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Environmental Business International

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## **Joint Working Party on Trade and Environment**

### **THE IMPACT OF MONITORING EQUIPMENT ON AIR QUALITY MANAGEMENT CAPACITY IN DEVELOPING COUNTRIES**

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**by Jim Hight and Grant Ferrier  
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## ABSTRACT

Reflecting the desire for cleaner air, many developing countries have enacted clean air laws similar to those of developed nations, although to date most of these laws have been poorly enforced. A key starting point to better enforcement is obtaining comprehensive and reliable air-quality monitoring data. This report explores the impacts of air quality monitoring programmes implemented over the last decade in five developing countries: Morocco, the Philippines, Malaysia, Indonesia, and India. These case studies also examine the role of procurement of specialised equipment, usually imported, associated with the various air quality monitoring programmes.

*Key words: air quality, environmental goods, developing countries, trade, Morocco, Philippines, Malaysia, Indonesia, India*

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The report is available on the OECD website in English and French at the following URL addresses: <http://www.oecd.org/trade> and <http://www.oecd.org/environment>.

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## **THE IMPACT OF MONITORING EQUIPMENT ON AIR QUALITY MANAGEMENT CAPACITY IN DEVELOPING COUNTRIES**

### **Air quality data: the first step toward cleaner skies in the developing world**

Air quality in many developing countries, particularly urban centres, has become severely polluted over the last several decades as a consequence of industrial development, economic growth and large-scale migrations by rural residents to cities. Air pollution degrades the health and quality of life for people. Air pollution also exacts direct costs on national economies in the forms of reduced productivity and greater demand for medical services. In addition, there are indirect costs that are rarely accounted for such as the decreased value of the natural resource ‘asset’ of clean air in a nation, decreased tourism and even reduced foreign investment as a result of polluted air or other environmental and health impacts of polluted air.

Citizens in the United States, Japan and much of Europe enjoy relatively clean air thanks to enforcement of air quality laws and market-based incentives for emitters to reduce their output of sulphur dioxide (SO<sub>2</sub>), nitrogen oxide (NO<sub>x</sub>), particulate matter (PM) and other pollutants. But efforts to reduce pollution lag significantly in most developing countries largely because the costs of obtaining cleaner air — through such measures as replacing and upgrading vehicles and installing air pollution control devices on industrial facilities and power plants — represent a large investment relative to national economic output.

Nonetheless, there is a strong interest in improving air quality among citizens and leaders of developing countries with heavily polluted airsheds. Reflecting the desire for cleaner air, many developing countries have enacted clean-air laws similar to those of developed nations, although to date most of these laws have been poorly enforced. Regional initiatives such as the Air Pollution in the Megacities of Asia (APMA) and Clean Air Initiative for Asian Cities are aiding national governments and developing transnational strategies for cleaner air; and multilateral institutions such as the World Bank and the Asian Development Bank are funding air-quality management programs.

The challenges to improving air quality in developing countries range from a lack of government commitment to even weak policies and standards to lack of accurate air-quality data, according to APMA’s Strategic Framework for Air Quality Management in Asia (2004). All these obstacles must be overcome to improve air quality in developing countries, but a key starting point is obtaining comprehensive and reliable air-quality monitoring data. Such data are scarce in developing countries, and where they exist, they are often incomplete or inaccurate. Without effective and useful data, it is impossible to identify and apportion the sources of emissions, and to establish permanent monitoring systems and hence impossible to develop effective measures to prevent and reduce harmful pollutants.

In the Philippines, for example, acquiring accurate and reliable data on the sources and levels of air pollution is viewed as a crucial first step in implementing national clean-air policies. While the government has the legal authority to regulate emissions through fees or taxes on major emitters, according to Air Pollution Control Policy Options (2003), a report by Resources for the Future, it must first develop the capacity to compile specific emissions data and validate data from emitters. The agency must also determine the “precise extent and distribution of stationary source and other emissions in Metro Manila,” according to the report.

### **Five case studies: NGOs, Governments and businesses collaborate to build air quality monitoring capacity**

A range of air quality monitoring projects has been implemented over the last decade in developing countries. This report explores the impacts of such projects, focusing on case studies from five countries: Morocco, the Philippines, Indonesia, India and Malaysia. These projects were selected and profiled in late 2005.

In all the case studies except for the Indian fuel testing project, imported air-quality monitoring equipment was crucial to the programmes' successes. Such equipment is not manufactured to any significant degree in developing countries at this point. (In the Indian case, advanced imported equipment for fuel testing would have increased the speed and efficiency of testing, but project funding limits forced the investigators to use older, indigenously manufactured equipment.)

With the vast majority of their sales in the developed countries, manufacturers still do not see much of a market in the developing world and have little incentive to license their technology to producers in developing nations. While manufacturers' instruments and monitoring systems source sub-components worldwide, virtually all technologically advanced components are sourced from developed countries, and virtually all assembly and testing is performed in the manufacturers' domestic factories. This could change in the future if the volume of purchases in developing countries increased to the point where manufacturers could achieve the economies of scale necessary to outsource or franchise production to manufacturers in developing countries.

Overall it seems to be clear that most analytical technology used in the developing world for environmental purposes is imported from developed nations. However, like much of the broader environmental industry that involves air, waste, wastewater, solid waste, recycling and remediation, there are significant service and labour components involved in almost every environmental project. So often, the importation of a piece of sophisticated machinery involves the employment and training of a large number of individuals and contributes to the building of institutions. An example exists in the Manila project where a USD2.3-million project funded by the Asian Development Bank involves the purchase of just USD170 000 worth of monitoring equipment, with most of the remaining amount used for data collection and analysis by local project team members.

A valid observation about the five cases profiled is that there is indeed a significant capacity-building element in each project. Monitoring stations or programmes are established and sometimes given the impetus to be self-sustaining. Besides the obvious capacity-building value of monitoring stations and programmes and environmental regulatory bodies given access to greater data, these projects also reveal a sort of non-institutional capacity building through actions of the citizens of the country to promote cleaner air. In at least two of the cases documented below, there are examples where the provision and dissemination or publication of environmental monitoring data has made people more aware of air-pollution sources and in a way empowered citizens and even agencies to act on the behalf of residents affected by air pollution. One case shows demonstrably the power of information, as the government banned the release of the data during the smoke-and-haze crisis knowing public pressure might increase if the extent of the degradation of the air were fully grasped.

The ultimate objective of these projects in air-pollution and air quality monitoring in the developing world is undoubtedly clear air itself. But the environmental regulatory apparatus can hardly operate and hold emitters accountable without sufficient data to demonstrate each emitter's impact on air quality. The capture and dissemination of air-pollution data is an important and inevitable first step in getting to the task of controlling air-pollution emissions. While the projects profiled below demonstrate little in the direct reduction of air pollution, the institutionalization of air-monitoring bodies and programmes represent an

important step in capacity building to address the very serious problem of air pollution in the developing world.



## **ANNEX 1. CASE STUDIES OF ENVIRONMENTAL MONITORING PROGRAMMES IN DEVELOPING COUNTRIES**

### ***Jorf Lasfar Energy Company Air Quality Monitoring Project El Jadida, Morocco***

To stimulate economic development and reduce poverty through the provision of reliable electricity, the Moroccan government embarked in the early 1990s on a project to build a large coal-fired electrical generation station near the port of Jorf Lasfar in El Jadida, 130 km west of Casablanca.

Two 330-MW units were constructed by the national electric utility, Office National de l'Electricité (ONE), and placed in service in 1994 and 1995. During this period, the national legal framework was modified to allow independent power production, and in 1994, ONE requested bids for the construction of two additional units. Because the electricity law required that power assets be owned by ONE, the agency sought a builder-operator team to construct the two new units and operate all four units with a 30-year power purchase agreement.

ABB Asea Brown Boveri Ltd (Zurich) and CMS Morocco Operating Co., a wholly owned subsidiary of CMS Energy Corporation (Dearborn, Michigan, USA) were the chosen bidders to build and operate the power plant. These entities formed the jointly owned Jorf Lasfar Energy Company and entered into a long-term agreement, which was a 30-year lease by the project company of the four units.

In addition to cash flows from the existing units and investor equity, the project was financed with loans from Swiss, Italian and U.S. export credit agencies and commercial loans backed by World Bank guarantees. The USD 1.483 billion project included port enhancements to facilitate the increase in coal shipments, as well as upgraded transmission lines from the power plant.

To meet World Bank standards for NO<sub>x</sub>, SO<sub>2</sub> and particulate air emissions, the power plant incorporated electrostatic precipitators and other measures. In accordance with loan conditions, the project also included an ambient air-quality monitoring system to evaluate the effect of the power plant on the local environment.

Two meteorological stations and one air-monitoring station were established to measure SO<sub>2</sub>, NO<sub>x</sub>, total suspended particulates (TSP), and respirable particulates (PM<sub>10</sub>). The initial contract for monitoring equipment and related services was approximately USD 250 000. The monitoring stations are operated by JLEC, but to ensure the data quality and the sustainability of the monitoring effort, URS Corporation (San Francisco) is under contract to perform annual audits of the monitoring network. Additional auditing, preventative maintenance and training are provided by URS, as needed.

The system has been in operation for almost 10 years and has a very good reliability record (valid data capture rates are consistently above 90%). The monitoring system has documented that the plant does not emit pollutants in excess of levels that would exceed World Bank or WHO guidelines for air quality. Of particular importance, monitoring data have shown that occasional elevated levels of SO<sub>2</sub> in the area are caused by other industrial sources and not the JLEC power plant. Similarly, the occasional days with high dust levels have been shown to be due to natural windblown dust (the plant is on the edge of the desert) and not the power plant.

The Jorf Lasfar power plant has brought enormous advantages to the country's people. It provides approximately 65% of Morocco's baseload electricity demand and one-third of the country's total electricity supply. And with this monitoring system, the government and plant operators are confident that the electricity is generated without significant adverse impacts on the environment.

Additionally, the project provides an example of the type of data that is needed to improve air quality in polluted airsheds throughout the country. In a recent report by the World Bank, (Sarraf and Jorio, 2003), improved air quality monitoring was cited as a top priority. "Despite progress to date, much still needs to be done in the area of air quality monitoring. Studies should be conducted not only to measure the concentration of air pollutants and track the effectiveness of pollution control mechanisms, but also to show the relationship between pollution and the environment, health, quality of life and natural resources," states the report. The JLEC air quality monitoring system provides an excellent example for other industrial and power generating plants.

*Goods associated with the project*

- Filter assemblies (HS 8421.39)
- Particulate samplers (HS 9027.10)
- NOx absorbers (HS 9027.10)
- SO2 absorbers (HS 9027.10)

***Metro Manila Air Quality Monitoring Project  
Manila, Philippines***

Pollution from vehicles and industries render the air in Metropolitan Manila increasingly dangerous for the region's approximately 20 million residents. When pediatricians were asked in the late 1990s to identify the most common illnesses they treated, respiratory diseases were cited by 100% of the respondents. While affluent families keep their children indoors, breathing filtered air, poor children, especially those who beg in areas with heavy traffic, suffer chronic exposure to the heavily polluted air. Adults suffer as well, with citizens complaining that the air on major thoroughfares leaves them dizzy and hyperventilating. Studies by European and British health experts have demonstrated a strong link between the region's polluted air and abnormally high rates of heart disease.

As the metropolitan population continues to grow, so does the rate of pollution emissions, taking an increasing toll on human health. If air-quality controls are not forthcoming, it is likely that the harmful effects of polluted air will undermine advances in economic and social development.

Cleaner air is a policy goal widely supported by citizens and leaders in the country. Indeed, the Philippines passed an air-quality law similar to the U.S. Clean Air Act in 1999. Yet relatively little has been done to implement the law. As in other developing nations, economic growth is the dominant priority, and the nation lacks the resources to subsidise the costs of replacing and upgrading vehicles and installing pollution controls on industrial emitters.

Acquiring good data on the sources and levels of air pollution is viewed as the key first step in implementing the nation's clean-air policies. While the Philippine Department of Environment and Natural Resources (DENR) has the legal authority to regulate emissions through fees or taxes on major emitters, the agency must first develop greater capacity to compile specific emissions data, validate data from emitters, collect fees, enforce penalties, and manage the resulting revenues, according to *Air Pollution Control Policy Options* (Krupnick *et al.*, 2003), a report by Resources for the Future. The agency must also

determine the “precise extent and distribution of stationary source and other emissions in Metro Manila,” according to the report. Of particular concern is the extent to which sulfur and SO<sub>2</sub> emissions must be reduced. Existing data are old and came from just one source. “Better data are critical to designing the fee and evaluating the program,” states the report.

To develop more comprehensive and reliable data on pollution levels and sources, DENR has created the Metro Manila Air Quality Improvement Sector Development Program. With funding from the Asian Development Bank, a major emission sampling programme was initiated in 2004. DENR contracted with TRC Environmental Corporation (Irvine, California) for a three-year, USD 2.3 million Outsource Sampling Program. TRC in turn contracted with a Filipino firm, Technical Experts on Environmental Management (TEEM), to provide the manpower for data collection. The Outsource Sampling Program involves four teams that are deploying mobile testing sets to measure stack emissions from about 1 000 sources in metropolitan Manila.

As of November 2005, 60% of the 500 emitters tested failed one or more criteria of the Philippine clean air law. While no enforcement action has been taken to date, the initial results indicate that there is a high rate of non-compliance. It is anticipated that the full data set and accompanying analysis will enable the DENR to adapt appropriate enforcement protocols.

At the conclusion of the project, the equipment — approximately USD 160 000 worth of U.S.-made gear for measuring PM, SO<sub>2</sub>, NO<sub>x</sub>, CO and some metals, as well as laboratory analysis equipment — will be turned over to the agency. Since the contract includes a training component, it is anticipated that the DENR will develop the capacity to operate the equipment in an expanded monitoring programme after conclusion of the contract period.

#### *Imports of goods associated with the project*

Because the project was government-funded, tariffs were waived, but clearing customs was still extraordinarily difficult, requiring specialised consultants and approximately 40 person-hours of staff time. With six major shipments to date, approximately 240 hours have been expended on this activity.

- Filter assemblies (HS 8421.39)
- Particulate samplers (HS 9027.10)
- NO<sub>x</sub> absorbers (HS 9027.10)
- SO<sub>2</sub> absorbers (HS 9027.10)
- Fluid filled impingers (HS 9026.80)

#### ***Malaysia Air Quality Monitoring Network***

In the early 1990s, the Malaysian government issued an unusual request for a contractor to build a nationwide air-quality monitoring system and provide its own financing. The government sought bidders who would finance the project’s construction and operating costs in exchange for a long-term contract to sell air quality data to the government and the rights to sell data to third-party entities such as media outlets. The high risks involved in such an arrangement dissuaded many would-be contractors and equipment suppliers from the United States and other developed countries, but ultimately a joint venture between Bovar (a Canadian company that merged with Orbus Life Sciences, a pharmaceutical company, in 2002) and PIC Corp., a Malaysian company, met the government’s terms.

Initiated in 1995, the network has become one of the most successful air-quality monitoring programmes in the developing world. The USD 6 million system includes 51 continuous monitoring stations, 44 to measure CO, SO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub> and ozone (O<sub>3</sub>), and seven to measure PM<sub>10</sub> only; in addition, there are 25 manual stations for TSP, PM<sub>10</sub> and heavy metals which are checked every six days. The continuous monitors provide real-time updates every hour. The average data capture rate has been more than 95%, and the project passed an audit by the US EPA.

The 20-year contract between the joint venture, Alam Sekitar Malaysia Sdn. Bhd. (ASMA), and the Malaysia Dept. of Environment included performance targets and penalties for nonperformance. Air quality data sales have yielded enough revenue (approximately USD 4.8 million in 2002) to sustain the company and finance its expansion. The company also maintains and earns revenues from a database of water-quality data, but revenue figures are not available for that data. The ASMA staff of approximately 100 is predominantly Malay; staffing by expatriate professionals has never exceeded five.

Prior to the ASMA network, the government of Malaysia operated approximately six ambient air monitoring stations with equipment donated by the Japanese government, with all stations located in the Klang Valley. The ASMA network provided data to assess the air quality throughout the country.

The ASMA air-quality monitoring network has greatly increased the national government's capacity to control pollution. During extreme haze episodes, ASMA data supplied directly to the government has been used to identify local burning, and investigators were dispatched to locate the fires and, if necessary, fine the people or company responsible. Haze monitoring and the co-operation of the local governments in the areas affected has improved. During the 1997 smoke-and-haze crisis, the Malaysian government used the data to target enforcement and public health responses toward the worst affected areas.

ASMA data have since been widely used as leverage by NGOs and citizen groups seeking improvements in air-quality policies and enforcement. ASMA data provided evidence for an August 2005 Malaysia University of Science and Technology study, which recommends that the air-quality monitoring network be expanded, that the state create and enforce air quality standards (as opposed to the "guidelines" that now exist), and require periodic inspection of all vehicles.<sup>1</sup>

Transboundary haze (predominantly PM<sub>10</sub>) continues to accumulate to critical levels in parts of Malaysia, and the air-quality monitoring system is indispensable to government agencies and NGOs seeking to respond; the data figure strongly in the country's negotiations with Indonesia in the context of the ASEAN Transboundary Haze Agreement.

Over its 10 years of operation, ASMA has evolved to offer broader sets of environmental services within Malaysia, including environmental impact assessment, site assessment and remediation, waste management and control, and training in these and other fields.

#### *Imports of goods associated with the project*

Import tariffs were not a significant barrier because the project was exempted from tariffs for its first four years, the period in which the bulk of the equipment was imported. But ASMA ran into difficulty importing specialised beta gauges that run on a low level radioactive source, carbon-13. While not requiring a special license in Canada (where the project managers came from), the Malaysian authorities considered that the devices contained hazardous materials, and fined the ASMA heavily for bringing in a shipment of the gauges without appropriate licensure.

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1. [http://www.sea-uema.ait.ac.th/snp/forum1/Air\\_Malaysia\\_kennedy.pdf](http://www.sea-uema.ait.ac.th/snp/forum1/Air_Malaysia_kennedy.pdf)

- Filter assemblies (HS 8421.39)
- Particulate samplers (HS 9027.10)
- NO<sub>x</sub> absorbers, analyzers, calibrators (HS 9027.10)
- SO<sub>2</sub> absorbers, analyzers, calibrators (HS 9027.10)
- Ozone absorbers, analyzers, calibrators (HS 9027.10)
- CO absorbers, analyzers, calibrators (HS 9027.10)

***Jakarta Health Risk Monitoring Project:  
Exposure to Particulate Matter and Carbon Monoxide  
Jakarta, Indonesia***

As in other Asian megacities, residents of Jakarta, Indonesia, suffer from extremely degraded air. Air pollution is estimated to result in net costs of at least USD 400 million annually, exacting a very serious health consequences in the form of respiratory diseases, which are the sixth leading cause of death in Indonesia (after accidents, diarrhoea, cardiovascular disease, tuberculosis and measles).<sup>2</sup>

The Indonesian government ordered the phasing out of leaded gasoline in 2001, but implementation has been repeatedly delayed, and nationwide phase-out of leaded gasoline is now expected to be accomplished in 2006. Lead levels in one study of children were high enough to impair cognitive development in one-third of those tested.

Air-quality monitoring in Jakarta has historically consisted of a dispersed system of five ambient air-quality monitoring stations that collect data of little practical use in identifying sources. In order to generate more reliable and useful data on air pollution sources and exposure levels, the Ministry of the Environment, the University of Indonesia, and the University of California Berkeley have collaborated to develop and implement a unique project that uses citizen volunteers to monitor other citizens' exposure to PM and CO. The project's USD 200 000 budget has been provided by the US-Asian Environmental Partnership (USAID), the project partners, and the Swiss Foundation for Technical Cooperation (Swisscontact).

State-of-the-art equipment for measuring PM and CO was borrowed and purchased from manufacturers and air-quality laboratories in the United States. It included highly sensitive devices capable of measuring particles from 0.1 microns to 2.5 microns. Placing the equipment in backpacks and shoulder packs, student investigators from the University of Indonesia shadowed more than 50 individuals — students of many ages, traffic officers, a variety of workers — for 8-hour and 24-hour periods. The investigators recorded the time, environment and conditions precisely, including such factors as whether the air conditioning on a bus was functioning and how long the subject spent on a particular street corner. Pollution levels were monitored continuously, with 10-second resolution.

Such a technically sophisticated measuring program is rare even in the developed world. Project managers designed the programme to provide extraordinarily robust and precise data to provide Indonesian air quality management policy makers with tools to craft and implement effective regulations in a cost-efficient and timely manner. By screening particle sizes so precisely, the resulting data will identify the types and locations of pollution sources with unusual specificity. Data analysis was still underway at the time this report was being written.

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2. <http://www.eia.doe.gov/emeu/cabs/indoe.html>

The project was also geared to empower Indonesian staff and volunteers to gain the technical expertise necessary to continue and expand such monitoring programmes. It has reportedly inspired officials at the city and national environmental agencies with a vision of what can be accomplished in terms of effective monitoring. However, additional resources and training will be required to assure that future monitoring yields reliable data.

*Imports of goods associated with the project*

To avoid the delays and unusual fees associated with Indonesian customs, project equipment was brought into the country as personal luggage by professional consultants travelling to the country. Importing the equipment commercially would have caused delays of 8 to 12 weeks and added significant costs.

- Filter assemblies (HS 8421.39)
- Particulate samplers (HS 9027.10)
- CO absorbers, analyzers, calibrators (HS 9027.10)

***Fuel Testing for Air Quality Project  
Tamil Nadu, India***

Air quality in Indian cities has deteriorated over the last decade due in large measure to the sharp increase in the number and use of motor vehicles of all types. In addition to the increase in numbers of vehicles and emissions, there is widespread evidence that the air-quality problems are compounded by retail gasoline dealers who adulterate gasoline and diesel with less expensive hydrocarbon fuels. Gasoline is typically adulterated with solvents such as hexane, benzene, toluene, naphtha and other hydrocarbon mixtures having the boiling range within that of gasoline, while diesel is typically adulterated with kerosene. Vehicles powered by adulterated fuel emit high levels of air pollutants, including PM, CO, NO<sub>x</sub>, SO<sub>2</sub>, and polynuclear aromatic hydrocarbons (PAH). The price differential between gasoline purchased from oil companies and these materials presents an irresistible profit opportunity to many fuel dealers. Even imported kerosene is less expensive than domestic diesel fuel.

Oil companies have begun testing fuel at retail outlets, but it is believed that fuel adulterated by as much as 30% still tests clean because of the range of values in the testing methods of the Bureau of Indian Standards (BIS), and also because the high-quality fuels provided by oil companies can accommodate significant adulteration without violating BIS specifications.

In 1999, CONCERT (the Center for Consumer Education, Research Teaching, Training and Testing) in Chennai (formerly Madras), Tamil Nadu, took samples from 21 retail fuel outlets in Chennai. Using a gas chromatograph method developed by a professor at the Indian Institute of Technology, CONCERT's research showed a high level of adulteration of diesel and gasoline in all 21 samples.

To more rigorously test for fuel adulteration, CONCERT proposed establishing a fuel-testing laboratory with a gas chromatographic to compare fuel obtained from retail outlets with fuel obtained from distribution depots and refineries. With funding and support from the Environmental Partnership Grant Program of the U.S. Council of State Governments, the US-Asian Environmental Partnership and the government of Tamil Nadu, and technical support and training from the California Air Resources Board, the project broke ground in 2003 and began operating in 2004.

After analyzing more than 60 retail gasoline and diesel fuel samples, CONCERT's data was highly suggestive of contamination because adulterants were found at the high end of allowable concentrations. Armed with evidence of likely fuel adulteration, CONCERT intends to expand its sampling programme, upgrade and procure additional laboratory equipment, establish a mobile laboratory to collect and test samples in the field, seek greater enforcement by government agencies, and increase outreach to retail fuel dealers. CONCERT believes widespread fuel testing, coupled with greater enforcement, would significantly improve air quality throughout India. CONCERT has informed the public and government about the results of their fuel testing, and the agency is now working with the local air-quality agency and NGOs to create more stringent fuel specifications.

All the equipment purchased for CONCERT's Fuel Testing Laboratory were indigenously manufactured. Project managers would have preferred to purchase automated equipment with computerized data-logging to speed up the process and increase the number of samples analyzed per unit of time and labor. But the necessary resources were not available. While the Indian-made equipment took longer to operate, it did not compromise the accuracy of analysis.

Sophisticated analytical equipment for fuel analysis is imported into India, but it is only utilised by the oil companies for quality control and for research related to refinery operations. CONCERT staff believe that if such equipment could be purchased, and if testing facilities could be established in every Indian state, the nation's fuel supply -- and hence its air quality -- would be greatly improved.

*Goods associated with the project*

As noted above, in this project, the project participants from the United States lent expertise only; all the equipment was procured within India. It included:

- Gas chromatograph
- Distillation unit
- Reid vapour pressure apparatus
- Pout point apparatus
- Hot air oven
- Viscosity bath
- Abel flash point apparatus
- Sample storage refrigerator
- Ramsbottom carbon residue apparatus
- Cold filter plug point apparatus
- Copper corrosion bath
- Extraction apparatus
- Aniline point test assembly
- Oxidation stability apparatus

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