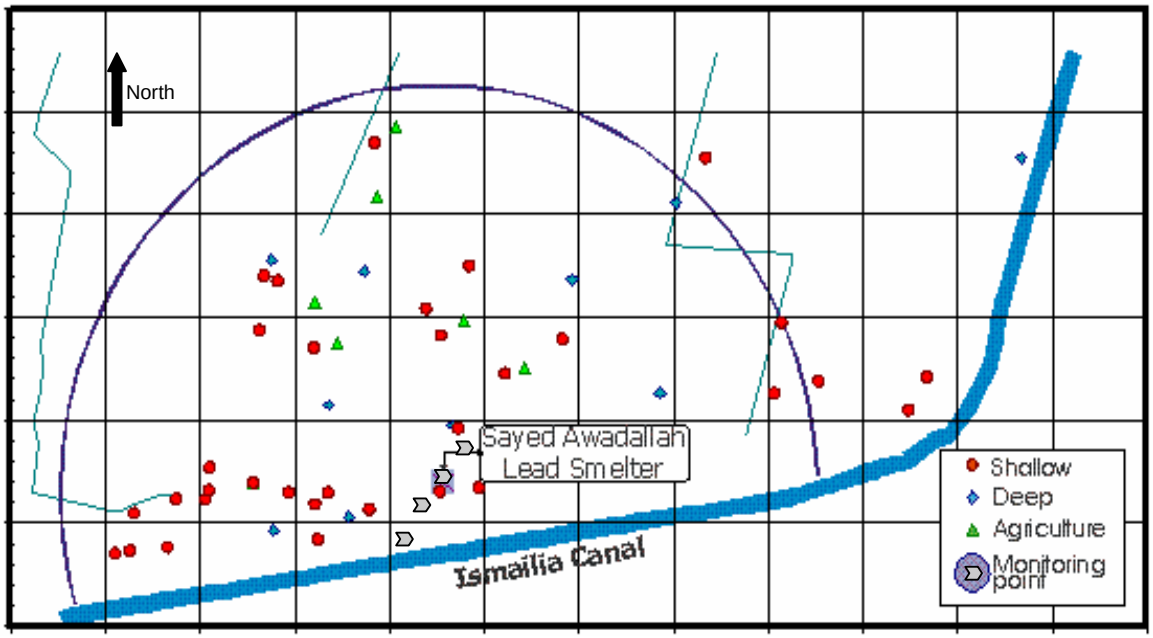


Figure 3-3. Monitoring Well Locations

4.0 HAZARD ASSESSMENT

In general, potentially hazardous waste sites such as the Awadallah smelter pose a multitude of health and safety risks to remediation workers, nearby residents, and the environment. Exposure to toxic elements such a lead can have a profound effect on the long-term health of workers at the site. Children and young adults playing near or within the smelter grounds can also be exposed to lead by inhaling or ingesting high levels of contaminated fugitive dust. Fugitive dust from the smelter can also be blown and deposited on agricultural products and onto the waters of the Ismailia Canal and a nearby water treatment plant.

As part of this assessment, a preliminary evaluation of potential hazards in dust, soil, and water was performed. These hazards mainly consist of trace metals and other contaminants that can be leached into the soil down to groundwater, or escape the site in fugitive dust blown in the air. The sections that follow present an overview of potential hazards found at the site, with a focus on:

- Characteristics and behavior of inorganic contaminants of concern found in the vicinity of the site
- Concentrations of these metals in dust, soil, and water samples

4.1 Contaminants of Concern

4.1.1 Lead (Pb)

Of the contaminants found at the site, lead is of most concern. Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. It has no special taste or smell, and can be found in all parts of the environment. The primary form of lead in its natural state is galena (PbS). Lead occurs mainly as PB^{+2} and forms several other minerals that are relatively insoluble in natural waters. During weathering, lead sulfides slowly oxidize and often form carbonates that can be incorporated in clay minerals, iron and manganese oxides, and inorganic matter. Lead is the primary component of grids and anodes/cathodes in lead/acid batteries.

At the Awadallah smelter, lead grids are resmelted to form lead pipe, lead ingots, and other products. When the plant was operating, workers were exposed to lead fumes and lead-containing fugitive dust. Air emissions released from the smelter stacks also exposed workers and nearby residents to lead-contaminated dust. In addition, lead in particles from stack emissions has contaminated soils and playing fields near the smelter.

The health effects of lead are well understood. Lead exposure affects many organ systems, including cardiovascular, renal, and hepatic. The most clinically apparent (i.e., symptomatic) effects occur with blood lead levels greater than 50 mg/dL. The central nervous system, particularly in children, is the most sensitive to lead, which also damages the kidneys and the immune system. The effects of lead exposure are the same whether lead is breathed or swallowed. Exposure to lead is more

dangerous for young and unborn children. Unborn children can be exposed to lead through their mothers. Harmful effects include premature births, smaller babies, decreased mental ability in the infant, learning difficulties, and reduced growth in young children. Small increases in systolic blood pressure have been associated with mildly elevated blood lead levels.

4.1.2 Antimony (Sb)

Numerous battery manufacturers use antimony to strengthen battery grids. The geochemical characteristics of antimony are similar to those of arsenic. Antimony found naturally in soil usually ranges between 0.05 to 4 ppm. Antimony is also fairly mobile in water and becomes more soluble under acidic conditions. Because antimony is found naturally in the environment, the general population is exposed to low levels every day, primarily in the air, food, and drinking water.

During the operation of the Awadallah smelter, workers were most likely exposed to antimony through skin contact with soil and dust, and through inhalation of fumes and fugitive dust. During remediation of the site, exposure to workers will most likely occur through dermal contact with dust and inhalation of fugitive dust. Breathing high levels of antimony for a long time can irritate the eyes and lungs, and cause problems in the lungs, heart, and stomach.

4.1.3 Arsenic (As)

Arsenic is an element that is widely distributed in the earth's crust. Elemental arsenic is ordinarily a steel grey, metal-like material that occurs naturally in soils and bedrock. Arsenic is a common component of the oxide paste that is used in pressing the metal grids in battery manufacturing. Arsenic metal is used as a minor additive (0.01% to 0.5%) to strengthen the posts and grids of lead-acid storage batteries. Arsenic is an extremely toxic metal that poses such a significant environmental health hazard that the U.S. EPA placed it at the top of the list of 200 hazardous substances with carcinogenic risk.

Some forms of anaerobic bacteria make arsenic water soluble or extremely volatile, and therefore biologically available and accessible. Arsenic can be immobilized by adhering to the surface clay particles found in soils or riverbeds. However, this immobilization may not be permanent. For example, as acidity increases, so does the solubility of arsenic, making it more likely to be mobilized.

Arsenic through dermal exposure and inhalation can cause skin damage, weight loss, circulatory system problems, increased risk of cancer, and death. Perhaps the single most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, kidneys, prostate, and lungs.

4.1.4 Cadmium (Cd)

Cadmium is a natural element in the earth's crust. It is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate/sulfide). All soils and rocks contain some cadmium. Cadmium does not corrode easily and has many uses, including batteries, pigments, metal coatings, and plastics. Alloys containing cadmium and lead are common in automobile batteries. The addition of cadmium reduces the corrosion of grids.

In the smelting process, levels of cadmium can be found in the fumes and fugitive dust. Breathing high levels of cadmium can severely damage the lungs and can cause death. Eating food or drinking water with very high levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels of cadmium in the air, food, or water leads to a build-up of cadmium in the kidneys and possible kidney disease. Other long-term effects include lung damage and fragile bones.

4.1.5 Selenium (Se)

Selenium is a metal commonly found in rocks and soil. In the environment, selenium is rarely found in its pure form. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals. Selenium and oxygen combine to form several compounds. In the battery manufacturing business, selenium is used as a degasing agent and as an alloy to lead to improve the machinability of grids and anodes/cathodes.

During the smelting process, entrained selenium particles can be released, exposing workers and nearby residents. These particles also precipitate to the ground, and abnormally high levels can be found in dust and soils within and near the smelter site. People exposed to very high levels of selenium have reported dizziness, fatigue, irritation, collection of fluid in the lungs, and severe bronchitis. The exact levels at which these effects occur are not known. Upon contact with the skin, selenium compounds have caused rashes, swelling, and pain.

4.2 Concentrations

4.2.1 Dust

In terms of site contamination, the most revealing results to date are soil analyses. The results of these analyses are summarized in Table 4-1 below.

Table 4-1. Analytical Results of the Dust Sampling Program

Sample No.	Pb (mg/kg)	Cr (mg/kg)	As (mg/kg)	Se (mg/kg)	Sb (mg/kg)
S-1	337750 (34%)	3.5	2250	18507	46295
S-2	224000 (22%)	14	891	10977	12337
S-3	242100 (24%)	15	406	1635	7612
S-4	55900 (6%)	15	51	312	730
S-5	1227 (0.1%)	30	-	433	183
S-6	160 (0.01%)	12	-	-	140

These results indicate that lead and other contaminant concentrations in dust within and just outside the smelter are extremely high and exceed natural occurring levels and accepted clean-up criteria (to be discussed later). Figure 4-1 illustrates that lead concentrations in dust on the smelter floor makes up as much as 33% of the total sample volume. This concentration goes down considerably as one proceeds south in the plant and outside the smelter walls. However, lead content in dust on the nearby soccer field is also of concern at 1,200 mg/kg because of the potential for children to inhale the dust while playing. Finally, it should be noted that lead concentration in bricks found at the plant site is relatively low compared to other samples, as shown for sample S-6 with a lead concentration of 160 mg/kg.

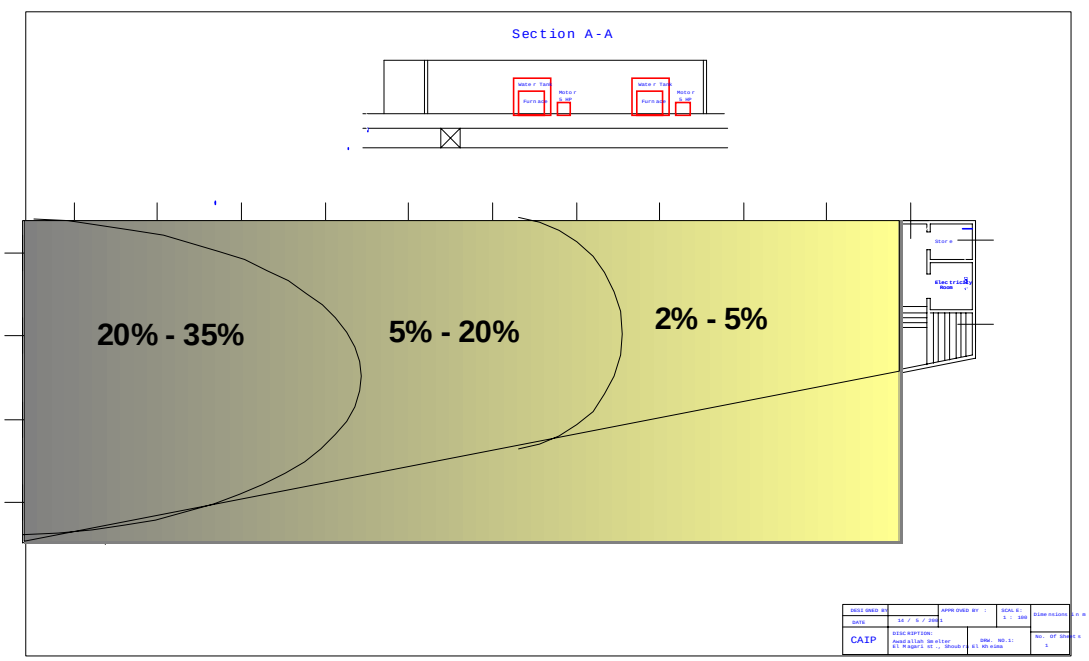


Figure 4.1. Estimated Percentages of Lead in Dust at the Awadallah Secondary Lead Smelter in Shoubra El Kheima

Other metals and contaminants, including chromium, arsenic, selenium, and antimony, have similar distributions in dust around the smelter site. The highest

levels of antimony and other contaminants were found near the furnaces, with antimony levels at 4%, and selenium levels at 1.8%.

4.2.2 Soil

The results presented in Table 4-2 below indicate that trace metal contamination extends to 8 m below the ground surface. In general, natural lead concentration in soils is rarely greater than 200 mg/kg. Although the highest value for soil lead contamination is between 0.0 and 0.5 m below the surface, the results indicate that lead from the surface has migrated below the water table.

In addition, antimony and cadmium in the soils underlying the smelter may be of concern. In natural soils, antimony and cadmium usually range from 0.05 to 4 mg/kg, and 0.06 to 1.1 mg/kg, respectively. The results of the sampling program indicate that these contaminants have migrated up to 8 m below the ground surface. The exact mechanism of this migration is unknown, but most likely due to leaching of the material, including dust and debris deposited on the surface. The leakage of acid from battery breaking at the site may have also caused leaching of the contaminants into the soil.

Table 4-2. Chemical Analysis of Soil Samples Taken from Boreholes at the Awadallah Secondary Smelter in Shoubra El Kheima

B.H.	Depth (m)	Pb (mg/kg)	Cd (mg/kg)	Sb (mg/kg)	Se (mg/kg)	As (mg/kg)
1	0.5	4,276	1.26	134	ND	ND
1	2.0, 2.5	468	1.24	64	ND	ND
1	3.5, 4.0	386	1.26	58	ND	ND
1	4.5, 5.0, 5.5	39	1.22	53	ND	ND
2	0.5	11,954	1.46	55	ND	ND
2	1.0, 2.0	4,566	1.28	52	ND	ND
2	4.0, 5.0	376	1.24	60	ND	ND
2	5.5, 6.0	226	1.18	55	ND	ND
2	7.0, 8.0	229	1.14	56	ND	ND
3	0.5	24,069	1.48	56	ND	ND
3	1.0, 2.0	17,380	1.38	62	ND	ND
3	4.0, 5.0	9,308	1.38	65	ND	ND
3	5.5, 6.0	231	1.30	66	ND	ND
3	7.0, 8.0	10	1.16	52	ND	ND
4	1.0	5,068	1.44	55	ND	ND
4	2.0, 3.0	2,512	1.30	53	ND	ND
4	4.0, 5.0	1,343	1.30	54	ND	ND
4	5.5, 6.0	760	1.12	52	ND	ND
4	7.0, 8.0	15	1.12	49	ND	ND

4.2.3 Water

For this hazard assessment, it was important to evaluate both surface and groundwater quality in the direct vicinity of the site. Surface water quality data from the Ismailia Canal is available from the Ministry of Public Health (MOHP 1999 cited in NWRP 2001) and is presented in Table 4-3 below. This data indicates that

concentrations of selenium, cadmium, mercury, and lead are high, occasionally exceeding limits for both ambient and drinking water standards, and are considered hazardous to health if consumed directly.

Table 4-3. Ismailia Canal: Surface Water Quality
(all figures are in mg/l)

	Fe	Mg	Se	F	Cd	Cu	Cr	Hg	Pb	Zn	Ni
Law 48/82 (ambient)	1.0		0.01	0.5	0.01	1.0	0.05	0.001	0.05	1.0	
Law 48/82 (drinking)	0.3	150	0.01	0.8	0.003	2.0	0.05	0.001	0.05	3.0	
WHO (drinking)			0.01	1.5	0.003	2.0	0.05	0.001	0.01		0.02
January 1999											
Mostorod	NA	NA	0.10	0.02	0.26	NA	0.02	0.95	0.04	0.33	0.02
El-Delta Co. for Iron	NA	NA	0.15	0.02	0.13	NA	0.03	0.032	0.02	0.37	0.07
Osman Bridge	NA	NA	0.15	0.02	0.16	0.11	0.03	0.034	0.18	0.34	0.19
February 1999											
Mostorod	NA	NA	0.20	0.07	0.20	0.01	0.06	0.12	0.22	0.81	0.06
El-Delta Co. for Iron	NA	NA	0.15	0.07	NA	NA	NA	NA	NA	NA	NA
Osman Bridge	NA	NA	0.15	0.07	0.80	0.03	0.05	0.12	0.11	0.52	0.06
November 1999											
Mostorod	0.01	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA
El-Delta Co. for Iron	0.11	NA	0.01	0.04	NA	NA	NA	NA	NA	NA	NA
Osman Bridge	0.01	NA	0.01	0.04	NA	NA	NA	NA	NA	NA	NA
December 1999											
Mostorod	NA	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA
El-Delta Co. for Iron	NA	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA
Osman Bridge	NA	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA

The water samples taken from nearby wells indicate that groundwater is slightly alkaline in this area and, as presented in Table 4-4, that:

- Antimony, selenium, and arsenic were not detected in the sample.
- Traces of cadmium were found in three samples.
- Lead was found and exceeded the drinking water limits in all samples, posing a hazard to human health if consumed directly.

Table 4-4. Site Investigation: Water Quality Analyses

Well No.	Company Name (Sample Type)	Sample Label	Well Depth (m)	pH	Eh	Ec (mmos/ cm)	Salinity (mg/l)	Pb (mg/l)	Cd (mg/l)
12	**Abdel Gabbar Dyeing Co.**								
	(Raw)	1201	45 m	7.88	-0.465	887	567.68	0.078	
	(Raw Duplicate)	1202	45 m					0.065	0.003
	(Filtered)	1203	45 m					0.054	0.002
16	**Mobil Fuel Station**								
	(Raw)	1601	40 m	7.65	-0.451	437	279.68	0.074	
	(Filtered)	1603	40 m					0.084	
	(Filtered Duplicate)	1604	40 m					0.071	
17	**El Ahram Foundry**								
	(Raw)	1701	Unknown	7.85	-0.463	364	232.96	0.05	
	(Filtered)	1703	Unknown					0.118	
22	**El Fottouh Cotton Factory**								
	(Raw)	2201	25 m	7.95	-0.469	386	247.04	0.106	0.003
	(Filtered)	2203	25 m					0.083	
24	**Noval Factory**								
	(Raw)	2401	24 m	7.73	-0.456	628	401.92	0.111	
	(Filtered)	2403	24 m					0.101	
35	**El Salam Dyeing Co.**								
	(Raw)	3501	45 m	7.29	-0.430	586	375.04	0.09	
	(Filtered)	3503	45 m					0.11	
93	**Sayed Awadallah Lead Smelter**								
	(Raw)	9301	Unknown	7.46	-0.440	374	239.36	0.082	
	(Raw Duplicate)	9302	Unknown					0.098	
	(Filtered)	9303	Unknown					0.061	
	(Filtered Duplicate)	9304	Unknown					0.052	
94	**Ismailia Canal 200 m U.S.**								
	(Raw)	9401	n/a	7.95	-0.469	288	184.32	0.076	
	(Filtered)	9403	n/a					0.065	0.001
95	**Ismailia Canal 200 m D.S.**								
	(Raw)	9501	n/a	7.99	-0.471	285	182.40	0.08	
	(Filtered)	9503	n/a					0.077	

5.0 PATHWAY ANALYSIS

There are three main pathways by which contaminants such as lead can reach potential receptors and the environment due to releases from the Awadallah site in Shoubra El Kheima. These are:

- Air through the dispersion of fugitive dust
- Water, through stormwater runoff, fugitive dust depositing on waterway, and migration of leacheate to groundwater
- Direct contact with contaminated dust and soil

The following sections present an assessment defining how contaminants are transported to various receptors through these pathways. Because of the preliminary nature of this study, no receptor evaluations or complex air or water modeling were carried out. However, more detailed studies should be considered if further steps are required to characterize the site.

5.1 Air

Airborne contaminants can present a significant threat to the health and safety of workers and potential receptors downwind. Of main concern is what is known as fugitive dust, which is defined as small particles of geological origin that are suspended into the atmosphere from nonducted emitters (Labib et al, 2001). Open fields and parking lots, paved and unpaved roads, agricultural fields, construction sites, unenclosed storage piles, and material transfer systems are major sources of fugitive dust.

CAIP began evaluating the air pathway in mid-1998 when the Awadallah smelter in Shoubra El Kheima was still in operation. To do this, four (4) air quality monitoring stations were established. These stations are part of the CAIP air quality monitoring network, which consists of 34 ambient sites located in the Greater Cairo area. The monitoring stations are distributed within an area defined by Kaha and Bilbeis in the north; Tebbin in the south; the 10th of Ramadan City in the east; and the 6th of October City in the west.

Currently, AIRmetrics™ samplers are used at the air quality monitoring stations to collect PM10 and PM2.5 fugitive dust samples (particles with aerodynamic diameters less than 10 and 2.5 μm, respectively). Samples are collected concurrently every six days and analyzed at the EGSMW laboratory for lead. During each sampling event, the samplers are programmed to continuously collect a particulate matter sample over a 24-hour period (0000 to 2400 hours). Additional details on this monitoring program are included in a study titled “Lead in Street Dust for the Greater Cairo Area for Year 2000,” by Mounir W. Labib, Mohammed H. Khalil, and Mohammed Sabry, which was presented at the Environment 2001 International Conference in Cairo, Egypt.

5.1.1 Air Quality and Wind Speed/Direction

As mentioned earlier, air quality has been monitored in the direct vicinity of the site since 1998. According to Labib et al (2001), the results of the 2000 CAIP air monitoring program indicate that the highest annual average Pb10 levels recorded were 26.2 and 25.4 $\mu g/m^3$ at the Shoubra El Kheima (Site No. 18) and El Sahel (Site No. 19) monitoring stations, respectively. The highest lead concentration, 184.2 $\mu g/m^3$, was recorded at Site 19. In addition, Pb10 lead concentrations exceeding 50 $\mu g/m^3$ were recorded at the Shoubra El Kheima and El Sahel sites a total of 11 times during baseline year sampling events. The El Sahel District is nominally downwind of lead smelters in Shoubra El Kheima. Annual lead concentration at the Shoubra El Kheima and El Sahel sites often exceeds the 1 $\mu g/m^3$ annual average limit set by GOE Law No. 4, while this standard was met at 19 other sites.

With the shutdown of smelter operations in August 2001, the air quality has improved significantly in Shoubra El Kheima, with an average Pb10 of 9 $\mu g/m^3$ — a 82% reduction. However, contaminated windblown dust from the smelter site still remains a potential hazard. Data on wind direction, presented in Appendix C, indicates that the predominant wind direction is from the north-northeast of the site, with sustained winds of up to 10 km/hr and gusts occasionally considerably higher. High wind speeds provide the energy needed to suspend loose particles from a surface. Turbulence associated with these winds elevates particles to high altitudes, where they can be transported over long distances.

5.1.2 Potential Receptors

Based on the data presented above, it is clear that residents living south of the site have a higher potential of being exposed to fugitive dust emanating from the site than those living in other directions. The degree of this exposure is dependent on several factors, including:

- Particle size
- Surface loading
- Surface conditions
- Wind speed
- Moisture content
- Vehicular movement
- Industrial and construction activity

How these factors affect the movement of fugitive dust is detailed in the Labib et al (2001) study. However, there is a potential for fugitive dust from the site to be deposited on the Ismailia Canal (just south of the site), contaminating surface water. It can also be deposited on nearby school yards, where the dust could be inhaled or ingested by children, on residential areas, or on agricultural products, which may be consumed by the public. In addition, workers still at the site, who will be involved with remediation efforts, could also be affected.

Calculating the exposure potential of workers, nearby populations, and the environment is beyond the scope of this work. Further investigation of fugitive dust from the site will need to be completed to gain a better understanding of the air pathway and exposure rates, as well as determine risks to human health and the environment.

5.2 Water

There are two water pathways through which contaminants can be transported from the site:

- Surface water of the Ismailia Canal, on which fugitive dust may be deposited, or stormwater runoff that may be discharged into the canal
- Groundwater in the Nile River alluvial aquifer underlying the site

Because of the limited scope of this assessment, these pathways are not well understood. However, the site investigation sheds light on whether these pathways pose a threat to human health and the environment.

5.2.1 Surface Water

The main surface water in the direct vicinity of the site is the Ismailia Canal. Water from this canal is used for irrigation, industry, and water supply for municipalities as it flows to the northeast away from the site. Data presented in IWACO Egypt ‘s site investigation report, including in Appendix B, indicates that concentrations of selenium, cadmium, mercury, and lead are often above GOE Law 48/82 and World Health Organization (WHO) drinking water standards.

The canal, as defined in Appendix B, is considered a point of recharge to the underlying Nile River alluvial aquifer. This indicates that water from the canal replenishes water in the aquifer, with groundwater flowing away from the canal. Since concentrations of dissolved lead in canal waters range from 0.02 to 0.22 mg/l, the canal is a major source of lead contamination in the aquifer.

Contaminated stormwater runoff and fugitive dust from the site may also affect the canal’s water quality, albeit to a minor extent. This is because average rainfall rates are low at about 25 mm per year, producing little runoff from the site. In addition, the site is mostly covered, limiting the amount of fugitive dust that can be released into the air. However, should the site be demolished, the potential for stormwater runoff and fugitive dust entering the canal may increase.

5.2.2 Groundwater

The second water pathway is groundwater. As mentioned earlier, the site overlies a major aquifer that consists of sands and gravel covered by silt and clay. Leaching of contaminated wastes from the site to groundwater is considered of limited concern due to four factors:

1. *Limited rainfall, coupled with the fact that the site is mostly covered, inhibit recharge to the aquifer.* To generate leacheate, waste must come in contact with water. Because of the limited amount of rainfall (averaging 25 mm/year) and the fact that the building is for the most part covered, leacheate generated from waste within the smelter is limited. However, during the site investigation (Appendix B), it was not noted that waste oil was found in at least one of the boreholes, and that the site has process water tanks that may have leaked over time. In addition, portions of the site were once used for battery breaking. During this process, acid was most likely spilled on the ground, dissolving lead and other contaminants. Each of these factors may have provided enough liquid to transport the leacheate downward toward the aquifer.

2. *Silt and clay layers above the aquifer provide sufficient ion-exchange capabilities to retain lead and other contaminants in the soil.* Boreholes drilled on site indicate that there is a layer of silt-clay soil that extends to 14 m below ground surface. Although saturated below 5 m, this layer acts as an aquiclude that prohibits the downward migration of contamination from the site. However, soil analysis indicates that some leaching of contamination has occurred over time, with levels of lead, cadmium, and other contaminants higher than natural levels at 6 to 8 m below ground surface or up to 3 m below the water table.

3. *Significant sources of aquifer contamination exist in the direct vicinity of the site.* One the major concerns of this study is that the aquifer in the direct vicinity of the smelter is already contaminated. Well samples indicate that both upgradient and downgradient wells exceed drinking water standards for lead and other contaminants (see Section 3, Hazard Assessment and Appendix B). There are numerous sources for this contamination, including the Ismailia Canal and up to 36 factories, as presented in Table 5-1 below.

Table 5-1. Other Potential Polluters

1.	National Plastics Company	19.	El Haj Abdel Monaim Foundary
2.	Mostorod Metal Company	20.	Aly Abu Sre'a Foundary
3.	Co-op Fuel Station	21.	Mahmoud Abdel Monaim
4.	Egyptian Textile and Dyeing	22.	Hashem Ibrahim Foundary
5.	Abdel Gabbar Dyeing, Printing	23.	Egyptian Company for Steel
6.	Esso Fuel Station	24.	Metal Forming Workshop
7.	Mobil Fuel Station	25.	Samira Takhtoukh Tyres
8.	El Ahram Foundary	26.	Samir Zaki Metal Forming
9.	El Mohandes Foundary	27.	Abdel Nabi Nassar Foundary
10.	Fouad Foundary	28.	Sayed Awadallah Lead
11.	El Gehad Foundary	29.	Paints Factory
12.	El Sad El Aaly Foundary	30.	Samir Morgan Tyres Factory
13.	El Azizy Foundary	31.	Plastic Factory
14.	Noval Factory	32.	Tyres Factory
15.	Hassan El Kassas Foundary	33.	El Dalta for Steel
16.	Arab Contractors Central	34.	El Haj Megahed Scouring
17.	Salah Attia Foundary	35.	El Haj Talaat Plastic Factory
18.	Mohamed Kamel Foundary	36.	El Salam Glass Factory

4. *Water from the nearby aquifer is used only for industrial purposes.* Water from this aquifer is consumed by various industries in the area. To our knowledge, it is only used for industrial purposes, and not for showers or drinking water.

Because groundwater is an important resource, an assessment was undertaken despite the fact that contamination is limited due to the four factors outlined above. Additional boreholes and wells were drilled to determine if groundwater in the direct vicinity of the smelter was affected by its activities. The paragraphs below present a brief summary of this assessment. Additional details are included in IWACO Egypt's site investigation report in Appendix B.

Recharge. The main source of recharge to the aquifer underlying the site is the Ismailia Canal. Additional recharge occurs from the Nile River and minor recharge comes from direct precipitation. Water levels in the canal and the Nile River are a controlling factor to recharge in the area. The higher the levels, the greater the recharge. Table 5-2 below presents the average water surface levels reported in the year 2000 for both the Ismailia Canal and the Nile River.

Table 5-2. Water Levels for the Year 2000
(all figures in meters amsl)

Period	Ismailia Canal	Nile River
Summer (May to August)	16.14	16.96
Winter (September to April)	15.72	16.79
Winter Closure (Mid-January to Mid-February)	15.52	16.52

As stated earlier, the canal is a potential source of contamination to the aquifer. However, the amount of recharge occurring at any given time from the canal or the Nile River is uncertain. Therefore, the loading of contaminants from these sources to the aquifer has not been calculated.

Discharge. Groundwater movement is toward the north, with aquifer discharge most likely going toward the Nile River. A well survey conducted by IWACO Egypt indicates that 92 wells at 72 locations are discharging about 3 million m^3 of groundwater per year.

Movement. The shallow aquifer at the site appears to be under water table conditions, with the deeper sand/gravel aquifer under semi-confined conditions. Groundwater movement occurs in two regimes in the shallow saturated silts and clays, and in the deeper, more permeable sands and gravel of the main alluvial aquifer. General movement in these regimes is primarily to the north at a relatively flat gradient of 0.14-0.17 m/km. In the area of the smelter, the hydrogeological map shows that movement is toward the northeast, with a must steeper gradient of 1.0-1.2 m/km. In addition, minor downward movement of water can occur in the unsaturated zone above the water table.

With a hydraulic gradient of 1.0 m/km and a permeability of 50 m/d, the average groundwater flow velocity (Darcy's velocity) from the site is 0.05 m/d or 5 cm/day, using Darcy's Law:

$V = ki$ where V = velocity
k = hydraulic conductivity (permeability)
i = hydraulic gradient

Groundwater quality. As described in Section 3, "Hazard Assessment," and Appendix B, groundwater quality in upgradient and downgradient wells exceeds Egyptian and international drinking water standards. Well samples taken by IWACO Egypt within and just outside the site indicate that shallow groundwater for shallow piezometer MW-3 has lead concentrations above drinking and ambient water quality standards, as presented in Table 5-4 below. In addition, water quality appears to improve with depth, with lead concentrations for filtered samples being undetectable as opposed to a lead concentration of 0.159 mg/l for the sample from the shallow piezometer at MW-3.

Table 5-4. Groundwater Analyses of Samples Taken from Monitoring Wells at the Awadallah Lead Smelter in Shoubra El Kheima

Well No.	Name of location (Type of sample)	Sample Label	Well Depth (m)	pH	Eh	Ec (mmos/cm)	Salinity (mg/l)	Pb (mg/l)	Cd (mg/l)
Mw1	**Ismailia Canal**								
	Deep piezometer (Raw)	1D01	20 m	8.08	-0.477	346	221.44	0.015	ND
	(Raw Duplicate)	1D02						ND	0.003
	(Filtered)	1D03						ND	ND
	Shallow Piezometer (Raw)	1S01	6.25 m					0.02	0.002
	(Raw Duplicate)	1S02						0.015	0.001
	(Filtered)	1S03							
Mw2	**Playground**								
	(Raw)	201	20 m	8.80	-0.519	336	215.04	0.012	ND
	(Raw Duplicate)	202						0.01	0.001
	(Filtered)	203						ND	ND
Mw3	**Sayed Awadallah Lead Smelter**								
	Deep Piezometer (Raw)	3D01	20 m	8.42	-0.497	440	281.60	ND	ND
	(Raw Duplicate)	3D02						0.01	ND
	(Filtered)	3D03						ND	ND
	Shallow Piezometer (Raw)	3S01	6.25 m	8.49	-0.501	1549	991.36	0.171	0.003
	(Raw Duplicate)	3S02						0.515	0.002
	(Filtered)	3S03						0.159	0.003
Mw4	**In front of Saad Thomas Smelter**								
	(Raw)	401	20m	8.94	-0.527	541	346.24	ND	ND
	(Raw Duplicate)	402						ND	ND
	(Filtered)	403						ND	ND

5.2.3 Potential Receptors

The only users of groundwater in the area are various industries identified in IWACO Egypt's well survey, which are presented in Appendix B, along with their respective consumption rates. This groundwater is only used for industrial purposes such as washing equipment. To our knowledge, it is not used for drinking, showers, or any other purpose. The nearest well downgradient from the site is located in Noval factory, about 1.5 km away. Assuming an average flow velocity of 0.05 m/day, it would take approximately 80 years for contamination from the smelter to reach this site. This assumes no retention of the contamination in the aquifer due to absorption or other geochemical processes.

5.3 Direct Contact

The third and final pathway is that of direct contact to contaminated dust and soils by workers and others. Currently, access to the smelter is controlled and only authorized personnel can enter the premises. However, these workers are exposed daily to fugitive dust, which they inhale or ingest. In addition, clothing worn by these workers is also contaminated by directly contacting the contaminated dust within the plant, which has up to 33% lead content. This clothing is then taken to the workers' homes, where children may be exposed by direct contact with the contamination.

With time, these workers will be relocated to the new smelter facilities in Abu Zaabal. Once the smelter is abandoned, remediation workers and children playing at the site could still come into direct contact with the contaminated waste unless proper steps are taken to eliminate this pathway.

To date, no studies on the potential exposure to contaminants through direct contact have been performed. Such studies would be an important aspect of future remedial analyses.

6.0 REMEDIAL ALTERNATIVES

This section presents some preliminary remedial objectives and provides insight into remedial technologies applicable in Egypt, along with rough cost estimates. These estimates cover the equipment and personnel required to remediate the site, as well as anticipated requirements for health and safety training, personnel protection, equipment washing and runoff control, and other interventions that can be used during the remediation process to reduce risks to human health and the environment.

6.1 Development of Remedial Objectives

6.1.1 Land Use Requirements

One of the primary considerations in developing remedial objectives for the site is to determine its final land use, which also has a direct bearing on clean-up costs. For instance, if the site is to be reverted back to an industrial area, remediation standards may not be as rigorous as if it were to be converted into a park, playground, or residential building. At this time, final land use for the site after remediation is uncertain. Establishing consensus between the owner and local government will be crucial to determining final land use, which will facilitate remediation planning.

6.1.2 Environmental Standards

In Egypt, environmental standards for lead focus mainly on air and water quality. For air, Law No. 4 sets the maximum annual average of lead concentration in the atmosphere at 1 $\mu g/m^3$. For water, the GOE established standards of 0.05 mg/l of lead for both drinking water and ambient conditions. At the site, both ambient air and water in the Ismailia Canal and in groundwater exceed these standards.

There are currently no lead standards for soil in Egypt. The development of site environmental standards should be an important aspect of the remediation plan. Worldwide lead hazard intervention has mainly focused on impeding the hand-to-mouth pathway of childhood exposure to environmental lead (Pb) sources in soil and dust. The U.S. Environmental Protection Agency recently developed standards identifying lead as hazardous if there is more than 250 ppm of lead in bare soil in children's play areas or an average of 1,200 ppm in residential yards (40 CFR Part 745, January 5, 2001). Consideration is being given for a lead standard in soils and dust at industrial sites of 2,000 ppm. However, standards in the United States vary from state to state. For instance, lead (Pb) in soil standards developed by the State of Rhode Island's Department of Health are as follows:

- *0-150 ppm: lead-free standard.* These soils are considered lead-free. They do not pose a risk to people, nor do they require any remediation measures.

- *150-500 ppm: lead-safe.* These soils are generally considered safe for older children and adults. If small children who eat more dirt than others or absorb

lead easily use these properties, efforts to make them lead-free are suggested.

- *500-1,000 ppm: lead contaminated.* These soils require efforts to keep the contaminated soil covered with at least 8 cm of lead-free soil.

- *1,000-10,000 ppm: significant environmental lead hazard.* Management of hazards would include soil removal and disposal, or covering the soil with concrete, asphalt, or any other permanent cover.

- *Above 10,000 ppm: extreme environmental lead hazard.* Excavation and removal of material would be required.

Lead concentration in dust samples taken from within the smelter ranges from 55,900 to 337,750 ppm. According to the Rhode Island standards, these values indicate an “extreme environmental lead hazard” if the site is left unremediated. Even the dust sample taken from the nearby soccer field would be considered “lead contaminated” at 1,200 ppm.

For other contaminants, arsenic concentration in three of the samples taken within the smelter ranged from 51 ppm to 2,250 ppm. These samples also exceed established U.S. clean-up levels of 20 ppm of arsenic for residential sites and 200 ppm of arsenic for industrial sites. Each sample analyzed for chromium ranged from 3.5 ppm to 30 ppm, exceeding U.S. clean-up standards of 2 ppm of chromium for residential sites and 10 ppm of chromium for industrial sites. Of special concern is the 30 ppm of chromium found in the dust sample taken at the nearby soccer field. Selenium, antimony, and zinc levels are also considered above normal levels. Finally, the upper 0.5 m of soil underlying the plant showed similar high levels of contamination. However, these levels substantially decrease with depth (see Section 3, “Hazard Assessment”).

If these soil and dust samples are considered representative of the site, removal and/or treatment of the shallow soil or at least the dust above the smelter’s concrete floor should be considered as part of the remediation plan. The brick sample analyzed indicates that most of the plant’s building material is not hazardous.

It should be noted that tests using U.S. EPA Method 1311, Toxicity Characteristic Leaching Procedure (TCLP), were performed on the smelter’s waste slag in 1998 (Osborn, 1998) to determine if this material was “hazardous” or “toxic.” The results of these tests indicated that the slag could be disposed of in a landfill without pretreatment. Assuming that the soil and dust within the plant would also be considered “non-hazardous,” this material could also be placed in a properly designed landfill.

Finally, with the completion of the site characterization study, additional information on the quantities of contaminated soils and dust on site will be available. Once the plant is relocated to the new site, additional soil and dust samples will need to be taken to quantify in definitive terms the amount of lead and metal soils on and near

the smelter for proper remediation planning. Specific clean-up standards should also be developed for the site and incorporated in the remediation plan.

6.2 Potential Remedial Technologies

The remediation program for the Awadallah secondary lead smelter in Shoubra El Kheima will serve as a model for similar efforts. Because this process is relatively new in Egypt, it is important to develop a practical program designed to reduce risks to human health and the environment. As described in Appendix B, the remedial actions considered in this assessment include:

1 Doing nothing
2 Limiting access to the building
3 Demolition of the building and salvage
4 Demolition of the building and acid washing salvage material
5 Demolition of the building, acid washing salvage material, and placement of clay cap
6 Demolition of the building, acid washing salvage material, and placement of three-layers cap
7 Demolition of the building, acid washing salvage material, and haulage of contaminated equipment
8 Demolition of the building, acid washing salvage material, and encapsulation of the site
9 Demolition of the building, acid washing salvage material, rinsing of soil, and rinsing of unsalvaged building material

In developing a final remediation program, other technologies may also have to be considered, depending on intended land use and clean-up standards developed for the site. Innovative technologies such as resmelting highly contaminated material, the use of trees and other vegetation to absorb trace metals, and the use of industrial vacuums to collect dust and other contaminants should be evaluated prior to developing a final remediation plan.

6.3 Cost Comparison

In carrying out this preliminary assessment, estimates were developed for each of the options outlined above, taking the following into account:

- Worker protection:
  - *Health and safety training:* setting aside time for employee training
  - *Personal protective clothing:* providing personal protective gear, such as respirators, disposable suits, and gloves
  - *Personal hygiene:* providing an area for clean-up
  - Cost estimates were also developed for medical monitoring, blood tests, and on-site air monitoring.

- Prevention of cross-media contamination:
  - *Dust control:* to prevent fugitive dust from leaving the site

- *Showers and laundry service:* to prevent the contaminated dust from going home with workers
- *Power washing of equipment:* to prevent contaminated soils from leaving the site
- *Runoff control and water treatment:* to keep contaminated wash water on the site
- *Infiltration control:* to keep contaminated wash water from contaminating groundwater
- *Environmental monitoring:* including air monitoring, site visuals, and clearance sampling and testing. The cost of environmental monitoring will be the responsibility of the contractor.

- Management decision factors:
  - *Public acceptance:* Public relations efforts should be conducted during the remediation process.
  - *Technology:* Is the remediation technology available in Egypt? Are studies required to ensure that the technology will work on site? If so, how much will these studies cost?
  - *Waste disposal costs:* The nature of the waste will determine cost. Debris that may be hazardous will require special handling.
  - *Moving and relocation costs:* Owner relocation can affect contract price.
  - *Bonding and liability insurance cost:* The nature of the coverage and type of liability covered, along with bonding issues necessary for some contracts, can greatly affect project costs.
  - *Clearance testing:* Clearance testing includes the cost of the inspectors' time and the cost to have a laboratory test the samples and report the results. However, it should be noted that failures on clearance samples will require additional cleaning in the unit. This could also affect relocation costs with tenants, additional testing costs, and in some cases performance bond issues.
  - *Damages:* Resolution of disputes over private property damage can be an issue because of the proximity of neighboring buildings.
  - *Engineering problems:* Unforeseen problems can arise throughout the project. Weather may on occasion be a problem and delivery of materials and equipment may be difficult. This kind of work is new to Egypt and was costed accordingly.

Table 6-1 below illustrates how these considerations were taken into account in costing various remedial alternatives.

Table 6-1. Remediation Considerations Matrix for Awadallah's Secondary Lead Smelter in Shoubra El Kheima

ACTION	Worker Protection			Prevention of Cross-Media Contamination								Management Decision Factors			
				Prevention				Water Treatment					Technology		
	Health/Safety Training	Protective Equipment	Personal Hygiene	Monitoring	Dust Control	Showers & Laundry	Runoff Control	Treatability Studies	Primary Settling	Neurtralization	Discharge to Sewer	Public Acceptance	Availability in Egypt	Studies Required	Costs
1. Doing nothing												L	H	N	L
2. Limiting access to building												L	H	N	L
3. Demolition of building and salvage	√	√	√	√	√	√						M	H	N	M
4. Demolition of building and acid washing salvage material	√	√	√	√	√	√		√	√	?	?	M	H	N	M
5. Demolition of building, acid washing salvage material, placement of clay cap	√	√	√	√	√	√	√	√	√	?	?	M-H	H	N	M-H
6. Demolition of building, acid washing salvage material, placement of three-layers cap	√	√	√	√	√	√	√	√	√	?	?	H	M	N	H
7. Demolition of building, acid washing salvage material, haulage of contaminated equipment	√	√	√	√	√	√	√	√	√	?	?	H	L	N	H
8. Demolition of building, acid washing salvage material, encapsulation of site	√	√	√	√	√		√	√	√	?	?	H	M-H	N	M-H
Others	√	√	√	√	√	√	√	√	√	?	?	H	L	Y	H

Table 6-2 presents preliminary cost estimates, developed by IWACO Egypt, for each of the alternatives presented above. Details and assumptions are presented in Appendix B. These costs should be used for comparison purposes only.

Table 6-2. Estimated Costs for Remediation Alternatives

Alternative No.	Description	Estimated Cost
1	• Doing nothing	N/A
2	• Limiting access to the building using guards (5 years)	L.E. 237,877
3	• Demolition of the building and salvage	L.E. 575,875
4	• Demolition of the building • Acid washing salvage material	L.E. 705,651
5	• Demolition of the building • Acid washing salvage material • Placement of clay cap	L.E. 871,863
6	• Demolition of the building • Acid washing salvage material • Placement of three-layers cap	L.E. 1,032,740
7	• Demolition of the building • Acid washing salvage material • Haulage of contaminated equipment	L.E. 723,934
8	• Demolition of the building • Acid washing salvage material • Encapsulation of the site	L.E. 1,068,159
9	• Demolition of the building • Acid washing salvage material • Rinsing of soil • Rinsing of unsalvaged building material	L.E. 1,633,305

In comparing these costs, it is important to evaluate their potential to reduce risks to people and the environment. Risk may be defined as follows:

RISK = the probability of an event occurring X the consequences

With this in mind, both near-term and long-term risks to people and the environment posed by the site must be considered. In the near term, limiting access to the building will considerably reduce risks to people and the environment. During remediation of the site, there will be a higher probability that remediation workers and others will be exposed to contamination, therefore increasing risks. In the long term, however, remediation of the site will reduce the probability of exposure to contamination, therefore decreasing risks.

As illustrated in Figure 6-1, near-term and long-term risks can be directly related to costs. In the short term, limiting access to the building is the least expensive option (except for doing nothing) and poses the least risk. As costs go up, more people become involved and the probability of exposure becomes greater. In the long term, the opposite is true: the higher the costs, the more likely it is that pathways for contaminants to the environment will be eliminated and long-term risks reduced. Risks to people and the environment from the site can be further reduced by using the risk management procedures outlined above.

6.4 Conclusions

Based on the results to date, the following conclusions can be drawn regarding the site's remediation needs:

1. Dust, soil, and surfaces contaminated by lead, cadmium, antimony, selenium, and arsenic are the principal hazards found at the site.

2. Through atmosphere dispersion, surface water, and direct contact, air is the major pathway of these contaminants to the environment.

3. Contaminated dust, soil, and waste within the smelter site pose a significant health and safety threat to workers, nearby residents, and the environment.

4. Although surface water and groundwater are considered major pathways to the environment, exposure to contaminants through water consumption is limited due to the following factors:

    a. Rainfall averaging only 25 mm per year limits stormwater runoff from the site and the leaching of contaminated lead and other contaminants from soil and dust.

    b. Groundwater in the area is consumed only for industrial purposes.

    c. The Ismailia Canal, considered the point of recharge for the aquifer, is contaminated with lead above GOE ambient quality standards, and is most likely a source of contamination for the aquifer.

    d. There are at least 36 other industries near the smelter that may be sources of contamination.

Based on the results to date, it is not possible to determine the best remediation option for the Awadallah secondary lead smelter in Shoubra El Kheima. This is mainly due to the fact that intended land use and specific remediation standards have yet to be developed for the site. However, it can be concluded that the final selection of the best remedial measure must be based on economics and the desire of the company to reduce risks to people and the environment. In light of the conclusions presented above, actions presented in the site's remediation plan should include the following:

- Remove contaminated dust from the floors, walls, and ceiling of the smelter site

- Clean and remove recyclable material from the site, including the corregated steel roof of the building, the stack, and the machinery

- Remove all contaminated material to a secured landfill or encapsulate the building site in concrete

- If the soil under the building is exposed to rain and wind, remove contaminated soil down to 1 m below ground surface and place it in a secured landfill

- Control access to the site, whether the smelter is demolished or not

- Control fugitive dust and direct contact with contaminants at the site through an appropriate remediation method to prevent further exposure to workers, nearby residents, especially children, and the environment

- Develop a monitoring plan for groundwater and surface water, though remediation is not recommended at this time

Through the Lead Smelter Action Plan (LSAP), Awadallah has expressed the desire to remediate the smelter. However, the costs associated with even the minimum steps required for remediation may be considered too high. To make a good decision as to the proper alternative, it is important to understand not only the economics but also the concept of risk reduction.

Finally, steps can be taken to identify the proper alternative through remediation planning. This requires taking into consideration factors such as remediation costs, land use requirements, clean-up standards, and the desire for risk reduction. The section that follows provides recommendations for appropriate remediation planning for the smelter site.

7.0 REMEDIATION PLANNING

So far, this report has provided a good indication of the potential hazards found at the Awadallah secondary lead smelter in Shoubra El Kheima and contaminant pathways to the environment. However, little has been said about how potential receptors can be exposed to these hazards and what the potential consequences might be if the site is left unattended. In addition, no recommendations have been made as to the most economically feasible way to remediate the site and reduce the level of risk to nearby residents. To address these issues, the Cairo Air Improvement Project (CAIP) has developed a conceptual remediation plan for the smelter.

This plan is based on the U.S. Environmental Protection Agency's CERCLA (Superfund) process. It consists of the following basic steps:

1. *Remedial investigation/feasibility study.* This step requires collecting additional environmental data on site, further analyzing pathways to potential receptors, evaluating exposure rates, developing a qualitative risk assessment with site clean-up standards, and defining specific remediation alternatives. Based on the results of the remedial investigation, a feasibility study will be conducted for each alternative.

2. *Economic evaluation.* Based on the results of the feasibility study, an economic evaluation will be conducted to determine the most cost-effective method of remediating the site.

3. *Remediation plan.* This task involves developing a final plan for the site, including terms of reference for the remediation contractor, a health and safety plan for the site, and detailed designs to meet final land use requirements.

This process is intended as a guide for the EEAA in developing guidelines for other sites. Throughout the process, CAIP will work with the smelter owner, the governorate, the municipality, and the EEAA to secure agreements on issues such as funding, final land use determination, procurement of land for staging operations, and other factors.

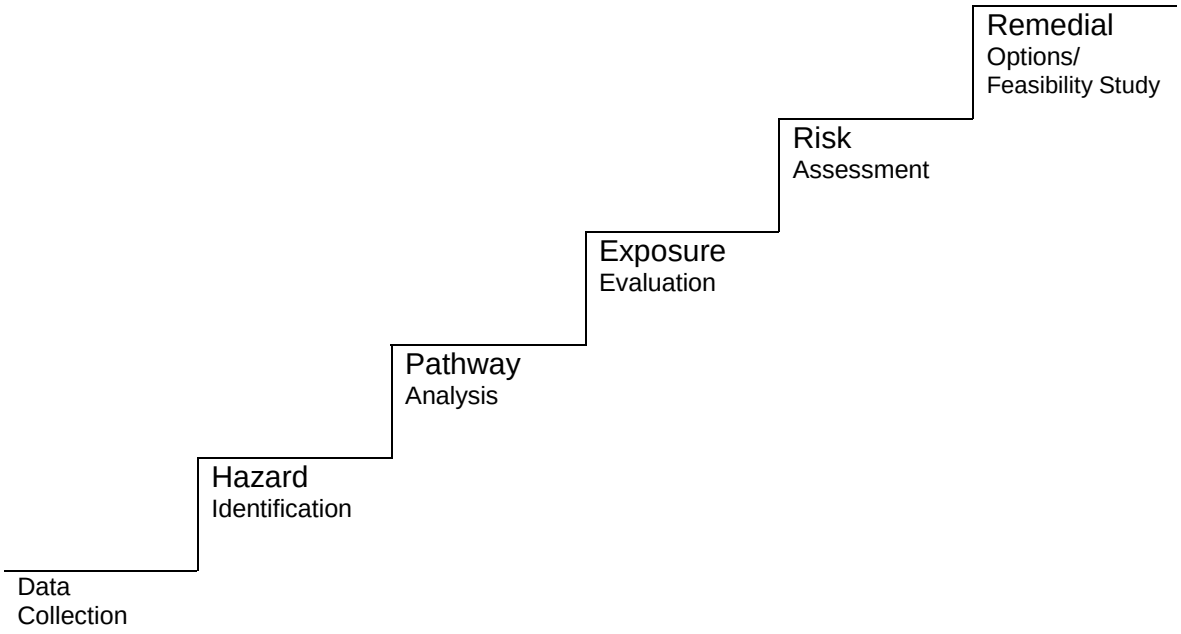
7.1 Remedial Investigation/Feasibility Study

As illustrated in Figure 7-1, a step-wise approach has been developed for remedial investigation of the site. This approach consists of:

- *Data collection* on the environmental setting and site history
- *Hazard identification* to characterize the potential hazards of the site in terms of the source of contamination, the nature and extent of contamination, and other factors
- *Pathway analysis* to define the potential pathways to people and the environment, including water and air

- *Exposure assessment* to define potential receptors and how they may be affected by various remediation alternatives
- *Risk assessment* to determine the probability of an event occurring, multiplied by the consequences
- *Risk management* (remedial action plan development) to develop remediation alternatives and implement the preferred option

Figure 7-1. Step-Wise Approach for the Development of Remedial Options



The following paragraphs briefly summarize the findings to date and what is being done to fill data gaps.

7.1.1 Data Collection

The following work has been completed to date:

- Review of existing data on water and air resources at the site
- Definition of types of waste
- Preliminary quantification of waste
- Data obtained from air monitoring, well completions, and literature search for preliminary pathway analyses
- Completion of a preliminary pathway assessment
- Preliminary quantification of contaminated material and soils

Data collection to date is suitable for a preliminary assessment of the site. However, much more needs to be done to develop a final site remediation plan, including the following:

1. The preliminary assessment of contaminated material at the site does not include roofing material or other metal items that could be recycled. Because the smelter was still in operation when this report was developed, it was not possible to identify the exact quantity of material that will need to be disposed of. Once the smelter has been entirely moved, a demolition firm will be contracted to develop more exact quantities. In addition, at least 10 additional boreholes should be drilled within the smelter to further quantify the extent of contaminated soils.

2. No data is currently available for exposure assessment. The blood lead levels of children and residents living near the smelter is not know. Initial contact with the Egyptian Public Health Department indicates that no such data is available. In the next data collection phase, a blood sampling program should be designed and implemented in the area.

3. Although surface and groundwater are not considered major pathways for contaminants, a monitoring program for the Ismailia Canal and existing wells should be implemented to determine the effects of the remediation process on these resources. In addition, pump tests should be performed on existing wells to determine hydraulic characteristics of the aquifer. This would help develop a transport model for the site should long-term monitoring indicate that such a model is appropriate.

4. An air monitoring program within the plant site should be implemented to help develop a remediation worker protection plan.

5. More details are required on waste containers, storage tanks, and any other potential physical hazards (e.g., electric lines) that may affect remediation.

6. Additional information is needed on the population and related land use in the direct vicinity of the site to serve as a basis for the exposure assessment.

7. A system should be developed to document and record additional data collected at the site. Terms of reference should also be developed for contractors to collect this data.

7.1.2 Hazard Identification

For the most part, hazard identification has been completed. However, additional hazards may be identified during the remedial investigation of the site.

7.1.3 Pathway Analysis

As with hazard identification, a preliminary pathway analysis has been completed. However, a more detailed program should be designed and implemented once additional information on the air, water, and direct exposure pathways is obtained.

7.1.4 Exposure Evaluation

Limited information is available to conduct an exposure assessment of the site. However, points of exposure include:

- Workers inside the plant through dermal exposure and inhalation
- Nearby residents through the inhalation of dust and dermal exposure
- Children playing on the nearby soccer field through inhalation of dust and dermal exposure
- Direct leaching of lead through groundwater to the Ismailia Canal
- Consumption of contaminated groundwater from industrial and domestic water supply wells

The availability of blood lead analysis in the area is uncertain. If data is limited or unavailable, steps should be taken to develop a before-and-after study to determine how remediation will affect workers and, if possible, nearby residents.

7.1.5 Risk Assessment

Because specific remediation standards have not been developed, it is not possible to determine what degree of remediation is required to reduce the risks posed to nearby residents and remediation workers. As data is obtained and evaluated, the potential risks of exposure to lead and other contaminants due to various remediation schemes must be evaluated, and standards for site remediation developed.

7.2 Remediation Alternatives Development/Feasibility Study

For this preliminary assessment, several remediation alternatives were considered, along with rough estimates of associated costs. Each alternative presents both advantages and disadvantages. Additional data collected during the remedial investigation will facilitate a more thorough evaluation and precise costing for each option described in Section 6, as well as others. A feasibility study will then be carried out to identify two to three appropriate options.

7.3 Economic Analysis

Based on the results of the remedial investigation and feasibility study, a detailed economic evaluation of the selected alternative will be conducted. This study will consider costs as well as the applicability of remediation programs to Egypt. Working with the owner and the EEAA, the most suitable remediation alternative will be selected.

7.4 Remediation Plan

Developing a remediation plan is crucial and should be completed before any work is done at the site. The remediation plan will be based on the remedial investigation and designed specifically for the accepted remediation alternative. By anticipating

and taking steps to prevent potential health and safety hazards, work can proceed with minimal risks to workers and the public.

In general, developing a remediation plan involves three phases:

1 Developing organizational structure for site operations
2 Establishing work plans for each specific phase of the operation
3 Designing and implementing a health and safety plan

7.4.1 Organizational Structure

The organizational structure will identify personnel needs for the operation, establish the chain of command, and specify the responsibilities of each employee. Among other things, this structure will:

- Identify a leader who has the authority to direct all activities
- Show lines of authority, responsibility, and communication
- Ensure that the remediation contractor has the proper equipment to do the job
- Assign responsibilities for personal protective equipment and inspection
- Provide mechanisms to control entry to and exit from the site
- Define worker responsibilities
- Develop a monitoring program for on-site hazards
- Define procedures to work with government personnel and local residents
- Enforce safety procedures
- Enforce site control
- Manage field operations
- Enforce cleaning of equipment and personal hygiene
- Maintain equipment
- Maintain medical care
- Ensure that waste is handled properly

7.4.2 Work Plan

Work plans should be developed for each anticipated clean-up activity and periodically reexamined and updated as new information about site conditions becomes available. The following steps should be taken in developing each work plan:

- Review available information (by the responsible person)
- Define work objectives
- Determine methods of accomplishing objectives
- Evaluate training needs of personnel
- Define equipment requirements

The preparation of these work plans requires a multidisciplinary approach. Input from all levels of management, as well as outside consultants, should be encouraged.

7.4.3 Health and Safety Plan

The health and safety plan must provide measures to minimize accidents and injuries that may occur during remediation activities at the site. This requires developing a written health and safety plan to ensure that all safety aspects of site operations are thoroughly examined prior to launching field work. The plan should include:

- Names of key personnel
- Description of health and safety risks at the site
- Description of personal protective clothing required
- Definition of air monitoring program
- Description of actions to be taken to mitigate existing hazards
- Definition of site control measures to be implemented
- Written set of standard operating procedures
- Training requirements

Before the work begins, all personnel should be properly trained in accordance with the plan and applicable regulatory requirements.

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APPENDIX A:

Site Photographs

Awadallah's Secondary Lead Smelter at
Shoubra El Kheima

Lead Ingots Currently Stored at the Smelter

Lead Pipe Extruded at the Plant Site

Refining Kettles

Rotary Furnace

Bag House

Duct Work

Battery Grids

Extrusion Area

Courtyard

Stack

Nearby Soccer Field

Residential Building Across the Street

Monitoring Well Drilling

Filtering Groundwater Sample

APPENDIX B:

IWACO'S Groundwater Investigation

Awadallah's Secondary Lead Smelter at Shoubra El Kheima

consultants
for environment & management

Chemonics International, Inc.
Cairo Air Improvement Project

Project no.: 54.0018

Groundwater Investigation of a Secondary Lead Smelter in Shobra El-Keima

Subcontract Number
263-C-01-LPA-009

CLIN –3,4, AND 5
FINAL REPORT

Cairo, February 2002

COLOFON

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Project Number: (Project 54.0018)

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Annex 8 Cost Analysis

LIST OF ABBREVIATIONS

amsl	above mean sea level
CAIP	Cairo Air Improvement Project
CLIN	Contract Line Item Number
EGSMA	Egyptian Geological Surveying and Mining Authority
LEAP	Lead Exposure Action Plan
LSAP	Lead Smelter Action Plan
MOHP	Ministry of Health and Population
MWRI	Ministry of Water Resources and Irrigation
NWRP	National Water Resources Project

1. INTRODUCTION

On September 4th 2001, Chemonics International / CAIP commissioned IWACO Egypt to carry out an investigation mission to assess the extent of pollution potentially generated by Sayed Awadallah Lead Smelter (the Smelter) in Shobra El-Khema. On December 6th, 2001, the contract was amended and accordingly this mission is to be carried out in five (5) consequent activities:

1- CLIN-1: Initial Literature Review and Well Survey,
2- CLIN-2: Well Drilling, and Soil Sampling Report,
3- CLIN-3: Sampling and Analysis Report,
4- CLIN-4: Cost Estimate for Remediation Alternatives, and
5- CLIN-5: Final Report.

This report is the last report. It includes the findings of CLIN-1 to CLIN-5. It is our aim to build the reports one over the other so that the last report will be a stand-alone document which contains all the findings of this mission. Under CLIN-1, IWACO-Egypt should review existing literature, and carry out a well survey for the area surrounding the Smelter and within one Km radius of it. Under CLIN-2, boreholes and monitoring wells are to be drilled, soil samples are to be collected and analysed. In CLIN-3, water and soil analysis to be presented and discussed. CLIN-4 was amended to present estimates of different alternatives remediation costs. And CLIN-5 is the final report were all the findings are consolidated.

- **Main objective**

The main objective of CLIN-1, as specified in the Statement of Work, is to : "preliminary define the site's hydro-geology regime and, to the extent possible, determine if there are any wells being used for domestic or industrial water supply purposes within a radius of one kilometre of the site. In addition, this task shall define other potential sources of pollution that may have impact on the hydrogeology system."

As for CLIN-2, the main objective is to: "define the hydrogeologic regime in the direct vicinity of the Smelter". This includes the drilling of four (4) boreholes to collect soil samples from inside the Smelter's boundaries, and to drill and install six (6) monitoring wells to collect water samples from the area immediately surrounding the Smelter's site.

For CLIN-3, the objective is to: "determine the concentration of trace metals including Lead, Cadmium, Antimony, and Arsenic in groundwater in the direct vicinity of the Shoubra El-Kheimah smelter as well as field measure field parameters including pH, Eh, specific conductance, temperature, and salinity of the groundwater at the site". Samples were also analysed for Selenium as a trace element.

CLIN-4 aims to "the development of preliminary cost estimates for site remediation" with different options.

CLIN-5 is to: "present the findings of the investigation, and recommendations on remediation methods to CAIP so that decisions can be made regarding the most appropriate remediation methods to be used". The report should include "hydro-geology of the site, geologic logs, well completion reports, groundwater quality, and

other findings of the investigation. It shall also contain recommendations for future work and a monitoring plan".

- **Methodology**

The activity was carried out using the following methodology:

(1) CLIN-1

- A desk study analysed the available data relevant to the subject. Annex1 – References, contains a list of documents reviewed. The main source of these documents is the IWACO / IWACO-Egypt document's library.
- Several site visits, to the Smelter and the area, mainly to assess the current land use and to locate the used wells. A GPS tool was used for accurate location of wells.
- For the estimation of the groundwater movement directions, a preliminary groundwater model was used.

(2) CLIN-2, 3

- A specialized subcontractor was hired for the drilling of the boreholes and collection of the soil samples.
- A sampling vehicle, equipped was enough tools for water collection, was used to collect the water samples from the existing water wells in the surrounding area.
- Samples of both soil and water were sent to the EGSMA laboratories for analysis.
- Samples were collected and analysed following the IWACO QC standards.

(3) CLIN-4

- A general outline for the cost items was designed.
- Each cost item was than sub-itemized to the basic cost components
- Cost component were estimated from: (1) interviews of specialised contractors, and (2) own experience of IWACO-Egypt.
- An Excel Work-Book (containing about 12 sheets) were used to store the data, handle information, and generate reports.

(4) CLIN-5

- The report was compiled to include all the findings and the overall recommendations.
- The report is considered a stand-alone piece.

- **Structure of the Report**

The report is structured following the items identified in the Statement of Work.
After this "Introduction", the "The geological nature and the extent of the aquifer"; including the location, the climate, the land use, the topography, the depth to the groundwater table, the geology and the soil, and the definition of the main aquifer, are described. Following this, some parameters are introduced as "The hydraulic properties of the aquifer". "Sources of recharge and sinks of discharge" are then calculated and presented. Other necessary information are presented and discussed as "Groundwater pollution assessment" with main emphasis on identifying other potential polluters in the area. "Soil sampling program" and "Water sampling program" are then discussed and presented. "Findings" for both soil sampling and water sampling are presented in this section. The last section, "Recommendations", discusses mainly the program for the coming period.

2. THE GEOLOGIC NATURE AND THE EXTENT OF THE AQUIFER

Location

The Smelter is located in a predominantly industrial area in the district of Shobra El-Kheima, Qalyubia Governorate. The Smelter is about 1,200 m downstream the intake of Ismailia canal and 120 m North to its left bank.

Climate

The area is subject to arid climatic conditions. Annual rainfall is low with a long term average of 25 mm/year. Average daily air temperatures are between 28 °C in the summer and 13 °C. the potential evapo-transpiration is more than 4,000 mm/year, with a maximum in the summer that exceeds 15 mm/day.

Land Use

Currently, the area under investigation is predominantly industrial area with some semi planned residential areas and scattered agricultural plots. The whole area was agricultural land until early sixties, when heavy -public owned- industries was introduced to the area. Small industries; including the Smelter, similar smelters, and small workshops, invaded the area in an unplanned manner only in late seventies. A map for land use in shown in Annex 2.

Topography

The topography of the area is almost flat with an average altitude of 17 m amsl.

Depth to groundwater table

The average depth to the water table in the area is 5-6 m.

Geology and Soil

The area, in general as part of the Northern tip of the Nile Delta, is an alluvial plain. The alluvial plains are formed as the Nile floodplain. Such silty and sandy clay deposits (Holocene – Q3) are overlaying the graded sand and gravel Pleistocene aquifer (Pleistocene – Q1) .

The Main Aquifer

The main aquifer belongs to the Quaternary formation -that is Nile recharged formation. The Holocene (Q3) layer is about 15 m thick, in the area of investigation, and the thickness of the Pleistocene (Q1) is not definitely known but extends beyond 200 m deep. The lower layer is considered the main confined aquifer, the upper layer is the aquitard confining layer.

3. THE HYDRAULIC PROPERTIES OF THE AQUIFER

Topography
The topography of the area is almost flat with an average altitude of 17.5 m amsl.

Depth to groundwater table
The average depth to the water table in the area is 5-6 m.

Hydraulic parameters
The Hydraulic Conductivity of the aquifer is around 50 m/d, and its transmisivity is ranging between 5,000 to 15,000 m^2/day.

4. SOURCES OF RECHARGE AND SINKS OF DISCHARGE

Sources of Recharge

The main source of recharge to the local aquifer is primaraly the Ismailia Canal, and then the River Nile. The average water surface levels, in this area as reported for the year 2000, for both the Ismailia canal and the River Nile body are as follows (in meters amsl):

Table-1: Surface Water Levels

	Ismailia canal	**River Nile**
Summer (May to August)	16.14	16.96
Winter (September to April)	15.72	16.79
Winter Closure (Mid January to Mid February)	15.52	16.52

Sinks of discharge

As the general direction of groundwater being to the North, the main sink the water leaving the aquifer to the North. However, the survey of the area shows that 92 wells, in 72 locations, are abstracting a caculated total sum of about 3 million m^3/year which is a considerable about for a local groundwater model. The following table shows these industries and their calculated abstraction rate.

Table-2: Inventory of the existing Wells

No.	**Establishment**	**Coordinates**		**No. of wells**	**Annual abstraction** (m3/year)	**Nature of well**
		North	East			
1	National Plastics Company	30 06' 46.6"	31 15' 50.2"	3	234,000	deep
2	Cotton Scouring Factory	30 06' 36.0"	31 15' 49.1"	1	18,720	shallow
3	Brick Factory	30 06' 36.7"	31 15' 44.7"	2	65,520	shallow
4	Ice Factory (Mohamed Zouel)	30 06' 37.8"	31 15' 52.2"	1	174,720	deep
5	Mostorod Metal Company	30 06' 37.8"	31 15' 52.2"	1	124,800	deep
6	Al Aziz for Textile Threads	30 06' 51.1"	31 15' 48.7"	1	24,960	shallow
7	Co-op Fuel Station	30 06' 51.1"	31 15' 48.7"	1	21,840	shallow
8	Egyptian Textile and Dyeing	30 06' 58.0"	31 15' 44.5"	3	436,800	deep
9	Ismail Awad Brick Factory	30 06' 56.4"	31 15' 45.1"	1	2,600	shallow
10	Agricultural Land	30 06' 51.5"	31 15' 51.0"	1	43,680	
11	Agricultural Land	30 06' 54.7"	31 15' 48.8"	1	24,960	
12	Abdel Gabbar Dyeing, Printing	30 06' 57.1"	31 15' 53.7"	1	109,200	deep
13	Agricultural Land	30 07' 03.0"	31 15' 55.0"	1	12,480	
14	Agricultural Land	30 07' 08.6"	31 15' 56.8"	1	18,720	
15	Esso Fuel Station	30 07' 07.3"	31 15' 54.7"	1	43,680	shallow
16	Mobil Fuel Station	30 06' 38.4"	31 15' 54.2"	1	43,680	shallow
17	El Ahram Foundary	30 06' 39.8"	31 16' 01.2"	2	41,600	shallow
18	El Mohandes Foundary	30 06' 52.1"	31 16' 01.3"	1	21,840	shallow
19	Fouad Foundary	30 06' 52.1"	31 16' 01.3"	1	18,720	shallow
20	El Gehad Foundary	30 06' 52.1"	31 16' 01.3"	3	56,160	shallow
21	El Sad El Aaly Foundary	30 06' 44.8"	31 16' 03.0"	3	32,760	shallow
22	El Fotouh Cotton Factory	30 06' 40.1"	31 16' 05.0"	2	74,880	shallow
23	El Azizy Foundary	30 06' 40.1"	31 16' 05.0"	1	8,320	shallow
24	Noval Factory	30 06' 45.0"	31 16' 02.4"	2	49,920	deep

No.	Establishment	Coordinates		No. of wells	Annual abstraction (m3/year)	Nature of well
		North	East			
25	Egyptian Company for	30 06' 49.1"	31 16' 07.6"	1	6,240	shallow
26	Agricultural Land	30 06' 49.5"	31 16' 09.6"	1	12,480	
27	Agricultural Land	30 06' 53.3"	31 16' 03.6"	1	7,280	
28	Hassan El Kassas Foundary	30 06' 54.2"	31 15' 59.8"	1	24,960	shallow
29	Pipes Store	30 06' 57.6"	31 16' 04.1"	1	1,040	shallow
30	Arab Contractors Central	30 06' 56.5"	31 16' 14.3"	1	24,960	deep
31	Salah Attia Foundary	30 06' 51.8"	31 16' 13.3"	1	4,160	shallow
32	Misr for Concrete Works	30 06' 47.5"	31 16' 23.0"	1	74,880	deep
33	National Company for Bricks	30 06' 47.5"	31 16' 34.3"	1	24,960	shallow
34	Mohamed Kamel Foundary	30 06' 53.1"	31 16' 35.0"	1	26,000	shallow
35	El Salam Preparation and	30 07' 02.5"	31 16' 24.6"	1	20,800	deep
36	Paints Factory	30 06' 48.5"	31 16' 38.7"	1	49,920	shallow
37	Revits Factory	30 06' 48.5"	31 16' 38.7"	1	3,120	shallow
38	Samir Morgan Tyres Factory	30 06' 48.8"	31 16' 49.4"	1	12,480	shallow
39	Revits Factory	30 06' 48.8"	31 16' 49.4"	1	12,480	shallow
40	Plastic Factory	30 06' 48.8"	31 16' 49.4"	1	18,720	shallow
41	Tyres Factory	30 06' 48.8"	31 16' 49.4"	1	6,240	shallow
42	Mahmoud Salama Land	30 06' 46.2"	31 16' 47.6"	6	149,760	shallow
43	El Dalta for Steel	30 07' 06.1"	31 16' 58.8"	2	168,480	deep
44	Vehicles Parking Area	30 07' 06.1"	31 16' 27.5"	1	14,560	shallow
45	El Ma'alem Ramadan Store	30 06' 52.5"	31 15' 43.3"	1	7,280	shallow
46	Tin Factory	30 06' 52.5"	31 15' 43.3"	1	7,280	shallow
47	Fruits Store	30 06' 52.5"	31 15' 43.3"	1	2,080	shallow
48	El Haj Megahed Scouring	30 06' 52.5"	31 15' 43.3"	1	7,280	shallow
49	El Haj Talaat Plastic Factory	30 06' 52.5"	31 15' 43.3"	1	29,120	shallow
50	El Haj Taha El Sayed	30 06' 56.8"	31 15' 43.8"	1	7,280	shallow
51	El Tawakol Wire Factory	30 06' 38.1"	31 15' 30.9"	1	14,040	shallow
52	Mahmoud Foundary	30 06' 38.1"	31 15' 30.9"	1	24,960	shallow
53	El Tawakol Foundary	30 06' 39.2"	31 15' 35.1"	1	24,960	shallow
54	El Haj Abdel Monaim Foundary	30 06' 39.2"	31 15' 35.1"	1	28,080	shallow
55	Aly Abu Sre'a Foundary	30 06' 39.2"	31 15' 38.0"	2	74,880	shallow
56	Mahmoud Abdel Monaim	30 06' 39.2"	31 15' 38.0"	1	10,400	shallow
57	Masged El Rahman Foundary	30 06' 39.2"	31 15' 38.0"	1	14,560	shallow
58	Mohamed Abdel Rahman	30 06' 39.9"	31 15' 38.3"	1	31,200	shallow
59	Hashem Ibrahim Foundary	30 06' 39.9"	31 15' 38.3"	1	12,480	shallow
60	Agricultural Land	30 06' 40.5"	31 15' 42.7"	1	8,320	
61	Mahmoud El Kilany Weaving	30 06' 34.9"	31 15' 29.0"	1	4,680	shallow
62	Egyptian Company for Steel	30 06' 40.5"	31 15' 42.7"	1	3,120	shallow
63	El Haj Salah Parking Area	30 06' 39.7"	31 15' 46.2"	1	5,460	shallow
64	Metal Forming Workshop	30 06' 39.7"	31 15' 46.2"	2	7,280	shallow
65	Samira Takhtoukh Tyres	30 06' 39.7"	31 15' 46.2"	1	15,600	shallow
66	Samir Zaki Metal Forming	30 06' 38.8"	31 15' 48.8"	1	27,300	shallow
67	El Haj Mohamed Youssef	30 06' 38.8"	31 15' 48.8"	1	37,440	shallow
68	El Haj Abdel Basset Ouda	30 06' 39.7"	31 15' 50.1"	1	31,200	shallow
69	Abdel Nabi Nassar Foundary	30 06' 41.7"	31 15' 38.4"	1	3,900	shallow
70	Sayed Awadallah Lead	30 06' 35.1"	31 15' 30.5"	1	9,360	shallow
71	El Salam Glass Factory	30 06' 35.4"	31 15' 34.2"	1	9,360	shallow
72	Ahmed Gharib Factory	30 06' 35.4"	31 15' 34.2"	1	6,240	shallow
		TOTAL		**92**	**2,833,272**	

5. Groundwater Pollution Assessment

Groundwater Quality

The only source we could locate is a groundwater quality survey carried out in the area of Shoubra El-Kheima and Mostorod in 1998. The survey, which included a total of 27 samples, was conducted as part of studying the potential sources of groundwater pollution within the area. Analysis of the collected samples indicated the following:

- The pH value ranged between 7.4 and 8 indicating slight alkalinity of the groundwater.
- The total dissolved solids were between 441 and 986 ppm, which is within the acceptable range of drinking water according to WHO standards (WHO, 1988).
- As for the heavy metals, except for Lead and Cadmium, all analyzed concentrations, i.e. Cu, Zn, and Fe, were below the allowable limits for drinking water.
- Lead and Cadmium concentrations ranged from 0.015 to 0.083 ppm and 0.007 to 0.031 ppm respectively.

Surface Water Quality

Available data (MOHP 1999 cited in NWRP 2001) on the water quality in the Ismailia canal, within the area under investigation, shows that the concentrations for Selenium (Se), Cadmium (Cd), Mercury (Hg), and relatively Lead (Pb), exceed the limits for both ambient and drinking water standards. Table-4 contains the water quality data.

Table-3: Surface water quality (all figures are in mg/l)

	Fe	Mg	Se	F	Cd	Cu	Cr	Hg	Pb	Zn	Ni
Law 48/82 (ambient)	1.0		0.01	0.5	0.01	1.0	0.05	0.001	0.05	1.0	
Law 48/82 (Drinking)	0.3	150	0.01	0.8	0.003	2.0	0.05	0.001	0.05	3.0	
WHO (drinking)			0.01	1.5	0.003	2.0	0.05	0.001	0.01		0.02
Jan-99											
Mostorod	NA	NA	0.10	0.02	0.26	NA	0.02	0.95	0.04	0.33	0.02
El-Delta Co. for Iron	NA	NA	0.15	0.02	0.13	NA	0.03	.032	0.02	0.37	0.07
Osman Bridge	NA	NA	0.15	0.02	0.16	0.11	0.03	.034	0.18	0.34	0.19
Feb-99											
Mostorod	NA	NA	0.20	0.07	0.20	0.01	0.06	0.12	0.22	0.81	0.06
El-Delta Co. for Iron	NA	NA	0.15	0.07	NA	NA	NA	NA	NA	NA	NA
Osman Bridge	NA	NA	0.15	0.07	0.80	0.03	0.05	0.12	0.11	0.52	0.06
Nov-99											
Mostorod	0.01	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA
El-Delta Co. for Iron	0.11	NA	0.01	0.04	NA	NA	NA	NA	NA	NA	NA
Osman Bridge	0.01	NA	0.01	0.04	NA	NA	NA	NA	NA	NA	NA
Dec-99											
Mostorod	NA	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA
El-Delta Co. for Iron	NA	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA
Osman Bridge	NA	NA	0.01	0.03	NA	NA	NA	NA	NA	NA	NA

Potential Sources of Industrial Pollution

Many factories in the area under investigation can represent another source of pollution to the aquifer. Namely these are:

Table-4: Other Potential Polluters

- National Plastics Company
- Mostorod Metal Company
- Co-op Fuel Station
- Egyptian Textile and Dyeing
- Abdel Gabbar Dyeing, Printing
- Esso Fuel Station
- Mobil Fuel Station
- El Ahram Foundary
- El Mohandes Foundary
- Fouad Foundary
- El Gehad Foundary
- El Sad El Aaly Foundary
- El Azizy Foundary
- Noval Factory
- Hassan El Kassas Foundary
- Arab Contractors Central
- Salah Attia Foundary
- Mohamed Kamel Foundary
- Paints Factory
- Samir Morgan Tyres Factory
- Plastic Factory
- Tyres Factory
- El Dalta for Steel
- El Haj Megahed Scouring
- El Haj Talaat Plastic Factory
- El Haj Abdel Monaim Foundary
- Aly Abu Sre'a Foundary
- Mahmoud Abdel Monaim
- Hashem Ibrahim Foundary
- Egyptian Company for Steel
- Metal Forming Workshop
- Samira Takhtoukh Tyres
- Samir Zaki Metal Forming
- Abdel Nabi Nassar Foundary
- Sayed Awadallah Lead
- El Salam Glass Factory

However, it can be noticed that Selenium, if used as a tracer, will indicate the extent of the pollution potentially generated from the Smelter as, to our knowledge, non of the above shown industries waste such element.

6. SAMPLING PROGRAM

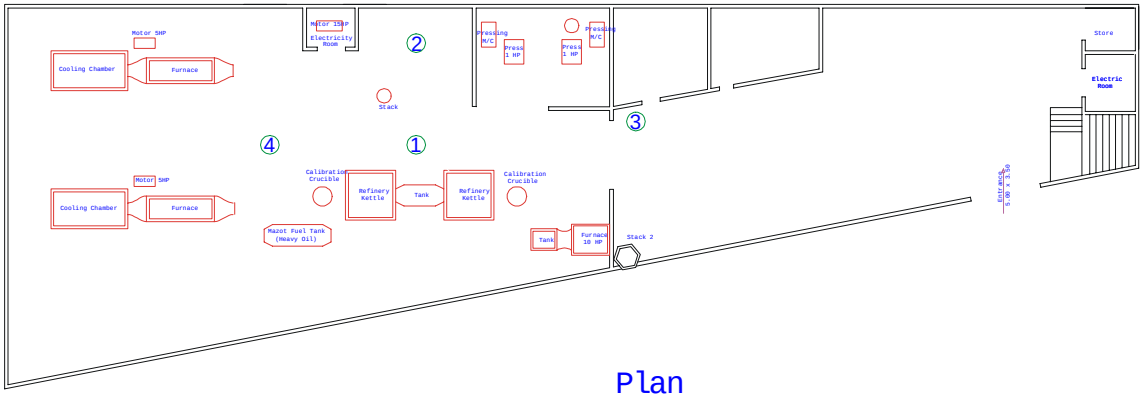
Bore holes

Four (4) boreholes were drilled on October 13th 2001, inside the Smelter, and a total of 19 soil samples were collected from the boreholes at following depths:

Table-5: Soil Samples

SN	Label	Borehole Number	Depth(s)	Remarks
1	0101	1	0.5	Single depth
2	0102	1	2.0, 2.5	Composite
3	0103	1	3.5, 4.0	Composite
4	0104	1	4.5, 5.0, 5.5	Composite
5	0201	2	0.5	Single depth
6	0202	2	1.0, 2.0	Composite
7	0203	2	4.0, 5.0	Composite
8	0204	2	5.5, 6.0	Composite
9	0205	2	7.0, 8.0	Composite
10	0301	3	0.5	Single depth
11	0302	3	1.0, 2.0	Composite
12	0303	3	4.0, 5.0	Composite
13	0304	3	5.5, 6.0	Composite
14	0305	3	7.0, 8.0	Composite
15	0401	4	1.0	Single depth
16	0402	4	2.0, 3.0	Composite
17	0403	4	4.0, 5.0	Composite
18	0404	4	5.5, 6.0	Composite
19	0405	4	7.0, 8.0	Composite

This figure shows the location of the boreholes



Plan

Water sampling program

Although this activity is related to CLIN-3, IWACO-Egypt elected to collect water samples from nine (9) different existing locations surrounding the Smelter and six (6) monitoring wells hat has been drilled specifically for this assignment. The locations of the existing points include the water well of the Smelter, two (2) points on the Ismailia canal, and six (6) other existing wells. A total of 22 samples were collected

from these points including raw water, filtered water, and duplicate samples. The following table shows the location of the selected points:

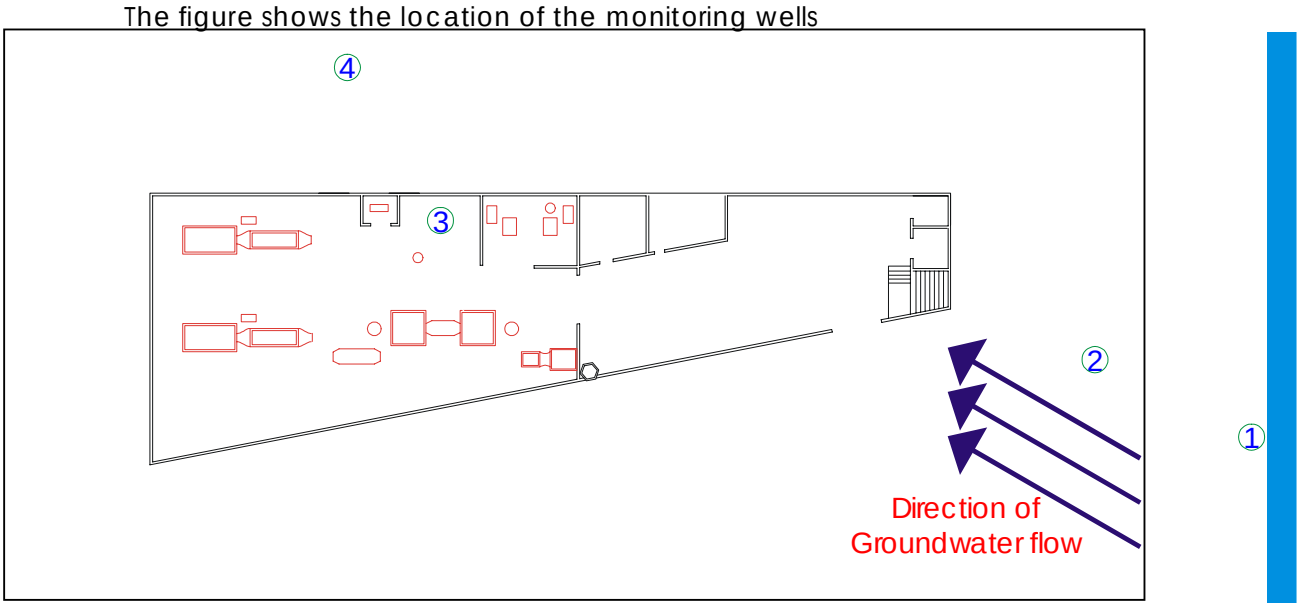
Table-6: Water Samples (existing locations)

Well No.	Name of Company (Type of sample)	Sample Label	Well Depth (m)
12	Abdel Gabbar Dyeing Co.		
	(Raw)	1201	45m
	(Raw Duplicate)	1202	45m
	(Filtered)	1203	45m
16	Mobil Fuel Station		
	(Raw)	1601	40m
	(Filtered)	1603	40m
	(Filtered Duplicate)	1604	40m
17	El Ahram Foundry		
	(Raw)	1701	Unknown
	(Filtered)	1703	Unknown
22	El Fottouh Cotton Factory		
	(Raw)	2201	25m
	(Filtered)	2203	25m
24	Noval Factory		
	(Raw)	2401	24m
	(Filtered)	2403	24m
35	El Salam Dyeing Co.		
	(Raw)	3501	45m
	(Filtered)	3503	45m
93	Sayed Awadalla Lead Smelter		
	(Raw)	9301	Unknown
	(Raw Duplicate)	9302	Unknown
	(Filtered)	9303	Unknown
	(Filtered Duplicate)	9304	Unknown
94	Ismailia Canal 200m U.S.		
	(Raw)	9401	n/a
	(Filtered)	9403	n/a
95	Ismailia Canal 200m D.S.		
	(Raw)	9501	n/a
	(Filtered)	9503	n/a

Table-6: Water Samples (Monitoring wells)

Well No.	Name of Company (Type of sample)	Sample Label	Well Depth (m)
Mw1	El Esmailia Canal bank		
	Deep piezometer		
	(Raw)	1D01	20m
	(Raw Duplicate)	1D02	
	(Filtered)	1D03	
	Shallow Piezometer		
	(Raw)	1S01	6.25
	(Raw Duplicate)	1S02	
	(Filtered)	1S03	
Mw2	Play ground		
	(Raw)	201	20m
	(Raw Duplicate)	202	
	(Filtered)	203	
Mw3	Sayed Awadalla Lead Smelter		
	Deep Piezometer		
	(Raw)	3D01	20m
	(Raw Duplicate)	3D02	
	(Filtered)	3D03	
	Shallow Piezometer		
	(Raw)	3S01	6.25
	(Raw Duplicate)	3S02	
	(Filtered)	3S03	
Mw4	In front of Saad Thomas Smelter		
	(Raw)	401	20m
	(Raw Duplicate)	402	
	(Filtered)	403	

The figure shows the location of the monitoring wells



7. FINDINGS

Lithology

The four boreholes show, in general, gradual change in lithology from silty-clay soil with very fine grain size to silty-sand soil with medium grain size. The sand layer appears at 14 m below ground surface, and the water table appears at 5.5 m below ground surface.

(Please refer to Annex-5 for a copy of the report of logs presented by the drilling company GeoGroup)

Soil analysis

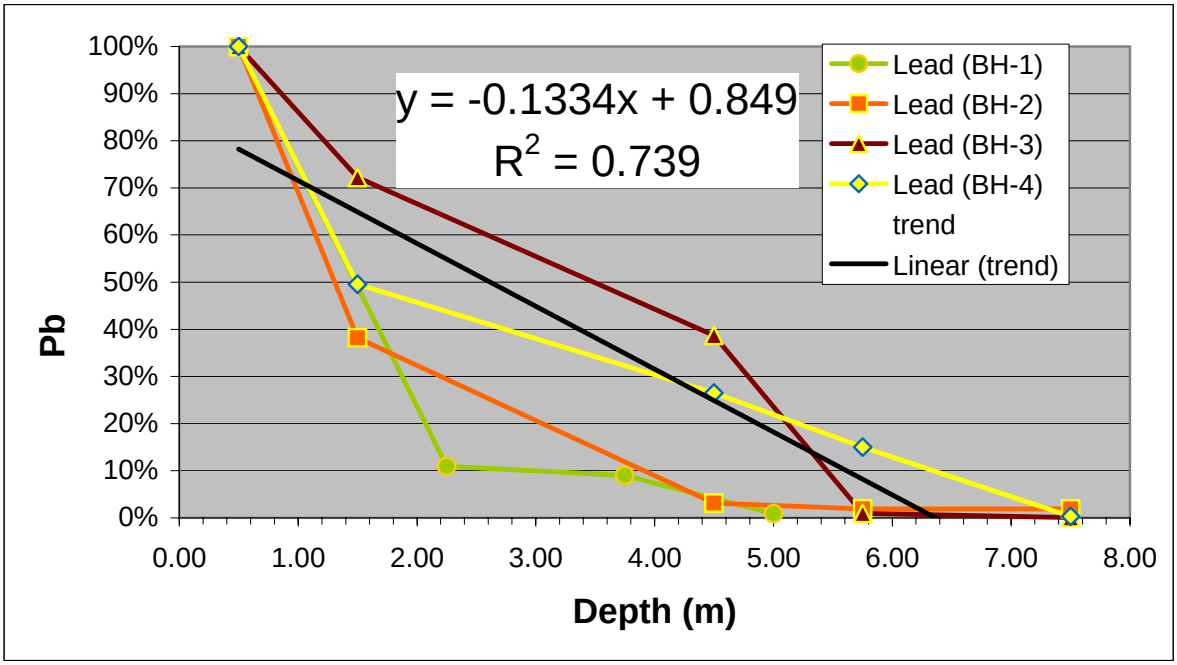
Soil analysis shows that:

- Selenium and Arsenic were not detected.
- Cd has an average concentration of 1.3 mg/kg with slight changes with depth.
- Sb has an average concentration of 57 mg/kg with slight changes with depth.
- Pb concentrations decrease with depth with a steep gradient of about 13%.

Results of the soil analysis are shown in the following table.

SN	Bore Hole number	Bore Hole location		Z-Surface (m a.s.l.)	D-Sample (m)	Z-Sample (m a.s.l.)	Concentration (mg/kg)		
		x (m)	y (m)				Pb	Cd	Sb
1	1	1.5	50.5	17.25	0.50	16.75	4276.0	1.26	134.0
2					2.25	15.00	468.0	1.24	64.0
3					3.75	13.50	386.0	1.26	58.0
4					5.00	12.25	39.0	1.22	53.0
5	2	8.5	50.5	17.50	0.50	17.00	11954.0	1.46	55.0
6					1.50	16.00	4566.0	1.28	52.0
7					4.50	13.00	376.0	1.24	60.0
8					5.75	11.75	226.0	1.18	55.0
9					7.50	10.00	229.0	1.14	56.0
10	3	3.0	35.0	17.00	0.50	16.50	24069.0	1.48	56.0
11					1.50	15.50	17380.0	1.38	62.0
12					4.50	12.50	9308.0	1.38	65.0
13					5.75	11.25	231.0	1.30	66.0
14					7.50	9.50	10.0	1.16	52.0
15	4	1.5	61.0	18.00	0.50	17.50	5068.0	1.44	55.0
16					1.50	16.50	2512.0	1.30	53.0
17					4.50	13.50	1343.0	1.30	54.0
18					5.75	12.25	760.0	1.12	52.0
19					7.50	10.50	15.0	1.12	49.0

(0,0) point for X,Y coordinates is set at the South-West corner of the smelter.
Z is relative to m.s.l.
D is depth from ground surface



(Please refer to Annex-6 for a copy of the report of water analysis presented by the laboratory of EGSMA)

Water pollution

The analysis of the 22 water samples (from 9 spots) and the 18 samples (from 6 monitoring wells) are summarized in the following table. It shows that:

- The water is slightly Alkaline in this area,
- Antimony, Selenium, and Arsenic were not detected in any sample,
- traces of Cadmium were found in few samples, and
- Lead was found, and exceeded the drinking water limits, in all samples.

(Please refer to Annex-7 for a copy of the report of water analysis presented by the laboratory of EGSMA)

Table-7: Water Samples Analysis

Well No.	Name of location (Type of sample)	Sample Label	Well Depth (m)	pH	Eh	Ec (mmos/cm)	Salanity (mg/l)	Pb (mg/l)	Cd (mg/l)
12	**Abdel Gabbar Dyeing Co.**								
	(Raw)	1201	45m	7.88	-0.465	887	567.68	0.078	
	(Raw Duplicate)	1202	45m					0.065	0.003
	(Filtered)	1203	45m					0.054	0.002
16	**Mobil Fuel Station**								
	(Raw)	1601	40m	7.65	-0.451	437	279.68	0.074	
	(Filtered)	1603	40m					0.084	
	(Filtered Duplicate)	1604	40m					0.071	
17	**El Ahram Foundry**								
	(Raw)	1701	Unknown	7.85	-0.463	364	232.96	0.05	
	(Filtered)	1703	Unknown					0.118	

Well No.	Name of location (Type of sample)	Sample Label	Well Depth (m)	pH	Eh	Ec (mmos/cm)	Salanity (mg/l)	Pb (mg/l)	Cd (mg/l)
22	**El Fottouh Cotton Factory**								
	(Raw)	2201	25m	7.95	-0.469	386	247.04	0.106	0.003
	(Filtered)	2203	25m					0.083	
24	**Noval Factory**								
	(Raw)	2401	24m	7.73	-0.456	628	401.92	0.111	
	(Filtered)	2403	24m					0.101	
35	**El Salam Dyeing Co.**								
	(Raw)	3501	45m	7.29	-0.430	586	375.04	0.09	
	(Filtered)	3503	45m					0.11	
93	**Sayed Awadalla Lead Smelter**								
	(Raw)	9301	Unknown	7.46	-0.440	374	239.36	0.082	
	(Raw Duplicate)	9302	Unknown					0.098	
	(Filtered)	9303	Unknown					0.061	
	(Filtered Duplicate)	9304	Unknown					0.052	
94	**Ismailia Canal 200m U.S.**								
	(Raw)	9401	n/a	7.95	-0.469	288	184.32	0.076	
	(Filtered)	9403	n/a					0.065	0.001
95	**Ismailia Canal 200m D.S.**								
	(Raw)	9501	n/a	7.99	-0.471	285	182.40	0.08	
	(Filtered)	9503	n/a					0.077	
Mw1	**El Esmailia Canal**								
	Deep piezometer (Raw)	1D01	20m	8.08	-0.477	346	221.44	0.015	
	(Raw Duplicate)	1D02							0.003
	(Filtered)	1D03							
	Shallow Piezometer (Raw)	1S01	6.25m					0.02	0.002
	(Raw Duplicate)	1S02						0.015	0.001
	(Filtered)	1S03							
Mw2	**Play ground**								
	(Raw)	201	20m	8.80	-0.519	336	215.04	0.012	
	(Raw Duplicate)	202						0.01	0.001
	(Filtered)	203							
Mw3	**Sayed Awadalla Lead Smelter**								
	Deep Piezometer (Raw)	3D01	20m	8.42	-0.497	440	281.60		
	(Raw Duplicate)	3D02						0.01	
	(Filtered)	3D03							
	Shallow Piezometer (Raw)	3S01	6.25m	8.49	-0.501	1549	991.36	0.171	0.003
	(Raw Duplicate)	3S02						0.515	0.002
	(Filtered)	3S03						0.159	0.003
Mw4	**In front of Saad Thomas Smelter**								
	(Raw)	401	20m	8.94	-0.527	541	346.24		
	(Raw Duplicate)	402							
	(Filtered)	403							

8. Cost Estimates

Remediation alternatives

Eight alternatives have been evaluated, and they are namely:

1. Limiting access to the site
2. Demolition of the building and salvage
3. Demolition of the building and acid washing salvage material
4. Demolition of the building, acid washing salvage material, and placement of clay cap over the footprint of the building
5. Demolition of the building, acid washing salvage material, and placement of three-layer clay cap over the footprint of the building
6. Demolition of the building, acid washing salvage material, and haulage of all contaminated equipment to an appropriate landfill
7. Demolition of the building, acid washing salvage material, and encapsulation of the site
8. Demolition of the building, acid washing salvage material, and rinsing the soil and unsalvaged material

These are not meant to be alternatives for one site remediation, but options for different conditions.

Cost component

Fourteen primary cost items have been identified. The items include direct costs (such as demolition, fences, soil replacement, etc…), indirect costs (such as training, consultant, etc…), costs related to administration and management aspects (such as monitoring, management office, etc…), and contingencies. The primary cost items are:

1. Demolition / dissembling
2. On-site encapsulation
3. On-site washing / rinsing
4. On-site treatment / process area
5. Workers washing area
6. Soil replacement
7. On-site soil washing
8. Fences
9. Transportation
10. Monitoring
11. Management Office
12. Training
13. Remediation consultant
14. Contingencies

Derivation and estimation of cost component

The primary cost items have been estimated mainly from the past experience of the study team, previous experience of IWACO Egypt, and interviews with specialised contractors. Contingencies varies according to the cost item and not the alternatives.

The design of the Cost Estimation system

An Excel Work Book were used to design the cost estimation system. It consists of 13 work sheets named as follows:

1. Generic Cost: which is the entry sheet for all the cost items, and sub-items, and also the cost factor for each alternative. It feeds sheets Alt-1 to Alt-8
2. Dimensions: is the entry sheet for the different dimensions that are used to calculate the quantities in the “Generic cost” sheet.

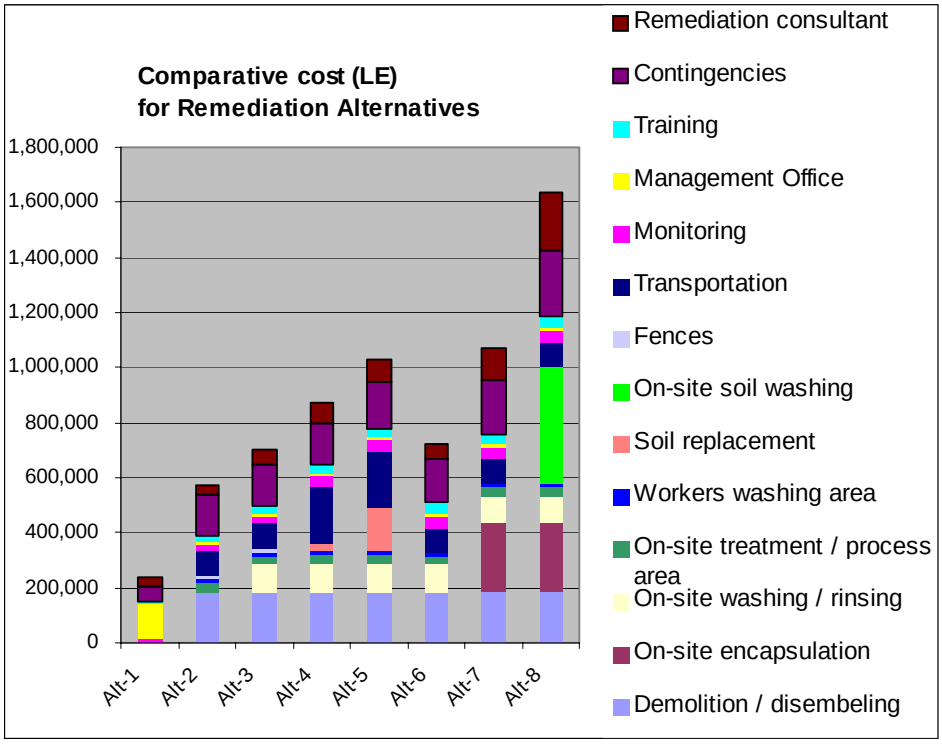
3. Prices: is the entry sheet for the prices of different material or services, it also feeds the "Generic cost" sheet.
4. Cost chart: is a chart (report) showing all the alternatives
5. Alt 1-8: is a table (report) showing all the alternatives
6. to 13. Alt-1 to Alt-8 theses are tables (reports) for the cost each alternative

Costs estimated per alternative

The following table shows the estimated costs (in LE) for each alternative.

Cost Item	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8
Demolition / disembeling	0	185,772	185,772	185,772	185,772	185,772	185,772	185,772
On-site encapsulation	0	0	0	0	0	0	248,993	248,993
On-site washing / rinsing	0	0	99,585	99,585	99,585	99,585	99,585	99,585
On-site treatment	0	29,229	29,229	33,227	33,227	29,229	29,239	29,239
Workers washing area	0	13,620	13,620	13,620	13,620	13,620	13,620	13,620
Soil replacement	0	0	0	29,287	161,076	0	0	0
On-site soil washing	0	0	0	0	0	0	0	425,330
Fences	0	16,000	16,000	0	0	0	0	0
Transportation	0	90,225	90,225	201,914	201,914	90,225	90,487	90,487
Monitoring	16,432	21,140	23,254	41,080	41,080	41,080	41,080	41,080
Management Office	126,000	11,042	11,042	11,042	11,042	11,042	11,042	11,042
Training	7,900	24,500	26,950	29,645	32,610	39,500	39,500	39,500
Remediation consultant	30,338	40,042	57,311	71,101	84,044	58,289	115,901	208,000
Contingencies	57,207	144,304	152,663	155,591	168,770	155,591	192,940	240,657
Total	**237,877**	**575,875**	**705,651**	**871,863**	**1,032,740**	**723,934**	**1,068,159**	**1,633,305**

The following graph shows the distribution of the costs for each alternative.



(Please refer to Annex-8 Cost Analysis for more details)

9. RECOMMENDATIONS

Soil Sampling

It is recommended to carry out a fine soil sampling survey inside the plant. The samples should be colleted at a grid of 4 X 4 meters and 0.5 m depth intervals from ground surface until 5 meters depth. The samples should be analysed for the concentration of Lead only. This allow for a better design for an excavation program, if the option is selected. Such sampling program, including the analysis, will cost between LE 25,000 to LE 30,000. In excavation is delayed for a later stage, the analysis of these samples can be a background for any future activity.

Water Sampling

It is recommended to use the monitoring wells for further water quality monitoring. Depending on the future of the site, a monitoring plan should be designed.

Remediation

Depending on the future of the site, an alternative scheme should be selected. For the time being, it is recommended to, at least, limit the access to the site. This means that the owner only and his staff will be allowed to access it, after attending a short training program on health issues and effect of direct exposure to lead contaminated material.

It should be also noted that activities such as collecting and breaking the used batteries should never be used inside this site. Leaking acid from the batteries may mobilise the adsorbed lead which is currently fixed to a certain limit.

At least the lead-rich dust overlaying the ground surface must be removed. It should be watered before moving it. It may be reused in another smelter.

A next, and ultimate, step would be following alternative –4. However, the top covering cap will be serving as soil replacement and not isolation tool. In this case, the cap can be also sand compacted at 15 cm layers instead of using clay.

Annex 1 – References

1. RIGW, 1989. "Hydrogeological Map of Egypt – Cairo." (scale 1:100,000)
2. Cynthia R. Evanko et al., October 1997. "Remediation of Metals-Contaminated Soils and Groundwater.", GWRTAC, Technology Evaluation Report TE-97-01
3. Mary P. Anderson et al., 1992. "Aplied Groundwater Modelling, Simulation of Flow and Advective Transport."
4. ESA, 1988, Cairo Maps # I11, I12, J11, and J12. (scale 1:5,000)
5. NWRP, 2001, "National Water Resources Plan for Egypt – Interim Report"
6. Water analysis reports of EGSMA, 27.11.2001, 27,1,2002
7. Logs report of GeoGroup, 16.10.2001

Annex 2 – Land Use Map

Annex 3 – Existing Wells Location Map

Annex 4 – IWACO Sampling Procedures

Annex 5 – Report on the Analysis of the Water Samples

Annex 6 – Report on the Analysis of the Soil Samples

Annex 7 – Report on the Logs of the Boreholes

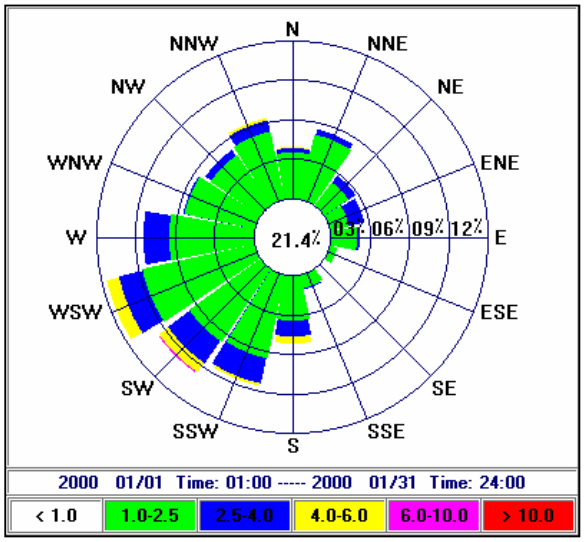
Annex 8 – Cost Analysis

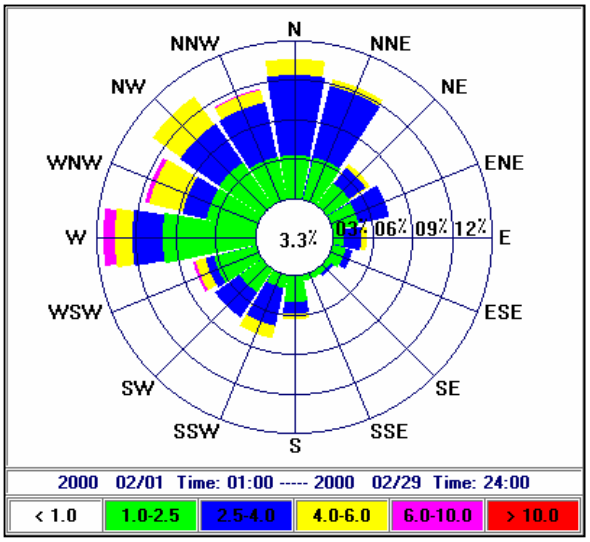
APPENDIX C:

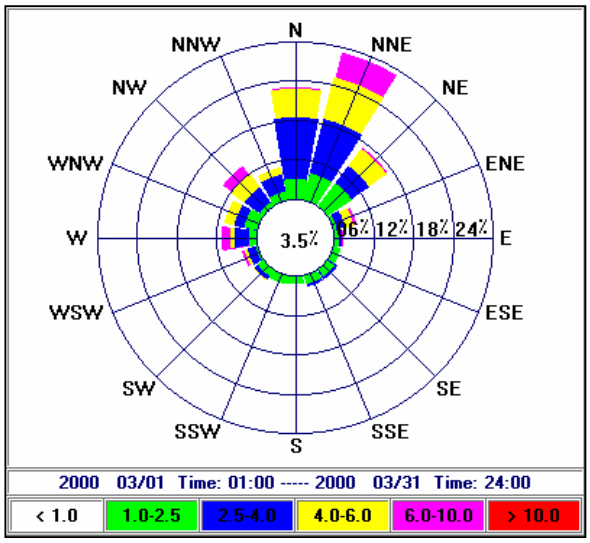
Wind Direction in the Vicinity of the Smelter

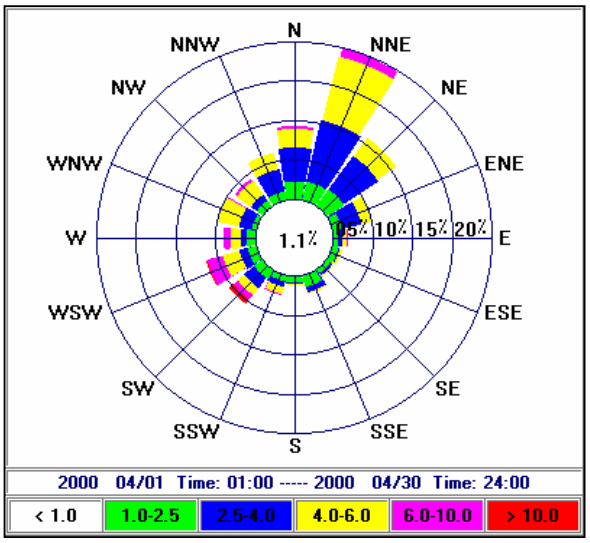
Awadallah's Secondary Lead Smelter at Shoubra El Kheima

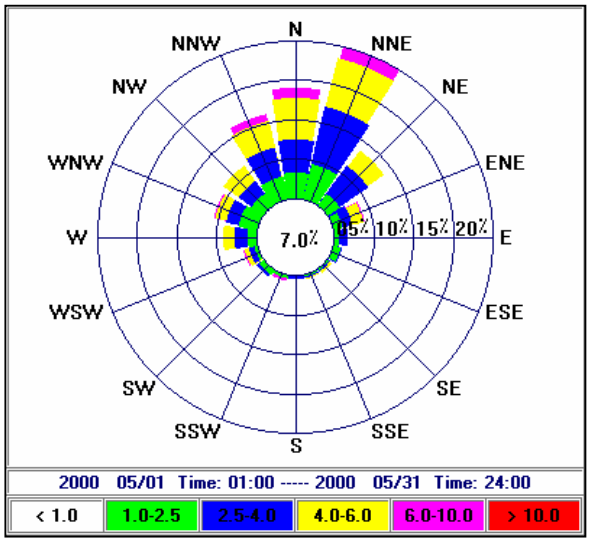
Site No. 26, Kaha (KFC) Monthly Average
Wind Roses from January to December 2000

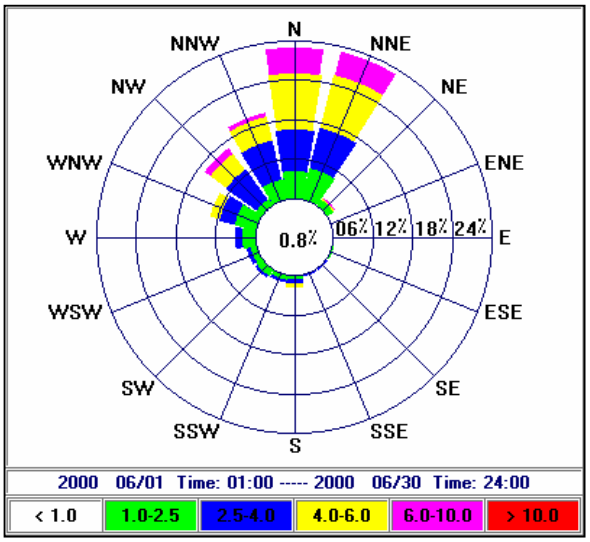


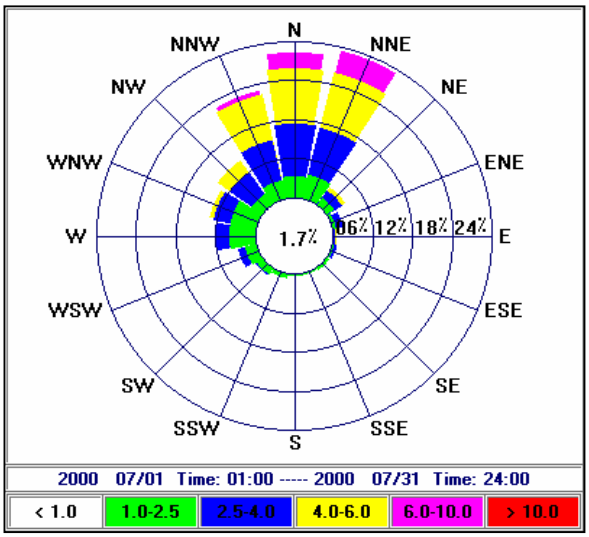








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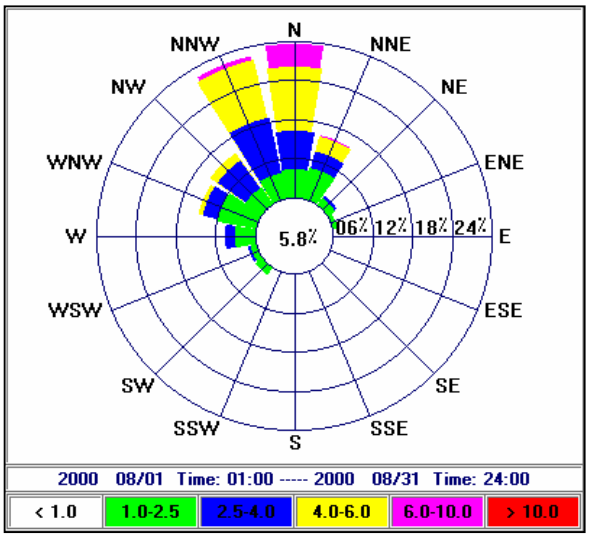
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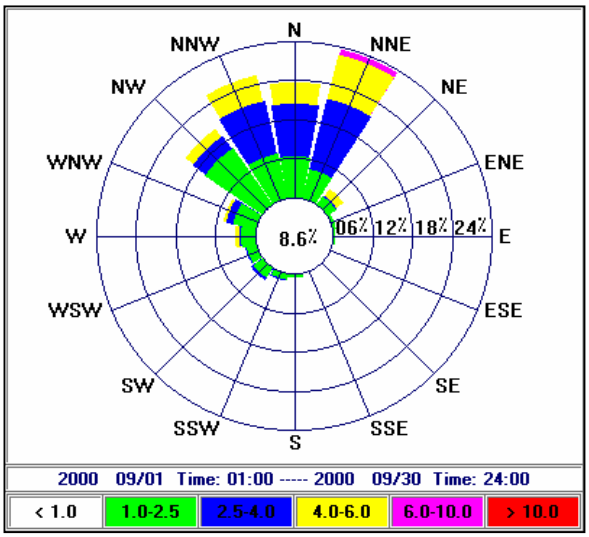
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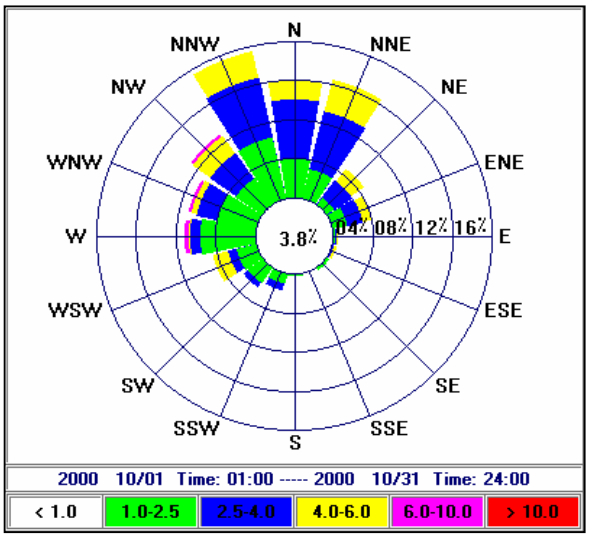
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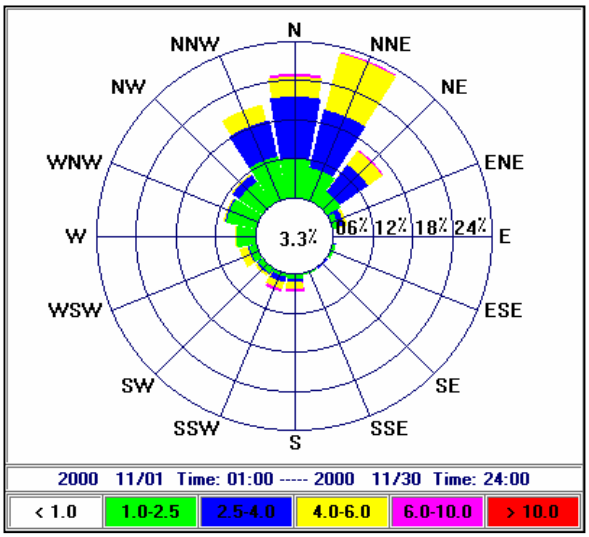
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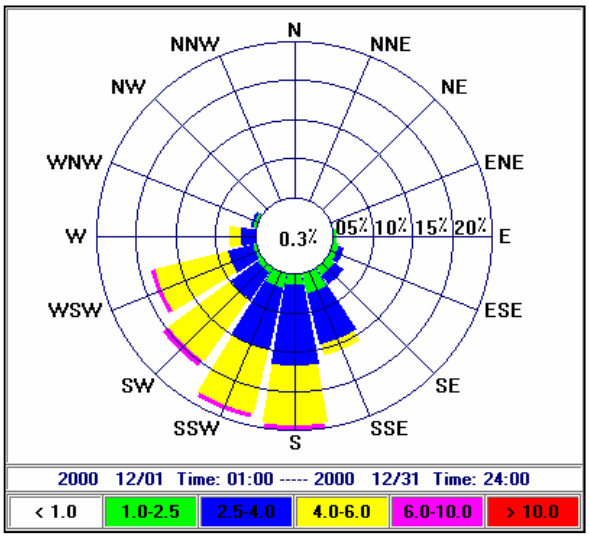
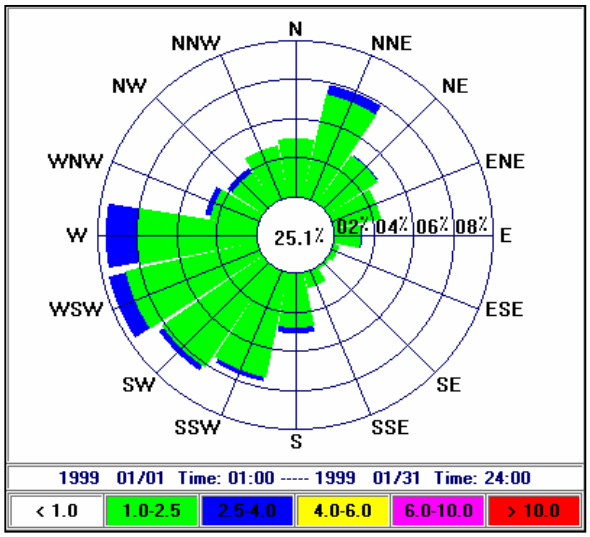
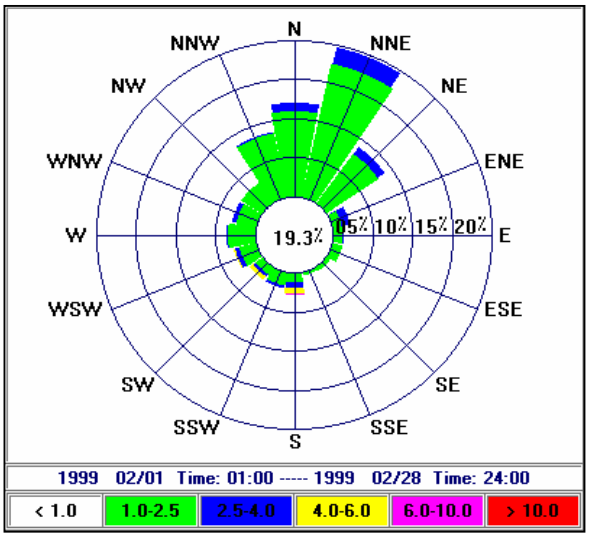
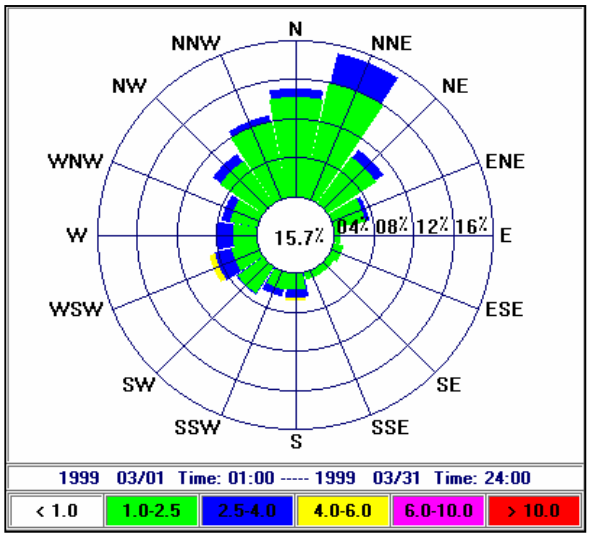
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0

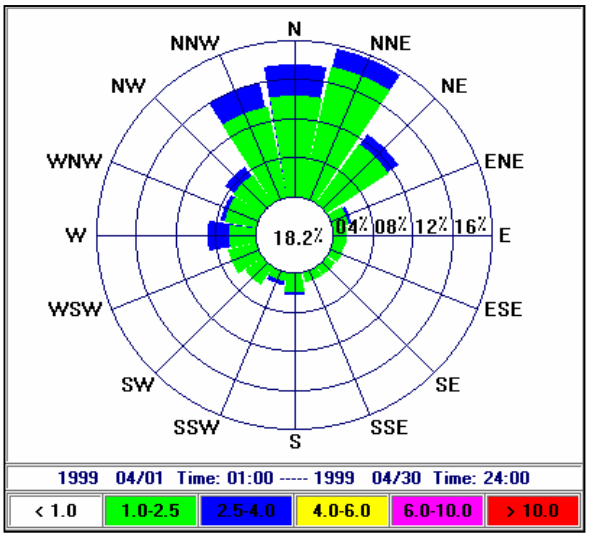

N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0.3%
05%
10%
15%
20%
2000 12/01 Time: 01:00 ----- 2000 12/31 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0

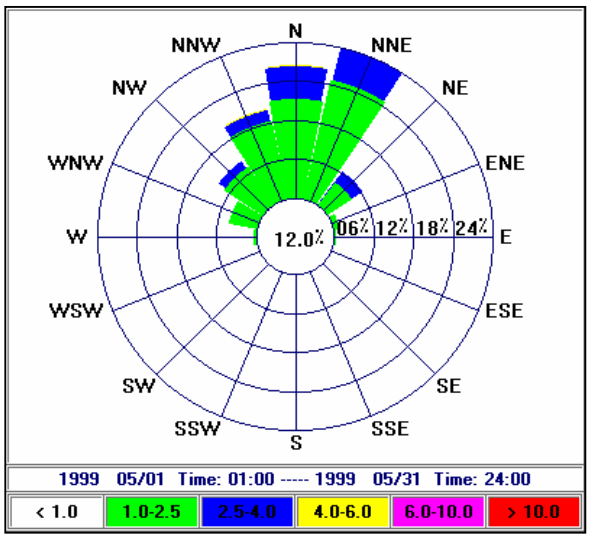
Kaha Monthly Average Wind Roses from January to December 1999

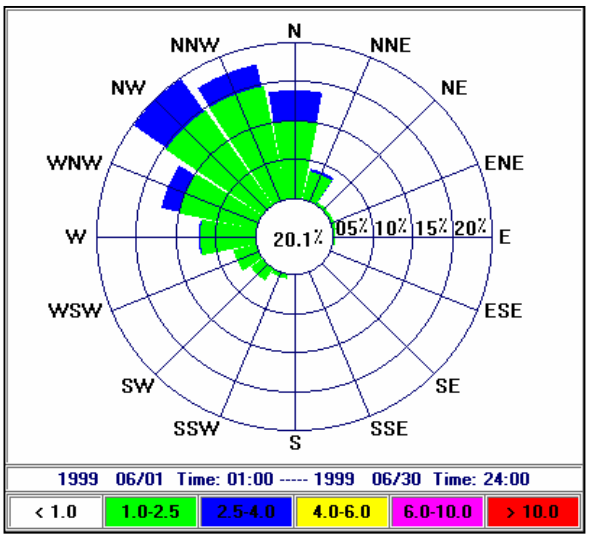


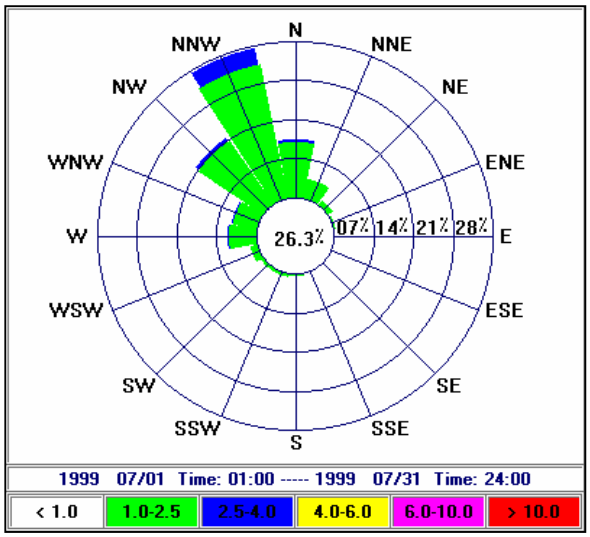


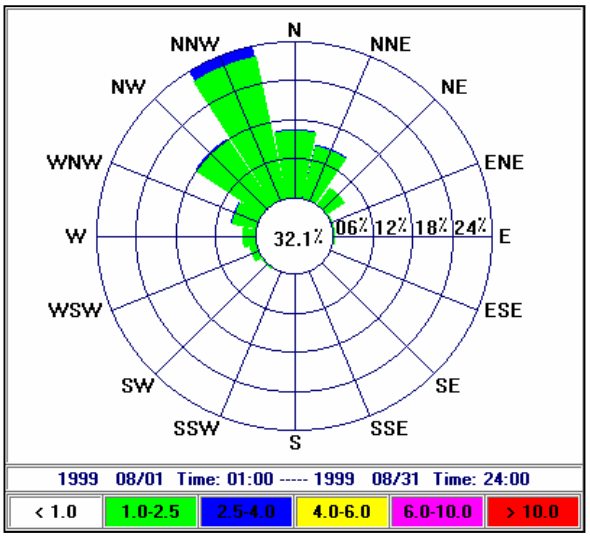


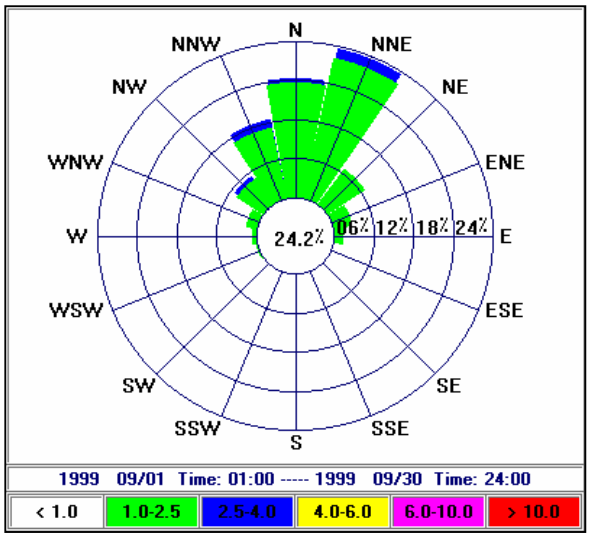


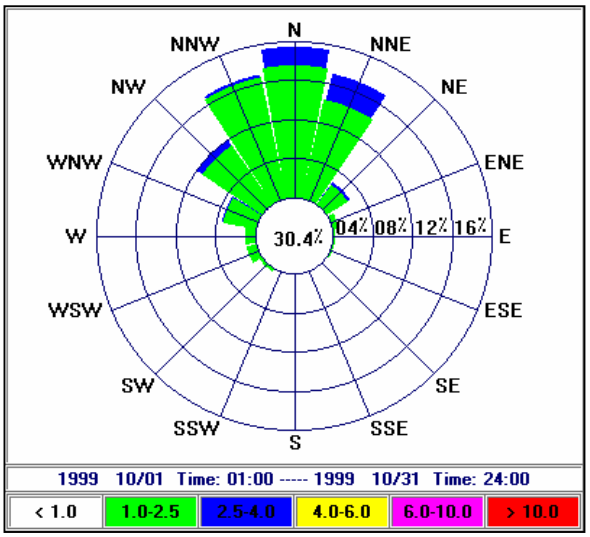


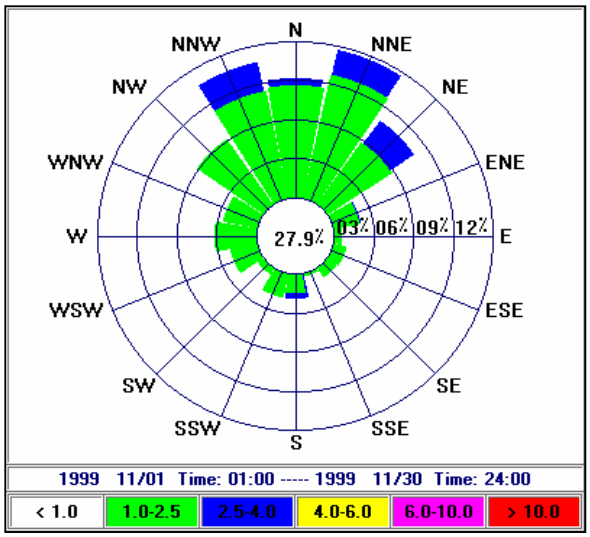


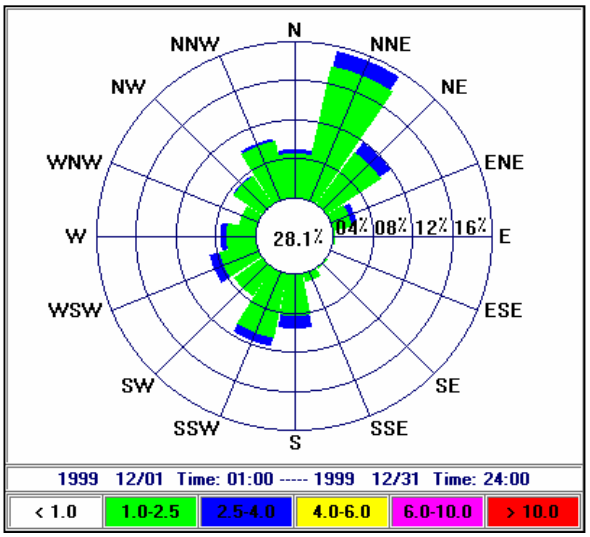

N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
26.3%
07%
14%
21%
28%
1999 07/01 Time: 01:00 ----- 1999 07/31 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
32.1%
06%
12%
18%
24%
1999 08/01 Time: 01:00 ----- 1999 08/31 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
24.2%
06%
12%
18%
24%
1999 09/01 Time: 01:00 ----- 1999 09/30 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
30.4%
04%
08%
12%
16%
1999 10/01 Time: 01:00 ----- 1999 10/31 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
27.9%
03%
06%
09%
12%
1999 11/01 Time: 01:00 ----- 1999 11/30 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
28.1%
04%
08%
12%
16%
1999 12/01 Time: 01:00 ----- 1999 12/31 Time: 24:00
< 1.0
1.0-2.5
2.5-4.0
4.0-6.0
6.0-10.0
> 10.0