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# Quick Assessment of Advanced Environmental Computer Technologies for Use in Developing Countries

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## Executive Summary

A priority of U. S. international policy, as carried out by the U.S.Agency for International Development (A.I.D.) and other U. S. Government agencies, is the improvement of the environment in developing countries. The United States, because of the preeminent state of it environmental technology and know-how, is in a particularly good position to assist developing countries with this task.

The relatively primitive state of the ability of developing countries to manage their environments is reflected in the low levels of information and analyses of environmental problems and abatement strategies in those countries. In the United States, environmental information systems are very advanced. In fact, U.S. technology is unsurpassed in environmental software and hardware that support environmental assessment, data handling and analysis, planning, enforcement, and reporting.

This report briefly assesses the application of U.S. environmental information technologies to the needs of developing countries. It describes the kinds of environmental problems for which enviornmental software has been developed, it describes illustrative software packages developed by U.S. industry and then suggests a series of activities USAID might take to accelerate the applicaiton of these technologies to developing country environmental problems.

The U. S. environmental software industry has available over 500 software programs. All the areas of technology are covered that may be needed to service the needs of developing countries in every stage of industrialization. Of course, software programs are in English and are tailored to the U.S. industrial economy with its advanced regulatory environment so some, translation and adaptation is required.

The environmental problems and needs of developing countries vary with industrial development. At the lowest level of development, the needs are for potable water and sanitation. At the mid level, these needs are augmented by some industrial pollution, especially air and surface water. At the higher levels of industrialization, the country typically experiences the same high levels of industrial pollution as the U.S., including vehicle discharges, hazardous waste, and toxic substances often arising from urbanization and industrialization.

Expenditures for environmental purposes arise from driving forces within the country. These driving forces were surveyed for seven Latin American countries representing all levels of development. The Government was found to drive expenditures through increased enforcement, new laws and regulations, improving infrastructure, and increased priorities due to citizen demand especially where democratization had taken place. The private sector was found to drive expenditures where a market economy had arisen which led to economic growth, privatization of nationalized plants and industries that had been immune to environmental regulation, modernization of industry in

preparation for promotion of exports, and, again, public pressure for an improved environment leading to action by industry.

All the expenditures arising from these drivers in every country result in needs for environmental software. These needs include the support of projects from the design stage through permitting, construction, operation, and compliance monitoring. There is also a need in every country surveyed to obtain software to aid in data handling, decision making, enforcement, and planning, and to support policy at the Minister of Environment level. This key function can best be supported by an environmental compliance management system (ECMS) tailored to the laws and regulations of the country.

The environmental software available in the U. S. has been surveyed and categorized. A total of 532 software packages were included in the survey. The twelve categories selected were not exclusive. That is, many software packages had capabilities in more than one category. The results of the survey are as follows:

- Comprehensive Systems - 27 software packages ranging from $5,000 to $100,000. Includes capabilities for environmental compliance management with varying numbers of data bases, modules, and capabilities.

- Modeling Systems - 186 software packages ranging from $50 to $20,000. Includes hazardous substances management and modeling of contaminant transport in water (surface and ground) and in air dispersion modeling.

- Data Management Systems - 155 software packages in the $400 range. Includes input, storage, and retrieval of data, graphical presentations and analysis of trends.

- Monitoring Systems - 76 software packages ranging from $5,000 to $100,000. Includes tracking of exposure data, emissions, operations, etc., generation of reports to regulators, and warning of abnormal functioning.

- Design Systems - 44 software packages ranging from $250 to $25,000. Includes analysis of process modifications, control alternatives, and project tracking for regulatory compliance.

- Risk Assessment - 68 software packages ranging from $500-$1500. Includes calculation of chronic and acute risk posed by environmental parameters, both continuing (stack emissions) or sudden (highway spill) and protocols to be followed to comply with human health and environmental standards.

- Reference Material. 76 software packages in the $40/hr to $2,000/yr. range. Includes data bases for chemical properties, toxicity, environmental effects, hazardous materials and regulations.

- Reporting Systems - 153 software packages ranging from $200 to $500. Includes compliance report generation and general reporting. Often a part of a larger program such as environmental compliance management systems.

- Calculation Systems - 186 software packages varying in cost. Includes various calculations such as human health effects, process design cost, equipment sizing, etc. Often included in other packages.

- Enforcement Systems - 67 software packages varying in cost. Includes determination of compliance with regulations for inspections, training, tracking, etc.

- Management and Administrative Systems - 6 software packages ranging from $3,500 to $100,000. Includes tracking of purchase orders, chemical inventories, shipments, and files. This capability is also included in other comprehensive packages such as environmental compliance management systems.

- Cost Systems - 24 software packages ranging from $450 to $1000. Includes budgeting, equipment cost, and cost estimating.

The study shows that the U. S. has the environmental software to meet the needs of the developing countries. The needs of the governments to deal effectively with environmental data, support policy decisions, and enhance enforcement (compliance management) is a key entry for U. S. software that can set the stage for penetration of the other environmental software markets.

The U. S. environmental software industry is diverse and fragmented. The U.S. Government could play a role in catalyzing industry activity to speed application of U.S. technology in developing countries. The following suggestions are in order of increasing funding:

- Help with marketing by including environmental software in the scope of the Environmental Training Institute that brings foreign executives from both government and industry to the United States for briefings on available export technology.

- Help with technology transfer by funding the pilot installation of an environmental compliance management system in a mid industrialized developing country such as Chile. This would be a "Beta Site" and would provide a test bed and showcase for this application. This requires translation of the software into the appropriate language, and tailoring to support local laws and regulations.

- Help with environmental software export by working with existing or new U.S. institutions to:

1. Support joint projects with each host country and the software provider for the translation, tailoring, and support of the environmental software required.

2. Create and operate a multi-lingual database of available U.S. environmental software for use by developing countries.

3. Support shows, expositions, and seminars in key export regions.

4. Create and operate an opportunities database for U. S. software companies using information amassed from U. S. embassy sources.

5. Operate an international users group of U.S. software to maximize long-term effectiveness.

6. Provide consulting advice to potential users in developing countries to aid them in selecting the software that they require.

7. Support training and seminar visits in the U. S. for key executives from developing countries.

## I. Introduction

A priority of U.S. international policy as carried out by the U.S. Agency for International Development (A.I.D.), the Department ofState, the Department of Commerce and other U.S. Government Agencies is the improvement of the global environment . U.S. environmental technology is preeminent in software and hardware that supports environmental assessment, data handling and analysis, modeling, planning, enforcement, compliance and reporting. This technology can be applied to developing countries around the world where it can positively affect the global environment and enhance U.S. exports.

### I.A. Background and Purpose

The main problems of developing countries have been poverty, need for infrastructure, industrialization, and existence of command economies. Recent moves toward democratization, privatization, and market economies have nurtured the emergence of environmental consciousness in many developing countries. This has been enhanced by increased trade making these countries a part of the world economy and, therefore, a part of the world environment. This change has created a need for use of advanced environmental technology in developing countries, and an opportunity for American technology to fill that need. Nowhere is the need greater and the U.S. technology more preeminent than in environmental data management.

Great strides have been made in economic and political spheres in developing countries. At the same time, high population growth rates, emerging industrialization, urbanization, and pollution have put great demands on the environment. These demands have not been met, and, as a result public health, quality of life, and the natural environment have all suffered. The response in many countries has been the passage of environmental laws which seek to improve the situation. This trend is being accelerated by emerging requirements for environmental improvement by trade partners, the World Bank, and their own populations.

Developing countries need help to improve their environment. In addition, the industrialized world, including the United States, needs the cooperation of developing countries to protect the global environment. Global environmental concerns including climate changes due to the greenhouse effect, depletion of the ozone layer, deforestation, and safe management of hazardous and toxic wastes can be met using programs designed to assist emerging economies in developing sound environmental programs. Ideally, these programs will promote environmental and economic partnerships rather than dependency on foreign aid from the industrialized world including the United States. Assistance programs that build strong, independent economies in developing countries hold the greatest promise for creating a healthy, growing global economy benefiting all countries. Building economic partnerships among the private sector in developing countries promotes prosperity at home and abroad. Mutual benefits in terms of worldwide economic growth and preservation of our global natural resources can be obtained by exporting existing environmental products and technological expertise from the United State to developing countries.

The United States began developing regulations for protection of the environment in

the early 1970's. Today these regulations encompass all contaminated media and span the range of environmental problems. Developing countries looking for assistance in finding solutions to environmental problems such as air and water pollution, industrial waste management, construction of secure landfills, and treatment of contaminated soil can benefit from expertise readily available in the United States. For this reason the United States Agency for International Development is investigating ways of helping to export existing United States products and technology to Asia, Latin and Central America, the Carribean, the Commonwealth of Independent States, and Africa. Environmental computer software and technology is an excellent candidate for technology transfer.

The purpose of this report is to provide an overview of environmental software available in the United States and describe potential applications to assist developing countries with their environmental problems. Examples of typical environmental needs in developing countries that can benefit from use of environmental software are described. Over 500 environmental software programs have been identified with applicability to a wide range of environmental problems. The range of environmental software programs available is presented along with the range of environmental problems they address. The study results are given, followed by conclusions of the study and recommendations for future projects in environmental software by A.I.D.

## I.B. General Description of Advanced Computer Technology in the United States

### a. Scope of Available Software

Environmental software began to appear on the market around 1985. There were approximately 50 programs available at that time. Many of these programs were general software programs that were repackaged and sold as environmental software programs. Since that time the number and sophistication of environmental software programs has increased dramatically. There are a wide variety of environmental problems that have been addressed by developers of environmental software in the United States fueled by ongoing environmental regulations, health and safety requirements, and high cost of environmental liability.

Currently there are hundreds of environmental software programs available. Each year environmental software progresses technologically making systems more functional and user-friendly through increased use of menus, self-help features, on-screen recognition commands and flexible report-writing tools. Managers are becoming more accustomed to using computers in their daily work to assist in solving the regulatory compliance problems that are an important part of all industrial operations.

Environmental software has become popular because it reduces the time needed to complete labor intensive tasks associated with organizing, searching and generating reports using large amounts of information. For example, leaks, spills, and human exposure occur in all industries using hazardous chemicals. In the event of an accidental toxic chemical release, plant managers need fast access to information on

the toxicity of the released substance and how it will disperse under various conditions. This information can be readily obtained using computerized systems that are designed to store and retrieve detailed information on emergency procedures, warnings, storage criteria, handling methods, and cleanup of hazardous material releases. Searching for information on a specific hazardous material by hand is very slow compared to using a computer. Once the emergency is under control, software programs are available that automate preparation of incident reports and maintain historical references on the corrective action measures taken.

All industries are required to monitor the handling of hazardous materials and plan for emergencies resulting from use of these materials. To remain in compliance, companies of all sizes must meet the requirements of pertinent regulations and amendments. As a result, a large number of compliance products have been designed to help users interpret and meet the requirements of a particular set of regulations. Generally, compliance software helps users with environmental regulations by providing a framework for data entry and manipulation or by providing access to regulatory text in a cross-referenced, accessible format. Typically, programs that perform data manipulation also allow users to generate forms that must be maintained and submitted to a regulatory agency. Data for these reports can be collected by a corporate office from several facilities, analyzed, and summary reports generated. This type of software is tied to specific regulations in the United States such as SARA Title III, OSHA's Hazard Communication Standard (HCS), and RCRA compliance and, therefore, could not be used directly by other countries with different regulatory requirements without tailoring. This category of software is discussed to present typical uses since compliance with regulations is an integral part of any country's environmental program. Custom application software could be developed on a country-by-country basis to include the text and requirements of their regulations. This would help the country to cope with the increasing stream of environmental regulations by standardizing the collection of data on disks or tapes for reporting purposes. The same computer software format could then be used to accept additional data and generate management reports needed by the institution overseeing the environment in the developing country in advance of the promulgation of specific regulations. In this case, the data would serve to scope the problem and be the basis for regulatory design and enforcement structuring. This may be one of the earliest payoffs from new technology that developing countries can take in starting to address their environmental needs.

In addition to using computers to help environmental managers cope with the complicated requirements of environmental laws and standards, they are also being used to assist with information management, handling, and dissemination of materials. Typical tasks relegated to computers include tracking of employee medical and exposure histories, recordkeeping for employee training, and maintenance of reference source information on hazards in the workplace (e.g., material safety data sheets). Other categories of environmental software include programs for air, land, and water pollution, industrial wastewater, chemicals and hazardous wastes, and general environmental database management. The range of functions performed by the programs include site assessments, hazardous material ranking, public and private wastewater disposal, modeling and simulations for solid and liquid wastes, risk reduction at hazardous waste sites, diagnosis of system breakdowns, monitoring of

emissions and process performance from an environmental standpoint, maintenance of records and report generation for permits and management analysis, and other compliance activities. Comprehensive environmental management software packages are available that combine the benefits of several stand-alone programs to solve problems associated with identifying sources of pollution, tracking waste, performing data analysis, and report generation.

One classification of environmental software, called advisory control software, is aimed specifically at the chemical processing industry. This software combines operating procedures, hazardous operation analysis results, optimization procedures, and environmental regulations, with real time and historical data from control systems, computer systems, and management systems. The software is designed to intelligently identify trends and problems and give operators on-line advice to manage day-to-day operations and prevent problems that can cause environmental degradation or generate hazardous waste products.

Advisory control software assists plant mangers in making decisions during potential environmentally threatening occurrences. For example, the fuel oil spill that occurred in the New York Harbor on New Year's Day, 1990, due to operator error, might have been prevented with advisory control software. An operator was monitoring a pipeline in New Jersey for a major oil company when the control system signaled a possible leak. Rather than following an emergency procedure from an operating guide written for that plant, the operator decided to override the alarm at least three times allowing 500,000 gallons of oil to flow into the harbor. The operator said he did not follow the emergency procedures because the manual was too hard to understand and used alternative measures instead.

This example shows that existing process control technologies sometimes do not go far enough to protect the environment. Procedures developed for avoiding plant emergencies and environmental threats are sometimes not implemented. Advisory control systems address such emergency needs by providing on-line, real-time expert advise that is available at all times. Use of these systems can help operators analyze and validate alarms, recommend process improvements in daily operation, draw from a wide range of plant information resources, and provide on-line advise that can prevent costly and environmentally damaging mistakes that inexperienced operators might make.

Some enterprises will benefit more than others from the use of environmental software. In some enterprises the number of chemicals is so small as not to warrant any efforts to automate the material safety data sheets themselves. However, for quick emergency response and for government recordkeeping requirements, some computerized inventory is helpful. Smaller enterprises and small health and safety offices can benefit by using one of the many specialized software packages that handle material safety data sheets and other occupational health information needs.

Computerization forces a standardization of reporting and recordkeeping. This is beneficial because it establishes a baseline set of data that can be used to track environmental issues both from the level of the enterprise tracking the information as well as by the regulatory agency responsible for enforcing environmental standards.

Initially, this requires data entry of information that was formerly recorded manually. There may also be a need to customize a software package to match the particular needs of an industry or agency.

When a spill occurs like the one in New York Harbor discussed above, or when chemical are released to the environment over time as from a smelter stack, a risk is created to the exposed population and to the environment. Software is available that accepts all parameters associated with the emission and estimates the chronic and acute risk expected. The software has the ability to predict the results of exposure as a function of time. These programs may also predict the effect on risk for various remedial actions. These results are used to guide the selection and design of emergency response actions or remedial designs.

Modeling programs are also used to predict the extent of contamination for chemicals released to the environment. This may include prediction of the movement of toxic chemicals in the vadose zone (air filled soil above the water table), contamination of the water table, or movement with the water table toward existing or planned wells. Modeling programs can also be used to guide site investigations and to evaluate the effectiveness of alternative response actions.

Monitoring programs may be used to monitor response actions such as off-shore oil spills, to organize data after a cleanup or during a pump-and-treat remediation, to follow the course of the project, and to predict the outcomes and schedules. Other programs can support facility design, follow construction scheduling, prepare budgets, and follow cost generation.

There are other specialized software programs that provide input data to support many of the other programs outlined above. These include chemical toxicity data, chemical property data, and regulatory data. In addition, there are special programs of limited application such as sizing of sewer lines and prediction of rain runoff volumes.

### b. Discussion of hardware, operating system and software requirements

Environmental software vendors produce software that is useful to the widest range of customers possible. The software is designed to run on many kinds of computers to market to the largest client base. Physically, software can be delivered in several forms. Programs are most often sold on 5.25-inch or 3.5-inch diskettes for use with personal computers. Most software is designed for use on IBM compatible or Apple Macintosh computers since these computers are most widely available to potential users. Software packages are also available for mainframe or mini-mainframe computers. Mainframe and mini-mainframe applications are more likely to be custom programs designed to meet the needs of particular users.

Software that provides access to large amounts of information, such as regulatory text or chemical lists, is usually purchased on compact disks and accessed using a compact disk reader. The compact disk reader is a piece of hardware that is either built into the computer as an internal drive or attached as an external drive. The compact disk drive allows information to be read only, not changed or updated. Huge

volumes of information can be stored on compact disks allowing convenient, speedy access to large bodies of information that would be cumbersome on paper. A major issue for the industry has been the effort and cost required for input of archival and existing information into a system. Current technology allows for optical scanning for input, but there is a limitation in the ability to search and retrieve the data. A more sophisticated optical character recognition (OCR) technology is starting to take hold which allows for significant improvement in search and retrieval capabilities.

Many environmental software vendors offer compliance programs for personal computers equipped with modems. The modem allows communication by telephone, setting up a network between the software provider and the end user. This configuration allows many users to access the same database from various locations. A company could store its chemical inventory on a disk in a database for selected employees to view from other locations using their personal computer. This same approach could be used on multiple-terminal mainframe or mini-mainframe computer systems.

Some vendors maintain their databases at a central facility and for access by modem. In this situation the company using the database would pay a yearly subscription fee depending on the number of employees using the system and the amount of time spent online.

Compliance software packages vary in purpose, capability, and how they are sold. Software programs sold on diskettes for data entry and manipulation usually have a one-time purchase price. Vendors typically offer maintenance and updating services that may or may not be included in the initial price. CD-ROM software, on the other hand, usually is sold on a subscription basis, with regular updates offered as the information becomes obsolete. Online access to commercially maintained, offsite databases accessible by modem also are marketed on a subscription basis. The method used depends on the needs of the company, organizational structure, and staff.

## I.C. Competitive Software in Other Developed Countries

Environmental software is available in other developed countries, but appears to be in the early stages of development. Gerald Rich has been doing an annual review of available environmental software for Pollution Engineering magazine since 1985. When asked about the existence of environmental software in other countries he commented that he has received many requests from other countries for a environmental software directory that he publishes, but he was not aware of much available environmental software from these countries.

An article in Datamation[1] states that Germany is taking the lead in Europe in application of computers to environmental problems. The article states that other countries were working on environmental problems as well, but Germany was the leader. The driving force for development of environmental software is due in large part to political pressure brought to bear by the Greens, an environmental action group whose concerns have come to be espoused all over Europe. The Greens have advertised problems with pollution in the Rhine River, chemical imbalances in the North Sea, air pollution in major cities, and continued erosion of the Black forest due to emissions and acid rain.The European Center for Medium-Range Weather Forecasts (ECMWF) in Reading, U.K. have developed a computer simulation to offer predictions about the effects of such practices as burning coal and oil. Professor Harold Sverdrup of the University of Lund in Sweden has been active in applying predictive risk assessment models for addressing global environmental issues such as acid rain in Scandinavia.

Outside the government research realm, private industry in Germany is also interested in applying computer technology to help monitor, simulate and, in some cases, repair damage that has already been done to the environment. This has created a market demand for hardware and software expected to grow at a rate of 40 percent per year.

WRc, located in Buckinghamshire, England, has developed a software program, called AARDVARK, for interpretation of water quality data. WRc has also been involved in review and development of mathematical models to predict the behavior of organic pollutants in the environment.

While this review has, of necessity, been somewhat superficial, the conclusion is clear. The United States is preeminent in environmental software technology.

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(1) Trautman, Peggy, "Systems Solution to Pollution" Datamation, Oct. 1, 1989, 72-1, 72-2.

## II. Environmental Needs in Developing Countries

The environmental problems in developing countries are predictable, although they vary in type and severity depending on the level of industrial development. All developing countries experience environmental problems with air pollution, inadequate sanitation, waste water, diminishing freshwater resources, soil erosion, solid and hazardous waste disposal, and deforestation. These problems extend to the international community through climate changes, acid rain, ozone layer depletion, pollution of the oceans, and changes in biodiversity. Of particular concern is the potential for global environmental damage that could result from continued operation of numerous unsafe nuclear power plants such as those present in Eastern Europe and the former Soviet Union.

Developing countries need help from industrialized nations if they are to develop in a way that does not irreparably damage the planet. They need financial assistance, but also they need access to advanced technologies being developed in industrialized countries. For these reasons international environmental issues have become a major foreign policy issue for the United States and other countries as well. The United States is becoming involved in a growing number of international environmental programs such as the Framework Convention on Climate Change and the U.N. Conference on Environment and Development's Agenda 21. The environment was a major factor in the negotiations over a North American Free Trade Agreement (NAFTA) and environment and trade linkages are being discussed in working groups in the Organization of Economic Cooperation and Development and the General Agreement on Tariffs and Trade.

The World Bank is supporting development of an institutional and policy framework for environmental and natural resource management. Multilateral and bilateral aid for the environment is increasing for the developing world. The Global Environmental Facility has been formed by the World Bank to fund global environmental projects. In addition, business organizations such as the Business Council for Sustainable Development, the International Chamber of Commerce, and the U.S. Environmental Technology Export Council are taking a growing interest in the global environment.

These programs are designed to manage global environmental problems by forging partnerships between industrialized and developing countries. Much of the environmentally sound technology used worldwide has been developed as a response to U.S. environmental standards and regulations, and policies. U.S. environmental technology and expertise, resident in the U.S. private sector, is preeminent in environmental protection, energy efficiency, renewable resources and other clean energy production and use.

Based on global interest for protection of the environment the U.S. Agency for International Development is in the process of developing a proactive environmental and energy program to promote public and private partnership activities worldwide. This program would serve to apply U.S. know-how to global environmental and energy problems by funding environmentally sound projects in developing countries. This program provides the benefits of creating more jobs in the U.S., increasing

exports of U.S. environmental technology and services, and protecting and improving the environmental conditions in developing countries.

## II.A. Environmental Needs by Industrial Development Level

Table 1 shows a summary of environmental needs in developing countries by level of industrial development. Developing countries with a low level of industrial development such as Nepal, Paraguay, and Sudan are generally characterized as having government ownership of major industries, few environmental regulations, and little enforcement activities. In general, countries in this category are opening their markets and are experiencing a rapid increase in urban population. The major environmental problems in these countries are associated to poor potable water quality, often the result of improper sewage disposal practices. Also their environment is stressed through improper agricultural practices such as slash and burn techniques to prepare land for farming. The population is struggling to produce enough food to support itself, often at the expense of the natural resources. The environmental problems in these countries for the most part are not industrial, although there may be isolated point sources of pollution due to wastewater discharges.

Developing countries with a moderate level of industrial development such as Venezuela, Philippines, and Singapore are generally characterized as having ongoing market reforms, semi-privatization of major industries, development of some environmental regulations and enforcement activities, and a rapid increase in urban populations. Countries with moderate level of industrial development have increasing problems with industrial wastewater discharges, air pollution, and some hazardous waste treatment and disposal.

Developing countries with high level of industrial development such as Taiwan and Mexico are characterized by increase in economic growth, strong move towards market economy, tendency to privatization of major industries, existence of environmental regulations, and moderate to increasing environmental enforcement. Environmental problems faced by these countries are domestic and industrial water pollution, air pollution, solid and hazardous wastes, and ecological deterioration.

When dealing with solutions to environmental problems in the developing countries, in general, the decisions are made in the absence of environmental information. Collecting and processing basic data is a need that requires immediate attention. Some of the priorities for monitoring pollution and waste problems are:

- Quality and availability of drinking water and sanitation facilities
- Exposure to air ambient pollutants, specially particulate matter and lead, in urban areas
- Fecal coliform and heavy metals in rivers and lakes
- Indoor air pollution from the burning of biomass
- Hazardous wastes and pesticides in selected "hot spots"

The use of environmental software tools may be of great help in these countries. These tools would allow the establishment of a baseline for existing environmental

## Table 1 - Environmental Needs by Level of Industrial Development and Software Needs

| Categories | General Conditions | General Environmental Activities | Software Needs |
|---|---|---|---|
| **Category 1**<br>High Level of Industrial Development (e.g., Korea, Mexico, Brazil, India) | Market Reforms, Open Markets<br>Privatization of Major Industries<br>Existence of Environmental Regulations<br>Moderate/Increasing Environmental Enforcement<br>Rapid Increase in Urban Populations | Typical media Affected Include Air, Water, Solid Waste, and Hazardous Waste | Data Management<br>Management and Administrative<br>Reporting<br>Modeling<br>Design<br>Reference Materials<br>Risk Assessment<br>Enforcement |
| **Category 2**<br>Moderate Level of Industrial Development (e.g., Venezuela, Philippines, Argentina, Singapore, Chile) | Market Reforms Underway<br>Semi-Privatization of Major Industries<br>Environmental Regulations Being Developed<br>Moderate to Little Environmental Enforcement<br>Rapid Increase in Urban Populations | Typical Media Affected Include Air, Water, and Solid Waste | Data Management<br>Reporting<br>Modeling<br>Reference Materials |
| **Category 3**<br>Low Level of Industrial Development (e.g., Nepal, Paraguay, Indonesia, Ecuador) | Opening Markets<br>Government Ownership of Major Industries<br>Few Environmental Regulations<br>Little Environmental Enforcement<br>Rapid Increase in Urban Populations | Typical Media Affected Include Air and Water | Data Management<br>Reference Materials |

resources. Monitoring water quality, for instance, would help to determine which areas are more polluted and would provide information to be used by the governments in the allocation of resources.

## II.B. Driving Forces for Environmental Software Market in Developing Countries

A recent survey of six developing countries assessed environmental market conditions in those countries. The main drivers for their environmental markets were, in the private sector, the improvement in the economy, privatization of government-owned businesses, and the shift to market economies. In the government sector, the drivers were new laws and regulations, increased enforcement, high priorities, and severe national environmental problems, often due to inadequacies in infrastructure.

The response to these drivers were different for countries in different stages of development, with the greatest need and greatest spending in the most developed countries. The more spending on environmental problems in a country, the more the need and opportunity for environmental software.

A survey of six South American countries, Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela, showed that all had environmental drivers in the economy and private sector. These include, for Argentina, improving economy, privatization and export promotion. The impact is that with the expected privatization of steel, power and petrochemicals, these industries will have to comply with environmental regulations. The planned modernization of these industries to achieve international competitiveness so that exports can be increased will also boost environmental spending. Privatization is expected to be a strong driver in Brazil and Mexico as well. In all countries except Venezuela, the nationalized companies have been practically exempt from environmental regulation. This ceases as soon as privatization occurs, resulting in the driver. In the case of Venezuela, the state-owned oil company, PdVSA, plans to make sizeable environmental spending commitments through 1996.

The shift to a market economy from a managed economy is also a driver, as is economic growth. These are important in Argentina, Brazil, Chile, Colombia, and Mexico. These economies respond to public pressure for an improved environment, which occurs in all market economies but is particularly strong in Brazil, Colombia, Mexico, and Venezuela.

A final driver is the desire to increase exports. This pressures the economy to upgrade, technically, in order to meet world competition, but also to meet the desires of trading partners like the United States that they meet minimum environmental standards. This is particularly true of Mexico and Chile.

Table 2 shows the results of the survey of the six South American countries. The most pervasive drivers in the private sectors are: market economy — 4; public pressure — 4; privatization — 3; improved economy — 2; export promotion — 2; and modernization of nationalized industry — 1. This gives 15 entries for the private, economic sector for a majority of the entries.

# Table 2 Drivers for Environr .al Spending

| Drivers | Argentina | Brazil | Chile | Colombia | Mexico | Venezuela |
|---|---|---|---|---|---|---|
| ***Private Sector:*** | | | | | | |
| Market Economy | | X | X | X | X | |
| Public Pressure | | X | | X | X | X |
| Privatization | X | X | | | X | |
| Improving Economy | X | | X | | | |
| Export Promotion | X | | | | X | |
| Modernization of National Industry | | | | | | X |
| ***Government Sector:*** | | | | | | |
| Improved Envorcement | X | X | | | X | X |
| Government Priority | | | X | X | | |
| Infrastructure Problems | | | X | X | X | |
| Formation of EPA | X | | | | | X |
| New Regulations | | | X | | | |

Ref: "Environmnetal Market Conditions and Business Opportunities in Key Latin American Countries", U.S.A.I.D. - Office of Energy and Infrastructure, October 1992.

The other important environmental market driver is government action, with 14 entries. The most important action here is improvement in enforcement, including criminal prosecution, with four entries for Argentina, Brazil, Mexico, and Venezuela. This driver results in expenditures from the industrial sector as they move to comply with the regulations being enforced. The next most important driver, with three entries — Chile, Colombia, and Venezuela, is government priority. This is usually driven by public pressure, and results in a commitment to action that results in the completion of highly visible projects such as the cleanup of air pollution in Santiago. Environmental sales resulting from this pressure include catalytic converters, low lead gasoline, flue gas treatment technologies, etc.

Some of the visible environmental problems arise from inadequate infrastructure. This is the case for Chile, Colombia, and Venezuela. Specific examples include the effort to clean up the conditions around Caracas and Lake Valencia. This drives investment in waste water treatment plants to clean up dead lakes and rivers.

The creation of an effective governmental body to generate and enforce regulations is a driver in Argentina and Venezuela. This action produces the ability by the government to respond positively to the countries' environmental needs, where such may not have been the case without such an organization. Expenditures for all aspects of the environment result in a need by the new agency for technical support. In countries which have such a structure, new regulations can produce a similar result, as is the case with Chile.

The above discussion encompasses all expenditures for environmental purposes. The environmental software market is only a small segment of this larger market. Software products are available which support the planning, design, construction, and monitoring of all of the environmental initiatives discussed above. Of particular interest, however, is the environmental compliance software which helps companies and their plants to comply with the regulations and report such compliance to the regulatory bodies. The drivers that produce regulation, laws, and enforcement result in the generation of data that must be managed by the regulators. These drivers create a need for environmental compliance monitoring by the regulators as well, so that they can easily determine the instances of non-compliance and respond appropriately. This is one of the best near-term opportunities provided by the drivers discussed above.

While we have only discussed the driving forces for six South American countries in this section, we believe that the conclusions and statistics will be the same for a larger sample of developing countries. The results for Asia and the more developed parts of Africa should follow the same general pattern. The brevity of this study did not permit the gathering of further data on this point.

## III. General Software Categories

The range of available environmental software was identified through literature searches, review of environmental software directories, and telephone conversations. Descriptions of each software program were collected and categories were developed to define the range of available programs. The methodology used to locate environmental software programs and a description of each software category is discussed in the following sections.

### III.A. Methodology for Collection of Available Software

The range of available environmental software was identified through literature searches, review of environmental software directories, and telephone conversations. Trade journals periodically publish summaries of environmental software. Pollution Engineering publishes an annual review of environmental compliance software in January. The author of the Pollution Engineering review, Gerald Rich, also sells a software program that provides listings of available environmental software. This program was obtained, along with another software directory called the Donley Technology Environmental Software Directory. The Donley directory contains listings for over 500 environmental software programs. In addition, HazMat World publishes an annual listing of environmental compliance software programs in July. Access EPA, 1992 Edition provided a complete listing of major EPA Environmental Databases, and the Federal Data Base Finder (Third Edition) is a directory of free & fee-based data bases & files available from the federal government. Information Systems Inventory (ISI), May 1991, is a sourcebook on approximately 500 of EPA's current information systems including models and and databases. Additional software program descriptions were obtain through a literature review at the Library of Congress. A total of 532 unique environmental software programs were identified.

### III.B. Software Categories

Each environmental management program was summarized according to software title, vendor name, address and telephone number, description of software capabilities and features, hardware and software requirements, and cost. A computer program was created to record this information for each software program. After reviewing the range of available environmental software programs, categories were created to describe, in general terms, the capabilities of the software programs. A total of twelve categories were defined: (1) comprehensive, (2) modeling, (3) data management, (4) monitoring, (5) design, (6) risk assessment, (7) reference material, (8) reporting, (9) calculation, (10) enforcement, (11) management and administrative, and (12) cost. In addition, categories listing the range of environmental problems addressed by the software programs were also created. The environmental problem categories are listed as follows: (1) surface water, (2) drinking water, (3) ground water, (4) industrial wastewater, (5) domestic wastewater, (6) ambient air, (7) mobile air pollution sources, (8) fixed air pollution sources, (9) fugitive air emissions, (10) toxic chemical use, (11) ocean disposal, (12) nonhazardous waste, (13) hazardous waste, (14) noise pollution, (15) radioactive materials. Each software package was labeled with one or more

software and environmental problem combination. Table 3 shows a matrix of the total number of software and environmental category combinations. A description of each software category is presented in the following subsections.

### III.B.1. Comprehensive System

A comprehensive system aids the user in all main compliance areas. Essentially, it is an environmental compliance management system (ECMS) containing one or more compliance reference database, allows for data input for management purposes, performs calculations, generates reports, develops emergency plans and risk analysis in support of industrial hygiene. The systems vary in terms of complexity and many are geared toward specific media (i.e., soil, water, air). The cost for these systems range from $5,000 to $100,000. The variation in cost arises because some systems are specific for one media (i.e., soil, water, air), whereas others have the capacity to support many different modules (i.e., soil, water, and air modules can all run on the same system). The cost is also generally a function of the computer hardware needed to run the program. A less expensive system (one module) would run on an IBM PC but a more expensive system (multimodule ECMS) would require the more expensive VAX or UNIX support.

### III.B.2. Modeling System

Modeling software consist of programs that model or simulate a process such as pollutant transport through various media, or air dispersion. Upon examination of available modeling software, most fell under three main subheadings: (1) hazardous substance management, (2) water, (3) and air pollution. The modeling systems ranged from extremely basic (a single pollutant introduced into an unchanging system) to very high complexity (complete simulation of an environmental situation including effects on the soil, water, and air).

Several types of modeling systems are available for hazardous substance management. These include systems that track leachate movement in a landfill based on design, calculation of radionuclide releases to air, land, rivers, and lakes as a result of repository accidents. In addition some of the programs were designed to estimate genetic risks, as well as study the impact of fires, explosions, and toxic chemical releases into the atmosphere. The modeling systems which fell under the subheading of water encompass process simulation of a wastewater treatment plant, contaminant transmisivity through an aquifer, simulation of reservoir for conservation and flood control purposes, and simulation of initial mixing of wastewater discharged into oceans to name a few. Air pollution modeling consists of emission predictions from mobile sources, from fixed sources, and from fugitive sources. Examples of these models include the prediction of carbon monoxide concentrations near highways and streets, a point source dispersion model accounting for the complex arrangement of emission sources, and the determination of long term seasonal or annual pollutant concentration in rural or urban areas. These are examples of the types of systems that can be modeled with computer aid.

# Table 3 - Matrix of Available Environmental Computer Software

Note : Total number of software programs reviewed = 532

Software Category

| Environmental Problems | Modeling | Calculation | Monitoring | Data Management | Reporting | Enforcement | Design | Reference Material | Risk Assessment | Managment and Administrative | Comprehensive | Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface Water | 6 | 6 | | 2 | | 1 | 1 | | 3 | | | |
| Drinking Water | 3 | 2 | | 1 | | 1 | 1 | | | | | 1 |
| Ground Water | 43 | 46 | 6 | 19 | 22 | | 13 | 2 | 5 | | 4 | 1 |
| Industrial Wastewater | 7 | 10 | 11 | 14 | 13 | 3 | 5 | 3 | | 1 | 5 | 3 |
| Domestic Wastewater | 6 | 6 | 8 | 11 | 5 | 4 | 3 | | | 2 | 2 | 2 |
| Ambient Air | 16 | 8 | 1 | 5 | 1 | 1 | 1 | 2 | 3 | | | |
| Mobile Air Pollution Sources | 7 | 3 | | 1 | | 0 | | | | | | |
| Fixed Air Pollution Sources | 52 | 34 | 6 | 24 | 14 | 10 | 9 | 4 | 11 | 1 | 4 | 6 |
| Fugitive Air Emissions | 6 | 8 | 1 | 1 | 1 | 1 | | | | | 1 | |
| Toxic Chemical Use | 1 | 1 | 1 | 1 | 2 | | | 3 | 1 | | | |
| Ocean Disposal | 1 | 2 | | | | | | | 1 | | | |
| Nonhazardous Waste | | | | 1 | | | | | | | | |
| Hazardous Waste | 17 | 42 | 40 | 75 | 93 | 46 | 10 | 61 | 34 | 2 | 11 | 11 |
| Noise Pollution | 1 | | | | | | 1 | | | | | |
| Radioactive Materials | 20 | 18 | 2 | 3 | 2 | | | 1 | 10 | | | |
| Total: | 186 | 186 | 76 | 155 | 153 | 67 | 44 | 76 | 68 | 6 | 27 | 24 |

The cost of these systems ranged from $50 - $20,000, with the average air modeling system costing less than $300, the water models priced between $500 and $2,500, and the hazardous waste systems spanning wide cost range depending on system requirements.

### III.B.3. Data Management System

Data management software permits the user to input, store, and retrieve data. Each system can be modified to be site/user specific. These software packages enable the user to prepare graphical representations of raw data and analyze general trends. Basic software systems are priced around $400, however, a system tailored for a particular pollutant or environmental problem will triple in price.

### III.B.4. Monitoring System.

A monitoring system was categorized based on its ability to track notices, exposure data, emissions, storage tank information, etc. A monitoring system has a built in trigger mechanism to inform the user of an abnormally functioning system (i.e., emissions greater than regulatory levels or overdue inspections). The price of a monitoring system could range from $5,000 to $100,000. This wide price range is accounted for in the variability of monitoring systems. Monitoring only one form of data such as stack emissions, would cost less and require less computer support than a system which could track stack emissions, storage tank data, and alert the user to any potential compliance violations.

### III.B.5. Design System.

Design software for environmental purposes included construction requirements for a wastewater treatment plant, a program which illustrated groundwater monitoring wells, and a system which anticipated future facility needs. These systems analyzed options for process modifications, control alternatives, or facility expansion necessary for regulatory compliance. The cost range for a design system is $250 to $25,000 depending on the system necessary for running the software package (i.e., an IBM would be cheaper but more limited and a VAX would be more expensive but limitless). Most design packages are specific for one facility type, the more expensive the package the more variability in designs are available.

### III.B.6. Risk Assessment System

Risk assessment software is used to predict or calculate the chronic and acute risk posed to humans based on variable environmental parameters (i.e., eating contaminated fish, land application of sludges, and percentage of fatal cancers due to a radioactive leak). The software includes information on protocols to be followed in the event of a hazardous spill or leak and those necessary to comply with regulatory work-place standards. Risk assessment software packages are generally used by

environmental agencies or industrial sites to determine exposure limits and proper safety precautions. The cost ranges between $500 and $1500.

### III.B.7. Reference Material System

Reference material systems consist primarily of database systems used for look-up purposes. Reference material programs are most abundant hazardous wastes. A comprehensive reference information system contains a network of smaller information systems which are accessible through a main database. Such information systems contain information relating to such areas as chemistry, toxicology, environmental pollution, and hazardous materials. This type of system varies in price depending on whether the user pays an hourly fee (approximately $40/hour), an annual charge (approximately $2000/year), or both (approximately $40/hour and $300/year).

An information system containing only one type of data (i.e., strictly chemical properties, aquatic toxicity, or hazardous material information) is less complex in scope, having costs ranging from $300-$700.

Comprehensive reference material systems are more extensive in scope of information available to the user. In general, these systems are accessed by modem and are maintained at central location such as a government agency (i.e., OSHA for safety information and EPA for hazardous chemical information and exposure data). Smaller databases are available for installation on the user's PC but are limited in the information it can provide.

### III.B.8. Reporting System

Reporting system software is used to generate outputs such as graphics or printing forms for compliance reporting purposes. The compliance reporting software has the ability to generate an agency specific compliance report and is generally included in a comprehensive package which has compliance tracking capabilities. Most graphical reporting programs are combined with a modeling program or calculation program. Reporting limitations are defined by the data management system. Some reporting software allows the user to customize certain reports while others simply print predefined forms. Reporting software programs range in price from $200-$500.

### III.B.9 Calculation System

Calculation systems are used to calculate values such as human health effects due to risk exposure, process design costs, and lethal dose levels. Numerous calculation programs exist, often in combination with other software packages (i.e., modeling, risk assessment, design). Because of this, it is difficult to compare packages on the calculation aspect alone.

### III.B.10. Enforcement System

Enforcement software systems determine compliance with specific regulations. Examples of systems include, but are not limited to, scheduling inspections, employee training, notification tracking, or calculating criteria for specific treatment processes to determine regulatory compliance. Price estimations were not available on the limited software packages that fell into this category.

### III.B.11. Management and Administrative System

Systems used for management and administrative purposes allow the user to generate reports based on entries from purchase orders, chemical inventories, pending chemical orders, and other user defined administrative requirements such as quarterly reports. This type of system is often included within a data management or monitoring software systems to track information. The price for these systems ranges from $3500 to $100,000.

### III.B.12. Cost System

Costs systems are used to estimate budgetary construction costs, process equipment costs, and conceptual design cost estimates. These software programs range in price from $450-$1000.

## IV. Results

The results from this assessment confirm the following statements:

(a) The U. S. environmental software industry is preeminent in the world. There is a great variety of software available to fulfill every need for software from the developing world. This software is easy to use and powerful in its application. The available U. S. environmental software is in English as are the associated manuals. Therefore, translations into the language of the user country will generally be required.

(b) The U. S. environmental software industry, with the associated hardware producers, make available all of the required technology for the developing countries. No gaps were found in the technology. New programs continue to become available providing increasing depth of technology.

(c) The environmental needs of developing countries vary with the type and extent of industrial development. Generally, the least developed countries have the simplest environmental problems centering around water purity and human sanitation. As one moves up the scale of industrial development, more complex problems are found, including hazardous waste, toxic substances, contaminated soils, and air pollution. While the problems become more complex, the ability of the country to cope with the problem also increases. The movement from command economies and nationalization to market economies with privatization is one of the strongest drivers

for a country to successfully meet environmental problems. A free society generally is successful in pressuring the government into taking effective actions to solve environmental problems. This is true at all levels of development.

(d) There is a need for environmental software at all levels of industrial development. At the least developed level, the needs are for water purity protection and management of human waste. An environmental management data base software will fulfill the basic governmental need. Some simple modeling of groundwater flow and geotechnical data base capability completes the basic requirements. Little need exists in the private sector at this level. Mid-developed countries have these needs plus compliance software at the governmental level. Further modeling capability is also needed to respond to air pollution problems. At the highest level, all of the above are needed plus software to respond to solid and hazardous waste and toxic substances in all the media. Refer to Table 1 for a summary of software needs for developing countries.

(e) Markets for environmental software in developing countries vary greatly, but generally increase with the country's development and the strength of its economy. If most of the country is starving, the environmental priorities tend to diminish. Marketing of software directly to the government to meet national environmental priorities is an excellent entry point. For more developed countries with a strong enforcement operation, sales to industry for their compliance management is also an excellent market entry. As expenditures build within a country to cope with environmental problems through upgrading of equipment, processes, and infrastructure, software to implement such programs become highly marketable. In each case, the U.S. has an excellent position to market environmental software. The detriments are the need for translation and tailoring, and the need for government financing to make the sale take place and prompt payment of bills possible. This is especially important in countries with hyper inflation that will not pay in hard currency.

(f) The export of environmental software and associated support services helps the developing countries to improve their environment and helps the U.S. to improve the balance of trade. Since we all live on the same planet, the improvement in the environment in any developing country also helps the U.S. In addition, the collection of data and their inclusion in environmental compliance management systems in developing countries makes those data available to the U.S. as well. Analysis of those data will lead to a better understanding of worldwide environmental trends. This will help the U.S. to make better, more informed decisions on U.S. policy in support of global environmental issues.

## V. Conclusions and Recommendations

The conclusions of this study are: (1) the U. S. has the required technology and is preeminent in environmental software and hardware; (b) the countries of the developing world have a need for technology in this area, the amount and kind depending on the industrial development of the country and the strength and market orientation of its economy; (c) the available software can fulfill those needs with the existing products and technology; and (d) hard currency is increasingly available to

pay for technology of this kind, making for a viable market.

There are two main obstacles to near-term market penetration by U.S. firms. The first is support to generate tailored software and manuals in the language of the various countries having the greatest need. The second is the cost of marketing, especially to achieve initial penetration.

From the U. S. Government's viewpoint, the first obstacle could be attacked by using AID grants to generate the software translation for a specific country, such as Mexico or Chile, and support installation and test. This would, of course, require a reconfiguration of the ECMS type software to support the specific laws and regulations of the host country. This installation would then support the environmental program of the country, and would also serve as a Beta test site for software development. Other countries could visit the site which would be the center for further marketing of the U.S. software in the region.

With regard to marketing in the developing countries, U.S. A.I.D. programs that bring key executives, both government and industry, to the U.S. for marketing by U.S. suppliers could have a positive impact on environmental software marketing. The trips are enticing to the developing country executive, and the day the company hosts the executive is a much lower cost contact than a sales call from the U.S. in the executive's home office. This program should be expanded to include environmental software marketing, perhaps through the Environmental Training Institute.

The penetration by the software industry can lead to sales of many other products and services. Therefore, it may be worthwhile to consider a U.S. initiative in this area similar to the Sematich initiative in computer chip development. The problem for the U.S. software industry export is not technology creation, but rather product tailoring (translations and alignment with local laws) and the high cost of individual selling. We recommend that these problems be attacked by the formation of an Environmental Software Export Institute or through numerous existing institutions. The institution would be supported by the U. S. Government, initially, with financial contribution from the software industry after sales start to build.

The purpose of the institution is to support the enhancement of the global environment through the promotion of the export of software to solve environmental problems in developing countries. This institution would carry out a group of tasks in support of its objective.

Task 1 would support the tailoring of U. S. environmental software products for export by the provision of funding for translation of the software and operations manuals into indigenous languages, and conforming of the software programs to meet local needs, laws, and regulations. This would be done in partnership with the target country, the U.S. software industry, and other funding agencies such as the World Bank.

Task 2. Create and operate a multi-lingual database of available U. S. environmental software for use by developing countries interested in procuring specific software capabilities.

Task 3. Support the marketing of U. S. environmental software by organizing and hosting shows, expositions, seminars, and training sessions in key locations around the world.

Task 4. Create and operate a database of the needs and opportunities for sale of environmental software in the developing countries. The information for this database would be solicited from the local U. S. Embassy staff, and processed by the institute.

Task 5. Set up an international user group for developing countries that use U.S. environmental software to assure that the software is meeting the needs of the developing countries.

Task 6. Provide consulting advice on the use of environmental software to solve problems in developing countries.

Task 7. A training and seminar task to disseminate information on the U. S. environmental software industry including the funding of trips to the United States by executives from developing countries.