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Green societies now

On 6 June, the German cabinet of Chancellor Angela Merkel decided to phase out nuclear power by 2022, based on a broad political consensus. The country's reactors currently provide about 22% of domestic electricity needs. Germany plans to compensate for this loss by reducing energy consumption by 10% and increasing the share of electricity from renewable sources from 17% to 35%.

This decision has no doubt been precipitated by the Fukushima nuclear disaster in March but, for Michael Dittmar from the European Organization for Nuclear Research (CERN), safety concerns are not the only reason why countries should begin gradually phasing out nuclear power. As he explains in this issue, nuclear power is not a renewable energy source and can thus only offer a stop-gap solution.

Germany's decision coincided with the publication of an alarming report by the International Energy Agency of the Organisation for Economic Co-operation and Development. It states that carbon dioxide (CO_2) emissions increased by 5% to 30.6 gigatons (Gt) between 2008 and 2010, despite the global economic recession. If the world is to keep global warming to 2°C this century, CO_2 emissions by the energy sector must not exceed 32 Gt by 2020.

This will entail 'rethinking every aspect of development,' UNESCO Director-General Irina Bokova observed in her opening speech to the Future Forum on Challenges of a Green Economy and Green Societies, at UNESCO in Paris on 24 May. 'The economy must embrace greater sobriety, particularly with regard to carbon, and become cleaner and more inclusive,' she urged.

'The future needs a green economy but above all a green society', she went on to say. 'Sustainable production patterns will only make an impact if they are accompanied by sustainable consumption patterns.'

As the article overleaf illustrates, green chemistry can contribute to defining this new development model. The momentum is there for more environmentally friendly products and processes. But there will be no point in scientists developing biodegradable bags to replace plastic ones if governments do not provide incentives for companies to market them and consumers do not plebiscite them with their wallets.

For our development model to change, every link in the chain will need to be solid: from North to South, from laboratory to consumer and from land to sea. Irina Bokova has observed that 'we need to get better at integrating the 'blue' with the 'green.' After all, environmental problems have no trouble integrating land and sea: the oceans are acidifying because of carbon emissions on land, overfishing is widespread and discarded plastic bags and agricultural pesticides ultimately find their way to the sea. We live in an interconnected world.

There is no question that we need to green our economies. Yet how difficult that seems to be. In the climate talks, for example, national considerations are still taking precedence over the imperative of fixing binding targets for carbon emissions. While the talks stall, carbon emissions are spiralling out of control and with them our capacity to control our planet's future.

Gretchen Kalonji
Assistant Director-General for Natural Sciences

From the Dark Ages to the Green Ages

The chemical industry is one of the biggest in the world, worth a staggering US$3.6 trillion a year. For decades, it had no interest in either sustainability or environmental protection. After major disasters such as Bhopal and Seveso, however, attitudes began to change. In the face of tighter regulatory controls and more vigilant consumers, industrial giants have begun reforming their ways. Green chemistry is now all the rage – including in developing countries, where they seem to have no intention of making the same mistakes as the West.

Photos: Flickr

Cleaning up a Kolontar street in protective gear after waste from an aluminium plant invaded the town. The toxic red mud is a mixture of water and mining waste containing heavy metals.

On 4 October 2010, disaster struck in Hungary. In the aluminium plant operated by the company MAL near the town of Kolontar, 160 km from the capital, Budapest, the walls of a reservoir gave way. A two metre-high torrent of red toxic sludge poured out, burying people and houses in its wake. Nine people died, 150 were injured. Several hundred thousand tonnes of toxic sludge contaminated 40 km^2 of land. The sludge was a waste product of the aluminium production process and hazardous because it contained highly caustic sodium hydroxide as well as toxic heavy metals such as mercury, arsenic and chromium.

In recent decades, chemical accidents have repeatedly been the cause of worldwide horror and dismay – and the apocalyptic images of them have had a lasting negative effect on the chemical industry. In 1976, dioxin gas was released from a plant operated by Icmesa, a subsidiary of Roche, in Seveso, a northern Italian town near Milan. The gas cloud, thousands of times more toxic than potassium cyanide, left a trail of death and destruction: plants shrivelled, trees were defoliated, thousands of animals perished. Pictures of children's disfigured faces and workers wearing gas masks and white protective clothing toured the world.

Bhopal: the world's most serious chemical accident to date

Eight years later, there was an even more horrific accident in India. Forty tonnes of highly toxic methyl isocyanate gas escaped from a factory belonging to the US chemical giant Union Carbide – now a subsidiary of Dow Chemical – in the central Indian town of Bhopal. Several thousand people died and up to half a million are still suffering from the after-effects of the disaster today. Bhopal is considered to be the most serious chemical accident to date.

Two years later, Europe became a victim once more when a warehouse near Basel belonging to the chemical giant Sandoz (now Novartis) went up in flames. Toxic pesticides poured into the Rhine River, turning the water red for hundreds of kilometres; tonnes of dead fish drifted down the river.

Shaking off a sulphuric reputation

Kolontar, Bhopal, Seveso, Sandoz. The reasons for these disasters are almost always the same: negligence, sloppiness and human error. Almost always, the companies try to cover up and play down the causes and the consequences of accidents. The results are similar too – a devastated countryside,

A resident of Kolontar telephones from his garden invaded by the toxic mud in October 2010.

Photos: Flickr

destroyed vegetation, dead animals and, in among them, workers in their protective gear, looking like aliens.

The general public is increasingly worried about these invisible, deadly dangers, with chemicals having joined radiation as the driver of this collective angst. It is these fears which lay behind the establishment of the environmental movement in the 1970s and 1980s. More and more often, practices of the chemical companies are now being exposed – whether they are simply pouring their toxic waste into the environment or dispatching it to poor countries. In the eyes of an increasingly ecologically aware public, the chemical industry has become number one polluter. The word 'chemical' has become synonymous with 'toxic'. Today, products use the 'chemical-free' tag to boost sales. Soap brands, for instance, boast that they are 'paraben-free' (*see photo*).

Within just a few decades, a dramatic change in image has taken place. In the 1950s, nylon, plastic and Persil washing powder stood for progress. By the 1970s and 1980s, the image of the chemical industry was as black as its origins.

The Ancient Egyptian word *kemi* originally referred to the black soil of Egypt but also to black eyeliner (kohl). In Arabic, *kemi* became *al-kimia*, or alchemy. This occult pastime had metamorphosed into a modern science by the 18th century and, from the 19th century onwards, into one of the most important industries in the world. This is when today's global players were founded: BASF and Bayer in Germany, DuPont in the USA and Roche in Switzerland. Today, The chemical industry manufactures over 70 000 different products, from plastics and fertilizers to detergents and drugs.

©UNESCO/Susan Schneegans

Beauty products in a French teenager's bathroom. In a surprise vote, the French lower house of Parliament passed a bill in May 2011 banning the manufacture, importation and sale of products containing phtalates, parabens and alkylphenols. These substances are considered carcinogenic, mutagenic or toxic for human reproduction, as they are thought to perturb the endocrine system. Phtalates are commonly used to soften plastics and have already been banned from toys in France. Parabens are preservatives found in some beauty products, medicines, food and tobacco products. Alkylphenols are the active agents in household or medical disinfectants and detergents. To pass into law, the bill will also have to be adopted by the upper house of Parliament.

The 12 principles of green chemistry

1. **Prevention**
   It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom economy***
   Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less hazardous chemical syntheses**
   Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing safer chemicals**
   Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. **Safer solvents and auxiliaries**
   The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. **Design for energy efficiency**
   Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of renewable feedstocks**
   A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce derivatives**
   Unnecessary derivatization – the use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes – should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis**
   Catalytic reagents (as selective as possible) are superior to stoichiometric reagents**.
10. **Design for degradation**
    Chemical products should be designed so that, at the end of their function, they break down into innocuous degradation products and do not persist in the environment.
11. **Real-time analysis for pollution prevention**
    Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently safer chemistry for accident prevention**
    Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Source: Anastas, P. and Warner, J. (1998) Chemistry: Theory and Practice. Oxford University Press, New York, p. 30

* *When chemists prepare a compound (or synthesis), this process produces waste products. Atom economy attempts to avoid waste by ensuring that as many of the atoms of the reactants as possible are incorporated into the final product rather than in by-products.*

** *a stoichiometric reaction goes to completion, rather than stopping partway at a point of equilibrium.*

Photos: Flickr

Dow Coating Materials has developed a solvent-free thickener for a range of its paints, as well as coatings which convert formaldehyde, a colourless toxic gas, into harmless water vapour. The company is also developing coatings capable of 'cleaning' other toxins, odours and pathogens from the air. Potentially, this means that simple house paint could one day protect us from viruses such as SARS or H1N1.

From waste product to miracle solvent?

The solvents used to trigger chemical reactions are often toxic, posing a threat to the environment. To solve the problem, chemists have come up with the idea of harnessing what is arguably the world's most abundant waste product: CO_2. But first you have to make a supercritical fluid out of it. Supercritical CO_2 is a state between liquid and gas achieved by raising the pressure and temperature above the so-called critical points of the gas. For CO_2, these points are a temperature of 31°C and a pressure 73 times that of our atmosphere. Above those values, CO_2 expands to fill its container like a gas but with a density comparable to a liquid. From this point onwards, CO_2 can be converted back into a gas simply by lowering the pressure, or into a normal liquid simply by lowering the temperature.

A supercritical fluid is less dense, less viscous and, most importantly for chemistry, a better solvent than a real fluid. Supercritical CO_2 offers numerous advantages over other solvents: it is non-toxic, nonflammable and inexpensive. It can be separated from the product by simple depressurization and its abilities as a solvent can be fine-tuned by adjusting the pressure and temperature.

Supercritical CO_2 can already be found in the dry cleaning industry, where CO_2 replaces organic solvents, as well as in semiconductor manufacturing and in chemical processing.

Hristio Boytchev

Its total global annual production is worth a breathtaking US$3.6 trillion, according to the American Chemistry Council. It has dramatically changed and improved our lives. It is impossible to think of modern-day civilization without it.

But after a century-long success story, the chemical industry, inflated by mechanized mass production, has become the cause of a growing number of ecological problems. It is enormously resource- and energy-hungry; many solvents and catalysts are toxic, disposal of its waste is complicated and expensive, while toxic and carcinogenic substances are released into the air and water. According to UNEP, Western Europe produced a total of 42 million tonnes of toxic waste in the year 2000, five million of which were exported in 2001.

The main principles of green chemistry are to avoid producing waste, lower energy consumption, improve the efficiency of production processes and explore renewable resources.

Milestones on the road to green chemistry

For a long time, the careless disposal of toxic waste was tolerated or concealed by politicians – the chemical industry was too important for the economy. But after Bhopal and Seveso, politicians had to act. In the 1980s and 1990s, chemical companies were obliged to meet increasingly stringent environmental requirements. In 1990, the United States Environmental Protection Agency (EPA) passed the Pollution Prevention Act, marking a change of direction in policy. Manufacturing processes and products had to be made sustainable, pollution was to be avoided; dirty chemistry gradually started to turn green.

'After defining the term "green chemistry" in 1991, it became clear that a design framework would be desirable for those wishing to put the theory of green chemistry into practice', says Paul Anastas, who is regarded as the Father of Green Chemistry. He is the director of the Center for Green Chemistry at Yale University and also works for the EPA. In 1998, he published the Twelve Principles of Green Chemistry, along with his colleague Jack Warner (*see table*). The first of these principles dictates that 'it is better to prevent waste than to treat or clean up waste after it has been created'. Harmless alternatives are also to be found to toxic chemicals and solvents (*see box*).

The latest milestone on the path towards green chemistry was the European Union's 2007 REACH Directive, which stands for the Registration, Evaluation, Authorisation and Restriction of Chemicals. Now it is no longer up to the authorities to demonstrate to manufacturers that the substances they use are potentially harmful; the shoe is on the other foot. Thanks to REACH, some 40 000 chemicals on the market now have to be tested by industry.

The world's largest chemical corporation adopts a low-energy diet

Other goals of green chemistry are to lower energy consumption, to improve the efficiency of the production process and to switch to renewable resources. After all, the chemical industry also depends on petroleum, consuming 10% of global oil production to make 80–90% of its products.

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Apartment building in Dhaka, Bangladesh. Cement-making involves heating limestone clay and sand to 1450°C. The process generates about 650–900 kg of CO_2 for every ton of cement, or the equivalent of about 5% of the world's CO_2 emissions in 2009. Nikolaos Vlasopoulos, chief scientist at the start-up Novacem in the UK, is trying to eliminate CO_2 emissions with a cement that absorbs as much as 100 kg of CO_2 per ton. He has discovered that atmospheric CO_2 reacts with magnesium to make carbonates which strengthen the cement while trapping the gas [1]

Just how green *is* bioethanol?

After prices rose steeply in the 1970s during the oil crisis, Brazil, the USA and a number of countries in Europe and elsewhere embarked on mass production of bioethanol to replace gasoline. Bioethanol is an alcohol produced by fermenting products like sugarcane and corn starch. Today, Brazil produces 60% of the world's ethanol derived from sugarcane.

Although bioethanol production is based on a renewable feedstock, it still causes some environmental headaches. For example, the technology used to make bioethanol generates toxic by-products. Traditional fermentation processes are also only able to make use of the sugar glucose, leaving other sugars behind. This makes bioethanol less environmentally friendly and lowers its economic competitiveness compared to ethanol based on crude oil. In addition, fermentation done by yeast typically produces a product with an ethanol concentration of around 10% as, above this level, yeast finds it difficult to perform. To gain a pure product, the mixture is distilled, an expensive, energy-intensive process that tends to negate the claim that bioethanol production is carbon-neutral.

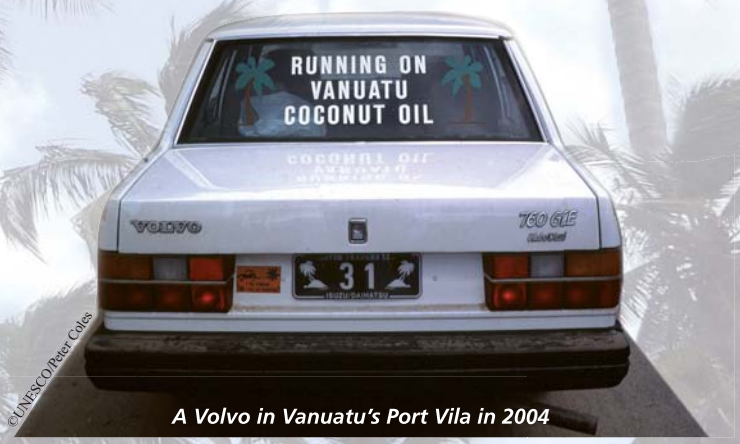
Bioethanol is also land-hungry. In May, Namibia was reportedly hesitating to renew concessions for foreign investors in biofuel production in the Kavango and Caprivi regions because the jatropha plantations there were competing with food crops.

While use of bioethanol is widespread today and has great potential, research is needed to make it truly sustainable. One possible approach would be to move towards the use of by-products from food processing or other agricultural waste products like rice straw, crop stalks and leaves. These so-called second-generation biofuels would alleviate the problem of sacrificing food crops to energy. Another strategy would be to use genetically modified yeasts or bacteria capable of achieving higher percentages of ethanol. Researchers are also studying the potential of seaweed as a raw material for biofuel production. An abundant resource, seaweed has the added advantage of not occupying valuable agricultural land.

Hristio Boytchev

The chemical industry is energy-hungry: in 2008, for example, the German chemical industry consumed some 12.5% of the entire national demand for energy. Since the 1990s, the industry has increasingly been pursuing the goal of sustainability, while improving its image at the same time. BASF, the world's largest chemical corporation with annual sales of 50 billion euros and more than 100 000 employees around the world, wants to become greener, as do fellow giants DuPont, Dow Chemical and Bayer. 'At BASF, we are running all our activities according to the principles of sustainable development,' says BASF Chief Executive Officer, Jurgen Hambrecht. He adds that 'we are developing products that help our customers to save energy and resources, while improving quality of life.' These new products are primarily insulating materials that enable home-owners to lower their heating bill and reduce carbon emissions.

BASF publishes its carbon emissions, not only those of its own production facilities but covering the entire life cycle of its products, from the extraction of the raw materials through to final disposal. The company's website reveals that the production of BASF products led to the overall release of some 90 million tonnes of carbon dioxide (CO_2) into the atmosphere in 2010 – corresponding to 10% of Germany's total CO_2 emissions. By 2020, BASF wants to



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A Volvo in Vanuatu's Port Vila in 2004

©Flikr

Newlyweds Prince William and Katherine Middleton take the groom's father's sportscar for a spin among cheering crowds in London on 29 April this year. Prince Charles has had this 1960s Aston Martin converted to run on bioethanol from surplus British wine. It is said that his other cars have been converted to run on used cooking fat.

Photo: Julien Mehl

lower its production-related greenhouse gas emissions by 25 % compared with 2002. But since the production process accounts for only part of the total, this reduction target represents just 7.5 % of BASF's total emissions.

Even so, Hambrecht emphasizes that BASF products themselves also reduce carbon emissions: a total of 287 million tonnes of CO_2 per year, or three times as much as is released during their manufacture, as the company website proudly proclaims. Also, BASF promises to implement the REACH directive by 2015 and to reduce the amount of organic compounds, nitrogen compounds and heavy metals released into the air and water by some 70% by 2020. On its website, BASF claims to have already done so. The company is also on the lookout for renewable resources, such as using natural castor oil in the manufacture of mattresses and the biodegradable plastic Ecovio, which is largely made from polylactic acid, derived from maize.

Courtesy of Paso Pacifico

Nicaraguan girls reading and writing at night. The lanterns can be detached from the bags for use at home in the evening.

A bright idea

The Portable Light Project brings clean energy and lighting to rural communities – in a bag. This non-profit initiative is the brainchild of Sheila Kennedy, Director of Design and Applied Research at KVA MATx, an interdisciplinary design firm in the USA.

Using flexible solar nanotechnology, she and her team developed a portable light in 2004 that combines photovoltaics with solid state LED lighting. The light can be woven or sewn into traditional bags, clothes and other textiles. During the day, the bag harvests solar energy as it is carried around. At night, it emits a bright, white light for four hours or a reading light for eight hours.

Courtesy of Paso Pacifico

Nicaraguan girls use locally made Portable Light bags for their conservation work with Paso Pacifico.

The bag can also be used to foster health services. In a pilot project in Haiti, travelling midwives in rural areas carry the bags with them on routine house visits and in emergencies. Each bag generates enough power to charge both electronic medical devices and a cell phone, enabling the midwife to keep in contact with physicians back at the clinic.

The project has been serving Huichol indigenous communities in the rugged Mexican Sierra Madre since 2005, Known for their beautifully woven garments and intricate K+tsuri bags, the Huichol artisans were fully associated in the design and creation of the bags for their community. Today, they use them to charge their cell phones when they need to speak to an art dealer or store-keeper in town.

More recently, the project has worked with the NGO Paso Pacifico to train local villagers as conservation rangers in Nicaragua's Paso del Istmo Biological Corridor. At night, the rangers patrol the area with their portable lanterns. They can even switch the LED light from white to red to avoid disturbing sea turtles on the beach. The villagers also use the lanterns for night classes and to develop their eco-tourism businesses.

A new project has just been launched in the Tapajos region of the Brazilian Amazon to adapt the kits for ten river communities lacking access to electricity, in collaboration with a range of partners.

For Sheila Kennedy, the project demonstrates how nanotechnology can benefit not only the developing world – where about 1.4 billion people lack access to electricity – but also the developed world, where energy-efficient design is becoming a priority. Her team is currently working on designs for Soft House, a pre-fabricated housing project with energy-harvesting curtains that generate up to 16 kilowatt hours of electricity, more than half the daily power needs of an average US household.

For details: www. www.portablelight.org; www. pasopacifico.org

Greening chemistry in Africa

Since its inception in 2006 with UNESCO support, the Federation of African Societies of Chemistry (FASC) has conducted three Pan-African conferences on green chemistry: in Ethiopia (2007), Egypt (2009) and South Africa (2011). Individual societies of chemistry have also conducted meetings of their own.

While these efforts are highly appreciated, they will only have a sustainable impact on African societies if green chemistry permeates all echelons of the education system from the primary to tertiary levels. In Ethiopia, for instance, individual instructors have attempted to introduce the concept of sustainability into their chemistry courses but neither the recently developed secondary school chemistry curriculum, nor the harmonized undergraduate chemistry curriculum for Ethiopia's 21 universities make any reference to green chemistry.

The more African universities engage in advanced chemistry research, the more they will need safe, secure facilities and related skills. This year, UNESCO'S International Institute for Capacity Building in Africa. conducted a survey of chemical safety in African univer-sities, via a quiz for Ethiopian undergraduate students and a questionnaire sent to colleagues at FASC and the Pan-African Chemistry Network. Overall, the study showed that students tended not to wear protective gloves in the chemistry laboratory and received little or no training in how to handle incidents of chemical intoxication. Of the 51 Ethiopian students surveyed, 80% were unable to differentiate among chemicals which become toxic after a single (acute), intermittent (repeated) or long-term (chronic) exposure. The chemistry instructors themselves admitted that their laboratories lacked functional basic safety equipment, reagents and skilled staff, especially in instrumentation. Moreover, the instructors were unaware of whether there were any government regulations regarding the safe use of chemistry laboratories in their respective countries. UNESCO is working with a number of African countries to introduce microscience kits into schools and universities to foster low-cost, safe chemistry experiments (*see page 17*).

It is true that universities and other stakeholders in Africa are pushing legislation to reduce toxicity and ensure safety guidelines are respected in the development and use of chemical products. For instance, the Chemical Society of Ethiopia is working with other NGOs to raise awareness of hazards related to pesticides used in agriculture. The Kenyan Chemical Society meanwhile is studying the extent to which DDT permeates the Kenyan environment. It has uncovered evidence suggesting that DDT remains a huge problem in Kenya.

Development partners who share Africa's goal of sustainable development need to collaborate with African chemical societies and FASC to institutionalize the principles and practices of green chemistry in African universities and industries. For instance, development partners can introduce 'advance market commitments,' by which they ensure a market for the green products and processes developed by African scientists.

At the University of Johannesburg in South Africa, for example, scientists are hoping to use nanosponges to purify water, SciDev.net reported in May. If the technology can be perfected, the idea would be to clamp the sponges onto the end of a tap or pipe to filter impurities such as pesticides or pollutants while allowing the purified water to continue on its way. Nanosponges were invented more than a decade ago at the Los Alamos National Laboratory in the USA.

The same month, the online journal reported that Olufunke Cofie from Ghana had won a US$100,000 research grant from the Bill and Melinda Gates Foundation to develop fertilizer pellets from treated human waste. A soil scientist, she hopes her project will not only improve agricultural productivity in Ghana but also sanitation.

Temechegn Engida*

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Photo: Hima Kenya

Drums of toxic waste at the Kitengela Store in Athi River in Kenya. In 2005, an inventory conducted by the Kenyan Chemical Society found 1500 tonnes of obsolete pesticides and contaminated soils. The polluted sites were situated in Nairobi, the Western Coast, Rift Valley and in the Central Nyanza, Eastern and Northeastern provinces. The main holding facility was at the Kitengela Store in Athi River.

Photo credit: Texas A&M University and the Soil (Crop Sciences Department)

Not made to last

Conventional plastic products can take between 100 and 400 years to decompose, even though they may only be used once, as in the case of supermarket bags, plastic cutlery and containers for take-away food. Biodegradable products, on the other hand, are intentionally made to last from just a few months to up to a year. As they degrade, the only gases emitted are CO_2 and oxygen, unlike conventional petroleum-based plastics which also emit a host of toxic gases as they decompose.

Over the past four years, a team of Mexican researchers led by Fernando Martínez Bustos at the Queretaro Unit of the Center for Research and Advanced Studies (CINVESTAV) has developed a biodegradable material with similar characteristics to petroleum-based plastic.

The team used corn starch to obtain their natural polymer but they could just as easily have chosen other waste materials that spare food crops, such as wheat bran, cactus fibre, or bagasse. Bagasse is the fibrous matter left behind after sugarcane stalks are crushed to extract their juice and is already being used in the manufacture of pulp and paper products and in building materials.

Dr Martínez Bustos's team mixed the corn starch with other types of starch from various products and with natural fibres to increase the material's strength, durability and rate of decomposition. They varied the ingredients, depending on whether they wished to make bags, buckets, trays, spoons, containers...

Now that their research is complete, the team is looking for a company to commercialize its products. Companies making conventional plastics have not yet adopted the new technology, even though it is inexpensive, easy to implement and produces much less pollution during both production and disposal. The infrastructure needed to manufacture biodegradable products is even the same as that used to produce conventional plastics, so companies would not even have to adapt their tools or methods. Visibly, one important challenge will be to explain the new technology to businesses.

The government is providing incentives for the marketing of biodegradable products by regulating the use of materials derived from petroleum. A law passed in Mexico City in August 2010, for example, prohibits supermarkets and other businesses from giving away plastic bags to customers. In February 2011, a law adopted by the State of Colima gave businesses 12 months to remove their own conventional plastic bags and provided incentives to replace these with biodegradable alternatives. The State of Colima has also introduced incentive packages for small and medium-sized enterprises willing to invest in 'green' products.

Octavio Hernández

Supermarket bags in a trolley in Naucalpan de Juárez, Mexico, in 2005 and (insert) corn starch

Green chemistry not only booming in the West

Green chemistry is not only booming in the West. 'Recently, there has been growing support for, and interest in, green chemistry in developing countries', says Paul Anastas. He recently addressed the Pan-African Chemistry Network, which he helped to establish at a conference on green chemistry in Addis Ababa (Ethiopia) on 15-17 November 2010 (*see box*).

'In emerging nations like India and China', he adds, 'green chemistry has been implemented in academia, research institutions and industry at a much faster rate than anywhere else in the world'. It seems that these countries do not intend to make the same mistakes as the West.

Jens Lubbadeh[2]

This article first appeared in the issue of The UNESCO Courier *entitled Chemistry and Life, in January 2011 (see page 24). It has been adapted for* A World of Science*, with the addition of boxes and illustrations by the Editor and other contributors.*

1. *For details, see www.technologyreview.com/energy/25085/*
2. *Journalist writing for* Greenpeace Magazine *and German correspondent for* The UNESCO Courier

An Arab network for converging technologies

Proposed by UNESCO, the Network for Expansion of Converging Technologies in the Arab Region (NECTAR) was launched on 20 June at a regional congress in Cairo. The meeting was organized by UNESCO's Regional Bureau for Science in the Arab States, under the patronage of the Egyptian Prime Minister Essam Sharaf, who is also President of the Egyptian Higher Council for Science and Technology.

Converging technologies is a generic term for technologies which interact with one another in the development of new products and services. Nanotechnology, biotechnology, information and communication technologies (ICTs) and cognitive science are all converging technologies.

UNESCO will select one or more recognized science or engineering institution from each of Bahrain, Egypt, Iraq, Jordon, Morocco, Sudan and Syria to act as the network's national focal points. These will each be responsible for developing a quality programme at their institution for education, research, innovation and the commercialization of new products involving converging technologies and the basic sciences associated with these technologies. Each institution will create an Innovation Centre in Converging Technologies within its walls and develop partnerships between universities, public research institutes and industry. It will also be expected to design exhibitions on clean technologies to raise public awareness.

©Michelline Pelletier/L'Oreal

L'Oréal-UNESCO laureate Prof. Rashika El Ridi from the University of Cairo in Egypt was recompensed in 2010 for paving the way towards a vaccine against the second-most common disease after malaria, the tropical parasitic disease schistosomiasis.

Every year, the Innovation Centres in Converging Technologies will be expected to publish at least one refereed scientific publication on its research. There will also be an annual international conference to promote North–South and South–South cooperation and knowledge-sharing. An exchange programme for scientists will also be put in place to attract Arab expatriate sciences back home and a prize for innovation may be instituted.

Now that NECTAR has been launched,, the next step will be to establish a seed fund with regional donors like the BAHGAT Group in Egypt to cover the initial phase of the project. A governance structure is also being put in place for the network, with a secretariat in Cairo within the newly established Egyptian Network for Technological Advancement.

Nanotechnology research in the region has received a boost recently in the Arab world with the founding of the North African Nanotechnology Research Centre in 2009 at the Smart Village near Cairo by the Egyptian government and the US-based International Business Machines (IBM), as well as the establishment of the Nanotechnology Centre of Excellence at King Abdul-Aziz City for Science and Technology in Saudi Arabia in 2008, again with IBM. A third nanotechnology centre is currently being established with the company INTEL at King Abdullah University for Science and Technology, also in Saudi Arabia.

For details (in Cairo): n.hassan@unesco.org; www.unesco.org/new/en/cairo

Launch of pan-African parliamentary science forum

On 2 May, parliamentarians from 21 African countries launched the African Inter-Parliamentary Forum on Science, Technology and Innovation (STI) at the United Nations Conference Center in Addis Ababa, Ethiopia. The meeting was co-organized by the United Nations Economic Commission for Africa (UNECA), the Islamic Educational, Scientific and Cultural Organization (ISESCO) and UNESCO.

The core members of the forum driving this process are the Central African Republic, Gabon, The Gambia, Kenya, Malawi, Mali, Morocco and Senegal. Chairing the Steering Committee will be the Hon. Abdirahin Haithar Abdi, Speaker of the East Africa Legislative Assembly based in Kenya. In early June, the draft charter for the forum was being circulated to all member parliaments for approval.

Increasingly, Members of Parliament are expected to be able to assess the implications for their county's development agenda of emerging trends in STI and

evolving policy practices. Parliamentarians are being called upon to legislate on emerging or technical issues that may at times be controversial. These issues include genetically modified organisms, bioethics, the protection of indigenous knowledge, technology transfer, climate change adaptation and mitigation, nanotechnology and biodiversity conservation and use. Given the socio-economic repercussions of legislation on these issues, parliamentarians need to be aware of the importance of STI policy for facilitating empowered, people-centred decision-making.

The forum will strengthen STI governance through co-operation and dialogue among parliamentarians, policy-makers, the scientific community, industry and representatives of media, civil society and the private sector. It will promote the development, dissemination and sharing among members of national parliaments of scientific information and knowledge, experience in policy-making, legislative action and funding. It will also undertake studies and foster debate among members on issues of common interest, including poverty reduction and attainment of the Millennium Development Goals. The forum will also promote the harmonization of national legislation and policies promoting STI for development. It will capitalize on the role the media could play in communicating science to parliamentarians and to the public at large. The forum will also promote the creation or strengthening, within all African parliaments, of a committee on STI and a technology assessment structure or support agency for science and technology.

The launch preceded the second meeting of UNECA's Committee on Development, Information, Science and Technology (CODIST) taking place at the same venue, the theme of which was Innovation for Industrial Development in Africa. The newly created forum appealed for CODIST support and recommended that African parliaments adopt innovative funding mechanisms and legal frameworks to attract foreign direct investment and help reach the goal of devoting 1% of GDP to research and development in each country.

In January 2003, UNESCO and the Parliament of Finland organized a roundtable which adopted the *Helsinki Declaration* recommending the creation of sub-regional parliamentary science fora. Regional and sub-regional fora within this programme have taken place in Cairo (Egypt) in 2004, in Chandigarh (India) and Buenos Aires (Argentina) in 2005, in Tehran (Iran) in 2006, in Brazzaville (Congo) in 2008, in Mombasa (Kenya) in 2009 and in New Delhi (India) and Paris (France) in 2010.

For details: (in Addis Ababa): a.makarigakis@unesco.org; (in Paris): d.malpede@unesco.org

Baby gorilla in Virunga National Park

Oil prospection suspended in Virunga National Park

The Minister for Environment, Nature Conservation and Tourism of the Democratic Republic of the Congo announced on 18 March the suspension of oil prospecting in Virunga National Park, inscribed on UNESCO's World Heritage List in 1979.

This 'is a very positive response to the concerns raised by the World Heritage Committee, the international community and UNESCO on the issue of oil exploration in the park', commented UNESCO Director-General Irina Bokova. I hope,' she added, 'that the Government of the Democratic Republic of the Congo will abandon all plans for oil exploitation within this World Heritage site.'

The decision was announced by Environment Minister José Endundo Bononge further to the commitments made on 14 January in the *Kinshasa Declaration* signed by the Prime Minister and the Director-General of UNESCO. Oil prospection has been suspended pending completion of a strategic environmental assessment early next year.

In May, the NGO WWF reported that a group of Congolese citizens had organized a march in support of the government's decision to suspend oil prospection in Virunga National Park. The rally was held in the fishing village of Vitshumbi on the banks of Lake Edward. The lake lies partially within the park in an area covered by much of the petroleum concession. Many villagers are fearful that petrol would pollute the river and lead to conflict.

Virunga National Park is famous for its chain of active volcanoes and the greatest diversity of habitats of any park in Africa: from steppes, savannas and lava plains, swamps, lowland and Afromontane forests to the unique Afroalpine vegetation and icefields of the Ruwenzori mountains, which culminate in peaks above 5000 m.

The park is home to one of the last remaining mountain gorilla populations. It has been on the List of World Heritage in Danger since 1994, due to the negative impact – mainly poaching – of the conflicts which have ravaged the Great Lakes region.

Virunga National Park: http://whc.unesco.org/en/list/63

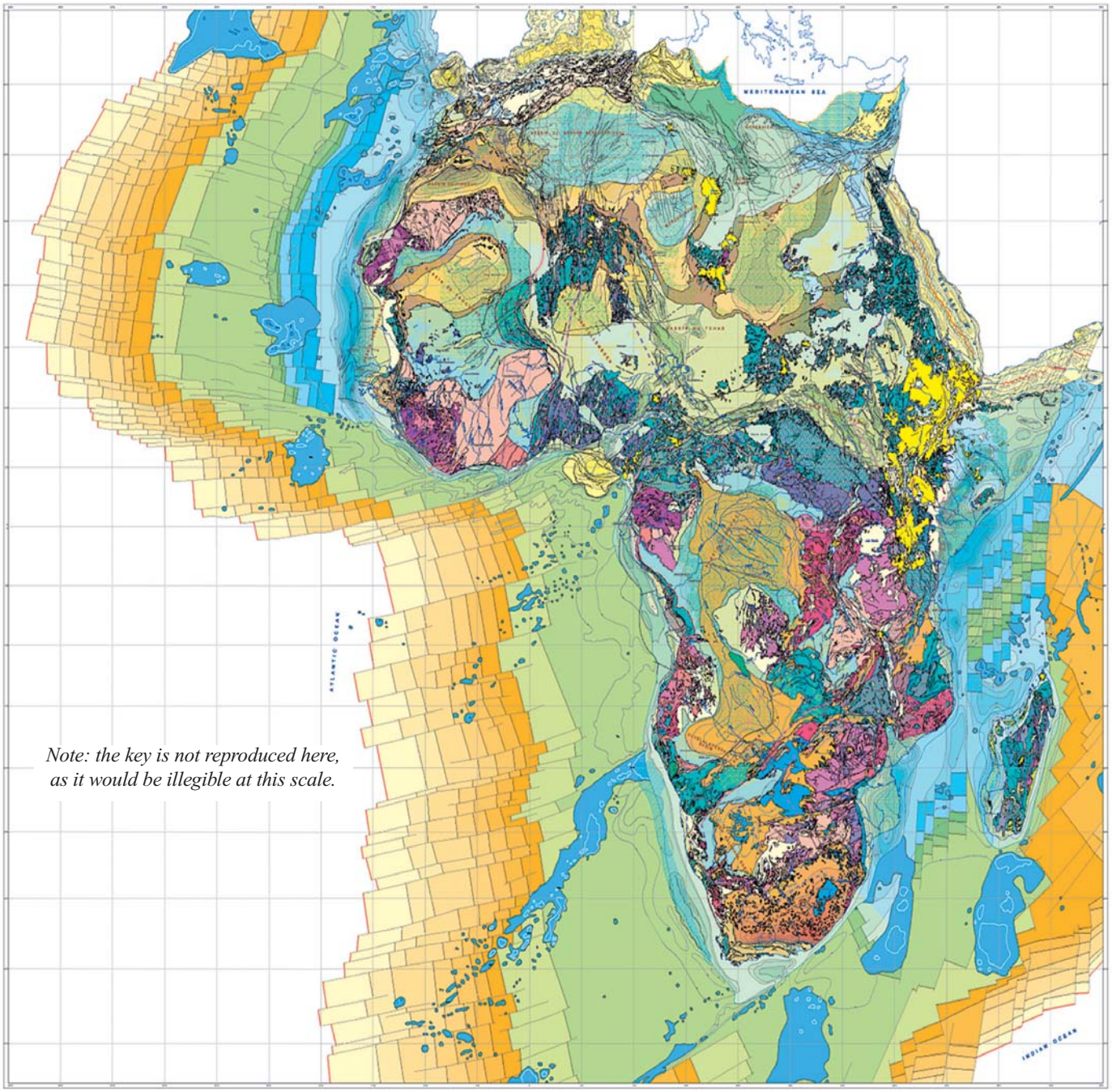
A **tectonic map** of Africa

Twenty-three years after this pharaonic project began, UNESCO and the Commission of the Geological Map of the World (CGMW) released the second edition of the *Tectonic Map of Africa* *(below)* on 8–14 January at the University of Johannesburg (South Africa), during the 23rd Colloquium of African Geology. The map was distributed to all African universities with Earth science departments and to all African geological surveys during the colloquium.

Over the past two decades, UNESCO and the CGMW have sponsored countless meetings to compile and harmonize the reams of data collected over the years by geologists from Africa and Europe, as well as by the oil industry.

This new edition takes into account the most recent developments in Earth sciences with ever-more precise and profuse radiometric dating of formations from the Archean [(4000–2500 million years ago (Ma^3)] and Proterozoic (2500–542 Ma), on the one hand, and a deeper knowledge of the structure of the great African sedimentary basins thanks to oil exploration, on the other.

The map portrays the successive orogenic systems (the formation of large mountain belts): Archean, Eburnean–



Note: the key is not reproduced here, as it would be illegible at this scale.

Palaeoprotorozoic (2500-1600 Ma), Kibarian–Meso-proterozoic (1600–1000 Ma), Panafrican-Neo-proterozoic (1000–500 Ma), Variscan-Cap Fold Belt (400–300 Ma) and the Atlas–Alpine Orogen (from 65 Ma onwards).

The map also shows the great magmatic outpourings during post-Palaeozoic times (less than 250 Ma) corresponding to the activity of hotspots: the Central Atlantic Magmatic Province (*in purple* on the map), Karoo (*sky blue*), Etendeka (*dark green*, related to the Parana traps in South America), Madagascar volcanism (*lime green*), the Ethiopian traps merged with the volcanism generated by the opening of the Great East-African rift (*yellow with overprints*), as well as other Cenozoic volcanics (*same yellow without overprints*) disseminated in Africa. Younger granites are also featured (*dark blue*).

Special attention was paid to representing the large sedimentary basins shaped from the Archean up to the Cenozoic (65 Ma to the present), with a specific colour being attributed to the date of initiation of each basin. Moreover, whenever the Cenozoic cover of an older basin is less than 1 000 m thick, this is shown by a scattering of superimposed dots.

Reflecting the importance of the African continental margins for oil and gas exploration, the map indicates the approximate limit between the continental and oceanic crusts of the Atlantic and Indian Oceans. The age of the oceanic crust is indicated by a succession of now conventional colours from blue for the oldest age through green and orange to cream for the youngest.

Geological maps are familiar tools for understanding the scientific processes of the Earth's formation and as a source of data for mineral and oil exploration. They are perhaps less known for their value as a basis for policies concerning groundwater evaluation, natural disaster mitigation, land use, soil conservation and environmental monitoring, among others. Moreover, geological hazards such as the East African Rift and the Cameroon Volcanic Line are also gifts, for they have favoured the development of biodiverse ecosystems over time and attracted human settlements in search of fertile soils for agriculture. Today, these features offer vast potential for geotourism and other socio-economic activities.

The *Tectonic Map of Africa* has been drawn to a scale of 1/10 000 000. UNESCO and CGMW are preparing a new 1/5 000 000 edition to provide more detailed information. This edition will be ready in time for the 34th International Geological Congress from 5 to 10 August 2012 in Brisbane (Australia).

UNESCO and CGMW are also currently preparing a Seismotectonic Map of Africa to serve as the basis for a realistic seismic hazard assessment. They are also planning a complete inventory of abandoned mines in sub-Saharan Africa. This map will serve as the basis for drafting practical guidelines for eliminating or reducing the associated environmental health risks.

The next challenge for geological mapping in Africa will be to ensure that all existing paper maps are conserved via digitalization. The OneGeology project launched in 2007 during the International Year of Planet Earth aims to produce a single transnational geological map which would be accessible to all online and ultimately linked to real-time databases. To date, only 10 African countries have contributed to this project, less that 20% of Africa's potential participation.

The first edition of the *Tectonic Map of Africa* was produced before the development of the plate tectonics concept. Compiled by the CGMW, it was published in 1968 by the Association of Geological Surveys of Africa and UNESCO.

For details: (in Nairobi) sf.toteu@unesco.org; to purchase the map: ccgm@club-internet.fr;www.onegeology.org

China hosting **centre on ocean dynamics and climate**

A Regional Training and Research Centre on Ocean Dynamics and Climate was launched on 9 June in Qingdao City at the host centre, the First Institute of Oceanography, which is part of the State Oceanic Administration of China. The centre is the first to join a network launched in 2008 by UNESCO's Intergovernmental Oceanographic Commission (IOC).

The centre will provide young scientists from developing countries in Asia in particular with training once a year on ocean dynamics, the interaction between air and sea and numerical modelling, at no cost to the beneficiary. The first regional training session on ocean models got under way just a day after the launch, winding up on 15 June.

Over the coming years, a network of training and research centres on oceanography will be established within national oceanographic institutes and universities to improve regional capacity in marine scientific research and foster more sustainable and systematic observations.

'Planet Earth really should really be called Planet Ocean,' observes Zhu Wenxi from UNESCO's Bangkok office, which piloted the project. 'The oceans account for 97% of the Earth's water. They are the lungs of our planet, providing most of the oxygen we breathe; they regulate the Earth's climate and are a major source of food and medicines.'

'The coastal and marine ecosystems of the Western Pacific are among the richest and most productive in the world,' adds Mitrasen Bhikajee, Deputy Executive Secretary of the UNESCO-IOC, who spoke at the launch. 'They are home to 76% of the world's coral species, for instance.' In an acknowledgment of the region's strategic importance, the UNESCO-IOC decided to create a Sub-Commission for the Western Pacific (WESTPAC[4]) in 1989, hosted by UNESCO's Bangkok office.

For details: www.fio.org.cn/english/training_center/index.htm; (in Bangkok): w.zhu@unesco.org; m.bhikajee@unesco.org

3. *All dates are approximate.*
4. *Covering China, Indonesia, Japan, Malaysia, Philippines, Rep. Korea, Singapore, Thailand and Viet Nam*

Michael Dittmar

What does the future hold for nuclear power?

Since the March disaster at the Fukushima nuclear power plant in Japan, countries have been inspecting the safety of their own plants, including those with the biggest number, the USA and France, and those with the most ambitious plans for nuclear power development, China, India and Russia. In June, Germany decided to phase out nuclear power completely even as Italy voted by referendum to drop plans for a first nuclear reactor.

Beyond the obvious safety issue and the problem of radioactive waste, do nuclear power plants have a future? Michael Dittmar doubts it. A physicist who divides his time between the Swiss Federal Institute of Technology in Zurich and the European Organization for Nuclear Research (CERN) in Geneva, Dittmar observes that the main fuel of plants, uranium, is less plentiful than some might think. According to the International Atomic Energy Agency[5] (IAEA), there are currently 440 operating nuclear reactors with a further 65 under construction. Operating nuclear reactors require the equivalent of about 68 000 tons of natural uranium ore every year. Yet, over the past 20 years, no more than 40–50 000 tons of uranium ore have been extracted annually from mines around the globe. Even taking into account accumulated stocks, demand for uranium could soon exceed supply, especially if the number of plants doubles by 2030. If nuclear power is no more sustainable than fossil fuels, what does that imply for our energy future?

Where does extracted uranium ore come from today?

About 97% comes from just 10 countries and 85% from 26 mines. The three largest uranium-producing countries are Kazakhstan, Canada and Australia, in descending order. Together, they produced about 63% of the total in 2009. The next three, Namibia, Russia and Niger, together produced 23% and another 11% came from Uzbekistan, the USA, Ukraine and China.

The largest mine in Canada alone produces about 15% of the world total. The three largest mines together extracted about 31% of all uranium in 2009 and the 10 largest mines 59%. The next 16 mines together produced another 25%. Thus, global uranium production is closer to a monopoly than any other energy source today.

About 30% of nuclear fuel currently comes not from mines but from an obviously unsustainable source, civilian and military uranium stocks[6] accumulated during the Cold War and, to a much lesser extent, from fuel reprocessing.

Before the accident in Japan, several countries were planning to construct a large number of nuclear power plants in the coming 20 years, the most ambitious plans being presented by China (*see graph*). If all these projects can be realized in time and only a few of the ageing[7] nuclear power plants are closed by 2030, the number of plants worldwide will nearly double, requiring a similar increase in uranium mining.

The IAEA estimates that the known uranium deposits of about 6.3 million tons are sufficient to fuel existing plants for 100 years. Do you agree?

First of all, one should distinguish between the known deposits of about 4 million tons of assured uranium and the 2.3 million tons of inferred extractable uranium. Given that one-third of the 'known' deposits are only an estimate, a more accurate interpretation would be that perhaps enough uranium exists to operate the existing nuclear power plants for about 70 years.

In my view, the real question is not whether there is enough uranium somewhere in the ground but whether the well-known and less well-known uranium deposits can be mined fast enough to satisfy the annual uranium demand under different scenarios.

The answer to this question depends not only on geological constraints but also on the demand side and thus on many assumptions. In recent years, essentially three scenarios have been considered for the future of nuclear-produced electric power: a so-called fast-growth scenario of more than 2% a year, a reference scenario of 1.5% growth and a constant or slow phase-out scenario of -1% capacity per year. If we choose the reference scenario of 1.5% growth, annual uranium requirements in 2030 would come to *circa* 90 000 tons, about 35% more than today.

Assuming a totally unrealistic growth scenario of, say, 5% per year, about 180 000 tons of uranium would be needed to fuel nuclear power plants in 2030 and the 'known' uranium resources would be exhausted by about 2047. It is important to realize that even a 5% annual growth scenario would still result in nuclear power contributing only about 2.5 times more nuclear energy by 2030 than today. Assuming that all other fuel types remained at 2010 levels of 86% of the total electrical energy mix, this unrealistic increase would still only provide about 30% of electrical energy in 2030.

However, all the available data about existing and future uranium mines indicate that it will be essentially impossible to increase the amount of worldwide uranium extraction in the next 10–15 years to much more than about 60 000 tons. Thus, in my view, without greater supplies from military sources after 2013, we shall only be able to avoid a severe

uranium shortage if we voluntarily begin phasing out nuclear power plants by reducing capacity by perhaps as much as 1% per year, or even more, in light of the Fukushima accident in March. This would create a much more relaxed ratio of supply and demand for uranium over the next 20 years.

Are you saying that nuclear weapons could be dismantled to recover uranium?

To understand how nuclear weapons can be recycled, you need to know how enrichment works. Natural uranium ore contains 0.71% of U235, which can be fissioned in reactors. The energy-intensive enrichment process enhances the U235 component to about 3–4% for reactor use and to more than 90% for nuclear weapons. It leaves behind so-called depleted uranium, which still contains about 0.2–0.3% of U235. Extracting the remaining U235 is even more energy-intensive. Moreover, limited infrastructure exists for this process at present.

The USA and Russia each have something like 10 000 nuclear warheads. Using a rough estimate that each nuclear warhead contains about 100 kg of the fissionable U235 that has been enriched to about 95%, one finds an equivalent of about 10 tons of natural uranium in each warhead.

It would certainly be much better to use uranium for power generation than for bombs but recycling uranium for a nuclear power plant generates its own problems. As the uranium in nuclear warheads cannot be used directly in today's nuclear reactors, it first needs to be downgraded from a 95% to 3–4% U235 content. As the original enrichment process was not only expensive but also very energy-intensive, recycling represents a huge waste of energy.

France and the USA consider that nuclear power gives them energy independence. Do you agree?

In the coming months, few people will want to be reminded of such statements from the past, preferring to talk about a long-term nuclear phase-out.

However, sooner or later, the Japanese nuclear disaster will be forgotten and the argument of energy independence will resurface. Yet, just how independent are France and the USA? Many countries import close to 100% of their uranium needs today; this is especially true for the USA, France and the rest of the European Union. Thirty years ago, the USA produced about 16 000 tons of uranium ore annually; today, that has declined to less than 2000 tons, whereas its power plants require about 20 000 tons. Thus, less than 10% of their needs are satisfied by mines on their huge territory.

It is especially interesting to note that 50% of US nuclear reactors are currently running thanks to the goodwill of the Russian government, via a contract that expires in 2013. Every year, the USA has to import about 10 000 tons of natural uranium equivalent nuclear fuel from Russian military reserves. This dependence on uranium imports has become much stronger in recent years because many US mines have been depleted and the country's civilian stocks of uranium have essentially been used up.

Do you see renewable energies as viable alternatives to nuclear power?

Nuclear power only contributes about 14% to the world electrical energy mix, compared to 16% for hydropower. Even in France where almost 80% of electrical energy comes from

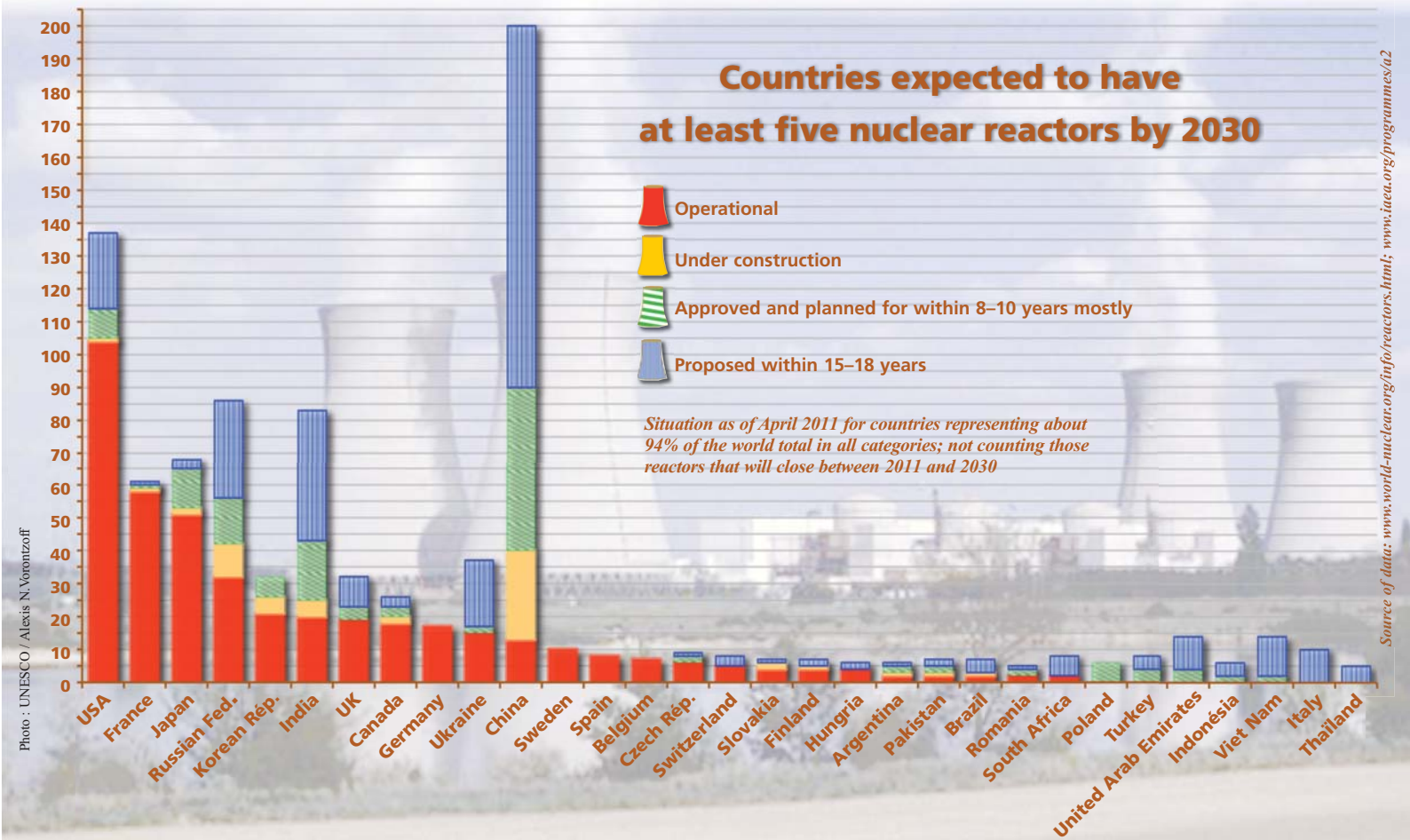
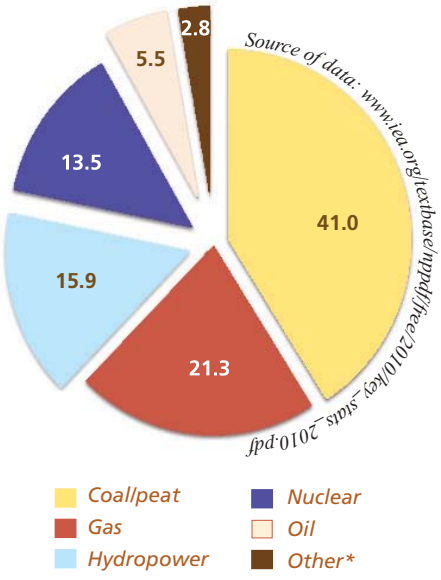


Photo : UNESCO / Alexis N.Vorontzoff

nuclear fission, its contribution to the energy sector is less than 20%, with the country's non-electrical energy needs being mainly fuelled by oil. Nuclear power is incapable of keeping up with large variations in demand, unlike hydropower. A consequence is that France is now dependent on the European electricity grid, especially during colder winter days when it imports large amounts of energy.

Unfortunately, biogas and wind and solar energy still play only minor roles worldwide. Even if the strong growth in renewables over the past couple of years continues, their share of the total electrical energy mix will remain small. Neither nuclear energy nor new renewable forms of energy will be able to forestall the inevitable decline in energy production in the coming decades. This decline will result from the combination of a slow nuclear phase-out and a decline in fossil-fuel use as a corollary of both the drop in oil extraction after stocks peak[8] and concern about climate change. If rich countries don't begin making energy savings soon, they can expect more frequent blackouts.



*Other includes geothermal, solar, wind and biogas

World electricity generation by type of fuel, 2008 (%)

Do you agree with South African nuclear physicist Kelvin Kemm that 'Africa should go nuclear – many countries are wholly dependent on hydropower and can lose 50% of their power if it does not rain'?

No, I disagree. As I indicated above, uranium shortages and the ageing of current nuclear power plants appear to be more consistent with a slow phase-out. It is hard to imagine that poorer countries will have an opportunity to construct nuclear power plants when major industrial countries are phasing them out.

Obviously, hydropower plants cannot function without sufficient rainfall. But nuclear power plants also require a huge amount of water to operate their reactors. The recurrent difficulties a water-rich country like France encounters in obtaining sufficient amounts of river water for its reactors during hot, dry summers[9] should set off warning bells in regions already suffering regular water shortages.

Are nuclear fusion projects like ITER a viable alternative to nuclear fission?

No, absolutely not. The International Thermonuclear Experimental Reactor is a very expensive plasma physics research project which is being sold to the public as the ultimate solution to the energy problem. In reality, it will need to overcome a long list of hurdles to achieve a sustained fusion reaction. Even the promoters of the project do not claim that successful experimentation in the next 20 years will result in knowledge of how to construct a commercial reactor. Assuming that all the other problems magically disappear, the most optimistic time scale for a nuclear fusion prototype reactor is 2050.

Does this mean we are condemned to burning copious quantities of coal?

In addition to coal being the dominant source of electrical energy worldwide, domestic and industrial coal fires are common in many countries. About 50 billion tons of coal were burned between 1999 and 2010 while consumption grew rapidly. Coal reserves dropped from 984.4 billion tons to 826 billion tons over the same period. How is that possible? Simply because estimations of coal reserves in Germany, South Africa and elsewhere were scaled down. The question of coal reserves has been neglected and needs to be studied in depth as soon as possible.

A study published in the August 2010 issue of *Energy* by Tadeusz Patzek and Gregory Croft from the US Universities of Texas and California concludes that global coal deposits will be insufficient to increase coal production much further and that, by mid-century, coal mining worldwide will supply only half as much energy as today. Their arguments have so far been found to be consistent with the latest coal data.

Compounding the problem of limited reserves is the fact that the entire infrastructure for extracting and transporting coal is based on oil. As oil production has already peaked, or will do so soon, it is hard to imagine that our capacity to extract coal will not suffer in a world where oil consumption is forced to decline by a few percentage points each year.

In sum, it looks like having a global energy sector based on the use of fossil fuels and uranium is totally unsustainable and that we shall soon see an inevitable decline in energy production. Once we have exhausted fossil fuels and uranium, the alternative energy options will all be renewable. But renewable sources of energy will never be able to compete with current energy production levels, so we shall have no choice but to become more economical with energy. We need to face these hard facts and begin preparing for that day, including by curbing our energy wastage.

Interview by Susan Schneegans

5. *See its PRIS database: www.iaea.org/programmes/a2*
6. *Prior to 1990, more uranium was extracted than used. See Dr Dittmar's paper (June 2011) on uranium stocks: http://xxx.lanl.gov/pdf/1106.3617v1*
7. *One-third (152) of nuclear reactors are more than 30 years old and 82% more than 20 years old.*
8. *The* World Energy Outlook 2010 *published by the OECD's International Energy Agency claims that conventional crude oil production peaked in 2006. Optimistic forecasts cite the year 2020. Unconventional sources include oil (tar) sands and shale oil (and gas), extracted using energy-intensive, environmentally damaging techniques.*
9. *In France and Switzerland, just 25–40% of normal rainfall has been recorded so far this year . See the global drought monitor: http://drought.mssl.ucl.ac.uk*

Small is beautiful

Teachers on Rodrigues Island in Mauritius using a microscience kit to oxidate ferrous sulphate at a workshop in August 2008

When UNESCO first launched its global microscience project 15 years ago, many countries still took a purely theoretical approach to science teaching, not out of choice but of necessity. They simply could not afford the exorbitant cost of equipping schools and universities with laboratories. The miniature kits proposed by UNESCO offered a low-cost, safe alternative for experimentation.

Given their multiple advantages, it was not long before the miniature kits caught on. Cameroon, Tanzania and South Africa have invested massively in them, as have Russia and the UK. Angola, Ethiopia, Namibia, Malaysia, Sudan, The Gambia and the Palestinian Authority have all held workshops to adapt the kits to the national curriculum, while other countries are still at the stage of demonstration workshops. Today, there is a growing demand for UNESCO's assistance in customizing the miniature kits for national use – and nowhere more so than in Africa.

If there is little or no experimentation in many classrooms and university laboratories in developing countries today, one also finds virtual substitutes for laboratory experimentation in the developed countries, such as computer-based simulations and video sequences. This can hamper learning, as even the most practical notions will appear abstract to a student who cannot put theory into practice. 'Nothing compensates for the solid grounding in physics, chemistry and biology which experimentation provides,' observes Alex Pokrovsky, a chemist who retired from UNESCO several years ago but still keeps an active interest in the project. 'How can any country train scientists, let alone promote the national research which is indispensable to development, without experimentation?' he wonders.

The first microscience kits were designed in the 1990s by the Research and Development in Mathematics, Science and Technology Education (RADMASTE) Centre at the University of the Witwatersrand in Johannesburg (South Africa). Veritable mini-laboratories, the kits replace the traditional glass test-tubes, beakers, flasks and measuring cylinders with miniature plastic alternatives. The kits are inexpensive, compact, re-usable and difficult to break. In addition, the small quantities of chemicals employed make the kits environment-friendly and safe, with low operating costs.

In 1996, UNESCO and the International Union for Pure and Applied Chemistry (IUPAC) were searching for a means of proposing low-cost experimental equipment at a price that any country could afford. They found the answer in South Africa. Initially, RADMASTE focused on experiments in chemistry. However, the basic concept can be adapted to experimentation in many other areas of science, including physics, material sciences, geology, hydrology, biochemistry, biotechnology and agriculture. Over the years, RADMASTE has added other kits to its repertoire, including the Basic and Advanced Microchemistry Kits, the Microburette Kit, the Bar LED Microconductivity Kit, Microbiology Kit, Microelectricity Kit and Microchem Water Field Kit. Most recently, it designed the International Year of Chemistry Global Experiment Kits for UNESCO and IUPAC (*see box*).

Cameroon was one of the first countries to see the kits' potential for strengthening science and technical education. By December 2000, more than 7000 kits were being used in secondary schools across the country. As the pilot project developed, it became urgent to provide a structure for the introduction and monitoring of microscience in the country's primary and secondary schools. UNESCO suggested setting up a Centre of Excellence in Microscience Experiments. The General Leclerc High School in Yaoundé, with a roll of almost 5000, was chosen to host the centre. It trains teachers and organizes sub-regional seminars for teachers and education specialists not only from Cameroon but also from the four other countries belonging to the Economic Community of Central Africa, namely the Central African Republic, Chad, the Republic of Congo and Gabon.

Big business

Today, the project is implemented within UNESCO's International Basic Sciences Programme, in collaboration with the teacher education section of UNESCO's Division of Higher Education. RADMASTE remains a key partner, as does the Islamic Educational, Scientific and Cultural Organization (ISESCO) for participating countries from the Muslim world. ISESCO was a key partner, for instance, in the introduction of the microscience kits into Jordan, Lebanon, the occupied Palestinian territory and Syria in 2006 via a series of workshops. UNESCO's Ramallah office recently signed a contract with the Ministry of Education and Higher Education to provide 15 kits to

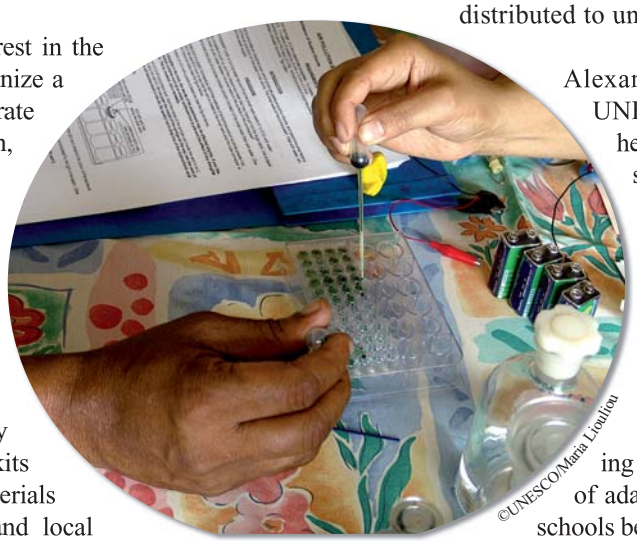
18 Palestinian schools for grades 1–9, or a total of 270 kits. The Ministry now plans to buy bulk quantities of the kits.

Various companies around the world manufacture the microscience kits. Prices vary but the kits can come with a price tag of as little as US$10–15 each. The sales price for bulk deliveries is negotiated directly by the country concerned and its chosen supplier.

UNESCO works primarily with three suppliers: Somerset Educational and RADMASTE in South Africa and Edulab in the UK[10]. However, UNESCO encourages countries to develop their own kits from locally available materials. For those countries which prefer to purchase the kits from abroad, it might help to generalize use of the kits in schools if donors were to propose debt swaps in exchange for bulk purchases.

A strong demand from Africa: the example of Sudan

Once a country expresses interest in the project, the first step is to organize a workshop in order to demonstrate how the kits work. In Sudan, for example, this workshop took place on 9 July 2010 at the International Academy School in Khartoum attached to the Ministry of Foreign Affairs. UNESCO and the National Commission for UNESCO then organized a second workshop on 31 January this year to adapt the standard kits and UNESCO's teaching materials to the Sudanese curriculum and local conditions.



Teachers using the microelectricity kit at the workshop in Mauritius in 2008

For two and a half days, Alex Pokrovsky and Hassan Elfatih, the national microscience project co-ordinator and Dean of the College of Science of the Sudan University of Science and Technology, guided 50 curriculum planners, trainers, policy planners and teachers in creating their own teaching materials and kits for physics, chemistry and biology for children aged 14–16 years. The participants then appealed to the Ministry of Education to introduce the new Sudanese kits into the country's schools.

Six months on, a Sudanese version of the kits has been developed which is currently being tested in 30 pilot schools for a period of four months, with funding from the Ministry of Education. Two schools have been selected in each of the country's 15 states. In parallel, the National Microscience Team is training teachers how to use the kits in the classroom.

Once the kits have been evaluated and modified as necessary, Education Minister Ustaza Suad plans to supply the kits to 3500 schools. Sudan is currently negotiating a loan with the Islamic Development Bank to purchase the kits in bulk.

Ethiopia: home to one of Africa's largest student populations

With 14 million pupils and university students, Ethiopia counts one of the biggest student populations in Africa. In March this year, Ethiopia opted for a combined demonstration and adaptation workshop at the Ethiopian Management Institute east of the capital. Run jointly by UNESCO and the Ministry of Education over three days, the workshop attracted more than 40 secondary school teachers, university professors, curriculum planners and policy-makers eager to see the kits being used in conjunction with the accompanying teaching materials. Three professors from the RADMASTE Centre demonstrated the kits, an exercise that has since been captured in a brochure distributed to universities and schools.

Alexandros Makarigakis from UNESCO's Addis Ababa office helped to organize the March workshop. 'Ethiopia began developing its own microscience kits in June,' he explains. 'The Ministry of Education plans to focus on secondary and tertiary education and is developing kits in biology, chemistry and physics.'

'The Ministry has set up a steering committee to guide the process of adapting and testing the kits in pilot schools between September and March next year,' he adds. 'It also plans to set up a national microscience centre by September this year, with UNESCO's assistance.'

Teacher training in Tanzania and The Gambia

Meanwhile, in the United Republic of Tanzania, UNESCO has been working within the United Nations Development Assistance framework to supply microscience kits and provide teacher training for 180 schools, at a cost of US$1.4 million. Tanzania is one of the eight pilot countries of the One UN Programme established in 2007[11].

In The Gambia, a consultative workshop for the introduction of microscience kits was run on 10–13 January this year at the request of the President. For lack of funding, most senior secondary schools lack functional science laboratories. The meeting report observed that even 'the small number of schools equipped with laboratories fail to utilize their facilities effectively due to the absence of a maintenance strategy and in-service training on how to integrate practical work into lessons.'

The Big Splash!

Schoolchildren of all ages are being invited by UNESCO and IUPAC to participate in what may turn out to be the biggest scientific experiment ever. With their teachers, children around the world are being asked to measure pH levels and salinity in water, to filter and purify the water then desalinate it.

The United Nations' World Water Day on 22 March offered an ideal opportunity to use the microscience kits designed for conducting experiments in water chemistry. As this year's theme was Water for Cities: Responding to the Urban Challenge, the 1000 participating pupils from schools in different parts of Cape Town were first exposed to a key urban challenge: the difficulties Khayelitsha slum-dwellers face daily in obtaining clean water from a standpipe. The children were then transported to Ratanga Junction to watch a delightful play performed by the Jungle Theatre on the importance of conserving and preserving local water supplies.

The next day, the children were handed the microscience kits so that they could conduct their own experiments, under the benevolent eye of Erica Steenberg from the RADMASTE Centre and three volunteers. The children first discovered the pH of a water sample taken from Intaka Island, a wetland in Cape Town, then filtered and purified the water. For most of the children, this was the first time they had ever conducted a chemistry experiment. Their excitement at completing the exercise successfully and the torrent of questions they asked were a pleasure to witness.

The kits were donated to the participating schools by the South African Department of Science and Technology and Sasol, a South African petrochemical company. The brief opening ceremony was presided over by UNESCO and by the Deputy Minister of Science and Technology, Derek Hanekom.

The Big Splash was part of a global experiment on Water: a Chemical Solution being run by UNESCO and IUPAC within the International Year of Chemistry. Since the Big Splash in March, a further 6303 students from 300 schools in 31 countries have registered the results of their own experiments in water chemistry at the dedicated website.

Rovani Sigamoney

To watch the video about the Big Splash: www.youtube.com/watch?v=r4gS9bep8Tc&feature=player_embedded#at=77
For details of the global experiment: water.chemistry2011.org; r.sigamoney@unesco.org

South African pupils measuring the pH of water during the Big Splash in Cape Town in March

A feasibility study conducted in 2003 by the Ministry of Basic and Secondary Education, in collaboration with UNESCO's Regional Bureau for Education in Africa (BREDA) based in Dakar (Senegal), concluded that the kits would be very beneficial. The Gambia then applied to be one of the 22 countries selected for the UNESCO project, which was essentially funded by the Gaddafi International Foundation for Charity Associations at the time[12].

The 15 participants in the January workshop comprised heads of secondary schools, representatives of the Science Teachers' Association, science lecturers from Gambia Collage and the University of the Gambia, staff from the Curriculum Research and Development Directorate and the Standard and Quality Assurance Directorate, as well as staff from the Directorate of Science and Technology Education.

At the end of the four-day workshop, the participants recommended that the project be introduced simultaneously for all 12 years of schooling and that one kit be provided ideally for every three pupils, or a maximum ratio of one kit to five pupils. They recommended teacher training and observed that teachers would need more time than at present to prepare their classes. The participants recommended that Gambia College, responsible for teacher training in the country, incorporate the use of microscience kits in its training curriculum. It was also recommended that the kits be adapted to the national curriculum 'to suit the country's needs and aspirations.'

Better teaching of science and mathematics

In April this year, the Pan-African Conference on Teaching in the Context of Education System Reform[13] recommended that microscience kits be used to improve science and mathematics teaching. The conference was organized in Lomé (Togo) by the African Union, BREDA, UNICEF and other partners within the framework of the action plan for the development of human resources adopted by the New Partnership for Africa's Development.

The microscience kits will next be demonstrated on World Teacher Day on 5 October at UNESCO Headquarters in Paris. Meanwhile, several workshops are planned for Haiti, Kazakhstan and Kyrgyzstan before the end of the year.

Imteyaz Khodabux

On the project in the Middle East, see also A World of Science*, October 2007: http://unesdoc.unesco.org/images/0015/001537/153797e.pdf;*

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10. Somerset International: microscience@isat.co.za; RADMASTE: joseph.mungarulire@wits.ac.za; Edulab: enquiries@edulab.co.uk

11. The others are: Albania, Cape Verde, Mozambique, Pakistan, Rwanda, Uruguay and Vietnam.

12. UNESCO ceased all co-operation with this foundation in February 2011 following the repression of civilian populations in the Libyan Arab Jamahiriya.

13. See www.teacherspacted.org

Saved by their ancestors

For Prime Minister Naoto Kan, the earthquake, tsunami and nuclear disaster which devastated Japan in March were the country's 'worst crisis since the Second World War'. Considering that he was comparing the tragedy to the dropping of atomic bombs on the cities of Hiroshima and Nagasaki in 1945, his statement is heavy in meaning. Although the provisional death toll of 25 000 is one-tenth that of both the Indian Ocean earthquake and tsunami in 2004 and the Haiti earthquake last year, the tragedy has deeply traumatized the population. It could also become the world's most expensive disaster on record, with government cost estimates of up to US$300 billion.

Amid the desolation, the Japanese could take comfort from the thought that knowledge passed down over the generations had saved some lives. While the benefits of local and indigenous knowledge in reducing disaster risk are increasingly being acknowledged, a challenge remains: how do you integrate such knowledge constructively with scientific knowledge and policy? This is a difficult yet important step, as it could help reduce the vulnerability of those communities most exposed to hazards. A project launched last year by UNESCO's Regional Bureau for Science in Asia and Pacific is taking up the challenge in three countries: Indonesia, the Philippines and Timor Leste.

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This monument in a village on the outskirts of Miyako proffers a warning: Do not build houses below this point.

The Sanriku coast in northeast Honshū faces the Pacific Ocean. It encompasses the Aomori, Iwate and Miyagi Prefectures and is known for its beautiful coastline and thriving fishing industry.

The Japanese are familiar with the region's long history of tsunamis but this particular characteristic only gained global exposure on 11 March, in tragic circumstances.

While there are written records dating from the early 17th century of large tsunamis generated by underwater earthquakes having regularly engulfed the region, only the three most recent have been recorded in detail. In 1896, the Meiji Sanriku O-tsunami claimed 22 000 lives across Aomori, Iwate and Miyagi Prefectures. In Iwate Prefecture, waves ranging from a height of 10 m to as much as 38 m killed nearly one-quarter of the population, according to Fumio Yamashita's 2008 *Modern History of Tsunamis in Japan*. The 1933 tsunami waves were generally smaller in size but devastated a wider region. Some waves were nevertheless up to 29 m high, resulting in nearly 3000 deaths, according to Yamashita. Takehiko Yamamura describes[14] how, in 1960, waves up to 6 m high travelled more than 17 000 km across the Pacific Ocean, arriving in Japan 22 hours after the world's biggest recorded earthquake of 9.5 magnitude struck the Chilean coast. The tsunami affected almost the entire length of Japan's Pacific coastline and claimed nearly 150 Japanese lives.

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Bulldozers clearing away the rubble in Minami-Sanriku in May. All the wooden houses were completely destroyed by the tsunami. On this part of the coast, the tsunami waves were more than 15 m high. Of the 14 000 inhabitants of the area inundated by the tsunami, 519 are dead and 664 missing.

The epicentre of the underwater earthquake on 11 March was situated 130 km east of Sendai and 373 km northeast of Tokyo.

A false sense of security

Many coastal towns and villages had put their faith in the expensive sea walls constructed along the shoreline, some of which were 10 m high. As the tsunami approached, some inhabitants were so confident in the walls' capacity to withstand the onslaught that they clambered on top of them. But the walls were no match for the waves. They collapsed upon impact, catapulting the refugees into the churning waters.

Others who ran to designated tsunami evacuation areas thought they had reached safety, only to be surprised by the waves. The population had known the waves were coming, thanks to the tsunami alert which had gone out three minutes after the offshore earthquake. But they were not warned that many of the waves arriving 25 minutes later would be more than 10 m high, some even a towering 38 m.

The coastal fishing town of Kamaishi in Iwate Prefecture has experienced many tsunamis. That of 1896 killed more than half its 7000 inhabitants. In 2009, the world's deepest breakwater – 63 m – was completed at a total cost of US$1.5 billion. The breakwater didn't prevent 1200 people from being killed or reported missing.

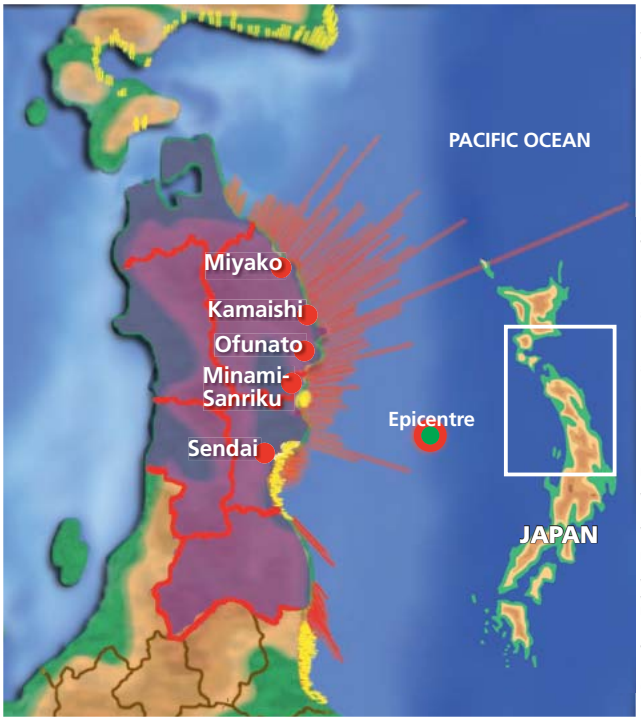
One of the lowest death tolls came from an unexpected quarter, the town's primary and lower secondary schools. All but five of the schools' 2900 pupils survived this year's tsunami. This is because the children knew what to do; experts in education for disaster preparation had toured the schools to share the teachings of *tendenko*. This term was born of the 1896 tsunami, when many lives were lost due to family members trying to save one other. The lesson learned from the 1896 tragedy was that, if everyone ran to safety separately rather than looking for family members, everyone would be saved.

Do not build below this point

In a small village on the outskirts of the city of Miyako in Iwate Prefecture, all 12 households survived the tsunami last March.

A monument erected after the 1933 tsunami stands 800 m from the port, on a steep slope 60 m above sea level. It bears an inscription telling how the tsunamis of 1896 and 1933 reached up to this point, leaving behind just two and four survivors respectively. There are over 200 such monuments across the region but this one has received particular attention recently due to the warning at the end of the inscription: 'Do not build houses below this point'.

On 11 March, fishermen and -women from the village were all working in the port area when the earthquake struck but they scrambled up the hill to their homes as soon as they heard the tsunami warning. The giant waves stopped 50 m below the monument. Consequently, while Miyako city as a whole suffered 900 casualties from the tsunami in March, there were no casualties in the fishing village.



Data from Tohoku Earthquake Tsunami Joint Survey Group as of 2 June 2011: www.coastal.jp/tjt

Height of tsunami waves off Japan's east coast on 11 March: the longest orange line corresponds to 40 m. The Tohoku Region (in purple) consists of six prefectures: on the east coast (north to south) Aomori, Iwate, Miyagi and Fukushima Prefectures and on the west coast Akita and Yamagata Prefectures.

Another village on the outskirts of the city of Ofunato in Iwate Prefecture had decided to relocate to higher ground after the 1896 tsunami. Last March, the village suffered only minor damage.

In neighbouring Miyagi Prefecture, an ordinance was issued after the 1933 tsunami obliging entire villages to move to higher ground or to limit construction in tsunami-prone areas. Unfortunately, this ordinance seems to have been abolished sometime between 1933 and 1954. Consequently, many buildings were built in tsunami-prone areas, especially during the construction boom from the 1980s onwards. All of these buildings were swept away in March.

There are other, less-publicized examples of local knowledge related to tsunamis having saved the population. A woman in Iwate Prefecture recalls being warned by a survivor of the 1896 tsunami to observe water levels in wells after a major earthquake. The elder told her that water temporarily dried up or made a lapping sound before a tsunami arrived. When the earth stopped shaking on 11 March, the first thing she did was to peer down the well in her back yard, only to discover that the water was darker than she had ever seen it. She ran for her life. Although she survived, her house was destroyed.

Other stories go back farther in time. Roads and post stations dating from the Edo period (1603–1868) in the Sendai area were deliberately built outside tsunami-prone zones. A shrine by the name of *Namiwake* (*nami* meaning wave

View of the hospital in Minami-Sanriku in May, one of the rare buildings left standing. The tsunami waves only spared the top floor. Of the 107 patients, 72 died. Most of the victims were elderly and needed help to evacuate. To make matters worse, the elevator was out of order following a power cut caused by the earthquake. The earthquake caused the ground in the region to subside by about 1 m.

and *wake* to divide or separate) marks the highest point of a tsunami dating from the 17th century. The shrine proffers a warning which unfortunately went unheeded this year.

Technology alone does not suffice

Efforts to mitigate the impact of natural hazards tend to focus on infrastructure development, such as the building of sea walls or breakwaters in the case of tsunamis, or on high-tech solutions such as sophisticated early warning systems based on scientific data and modelling. While these technical solutions save lives when hazards strike, the stories above remind us that community-based education and awareness-raising campaigns are just as important in saving lives.

An added advantage is that, when community education is based on local and indigenous knowledge, it tends to resonate more with the population. *The Hyogo Framework for Action* highlights the importance of such knowledge. Adopted in the Japanese city in 2005, this ten-year action plan stresses that upholding the importance of 'traditional and indigenous knowledge and culture heritage' is 'critical for disaster risk reduction'.

Local and indigenous knowledge has its place in policy

UNESCO's programme on Local and Indigenous Knowledge Systems (LINKS) defines local and indigenous knowledge as 'understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings'. Synonymous with terms such as traditional ecological knowledge and rural peoples' and/or farmers' knowledge, local and indigenous knowledge is not necessarily restricted to knowledge owned by people who are either officially recognized as indigenous people, or consider themselves as such. Rather than associating knowledge with a group of people, local and indigenous knowledge typically shows the following characteristics: it originates and is maintained within a community; it is disseminated orally from generation to generation; it is owned collectively; it develops and changes over generations and: it is embedded in a community's way of life.

People tend to interpret and deal with disasters primarily in two ways: via folklore, in the form of legends, songs, stories and so on; and via customary practices that include settlement patterns, architecture and resource use. A 2008 publication by the United Nations International Strategy for Disaster Reduction (UNISDR) presents 18 case studies of 'good practices' in Asia and

This apartment building near the coast in the town of Minami-Sanriku was a designated evacuation point. Although the tsunami reached the roof, many of those who took refuge in the building were rescued.

the Pacific where indigenous knowledge contributed to disaster risk reduction. According to UNISDR, the four primary arguments for including indigenous knowledge in disaster risk reduction policies are:

- indigenous knowledge can be transferred and adapted to other communities in similar situations;
- incorporating indigenous knowledge encourages community participation and empowers communities in reducing disaster risk;
- indigenous knowledge can provide invaluable information about the local context;
- the non-formal means of disseminating indigenous knowledge can serve as a model for education about disaster risk reduction.

Social factors play an important role in determining the extent to which a community is exposed to hazards. They determine where people live and work, their levels of preparedness, their access to information and state of health. Communities accustomed to living with natural hazards often possess knowledge and have adopted practices that help them cope. By focusing attention on such knowledge, emphasis shifts from the hazard itself to risks surrounding the hazard and the underlying components of vulnerability which can contribute to turning a hazard into a disaster.

Strengthening the resilience of coastal communities

In 2010, UNESCO's Regional Bureau for Science in Asia and Pacific launched a three-year project to strengthen the resilience of coastal and small island communities to hydrometeorological hazards such as drought, floods and storms, together with the impact of climate change. Thanks to Japanese Funds-in-Trust for Scientific Programmes on Global Challenges in Asia and the Pacific Region, the Jakarta-based office has been able to implement this interdisciplinary project in Indonesia, the Philippines and Timor Leste. These three countries were chosen for their particular vulnerability to the impact of hydrometeorological hazards and climate change, as well as for their rich cultural and biological diversity.

The project builds upon the experience of the Jakarta Tsunami Information Centre run by UNESCO's Jakarta office in reducing communities' vulnerability to disasters. Two of the case studies in the aforementioned UNISDR publication concern indigenous peoples whose traditional knowledge saved them from the clutches of the Indian Ocean tsunami in December 2004: the Moken[15] of the Surin Islands off the coast of Thailand and Myanmar; and the people of Simeulue Island in Indonesia. UNESCO's offices in Bangkok and Jakarta had worked with both populations after this terrible catastrophe to help them rebuild their lives.

Last March, UNESCO organized an expert meeting in Jakarta to fix the timetable and agenda for the three national workshops planned in Indonesia, the Philippines and Timor Leste in July and August. These workshops will be followed by research to identify and document

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Operations room in the Sendai District antenna of the Japan Meteorological Agency, which monitors earthquake, tsunami and volcanic activity in the Tōhoku Region. Here, the team is monitoring volcanic activity on 11 May 2011.

local and indigenous knowledge in each of the three participating countries related to climate change and hydrometeorological hazards.

The expert meeting was followed by a regional workshop attended by 40 participants from national and international NGOs, governments and United Nations agencies, as well as donors.

As indigenous knowledge is largely absent from policy-making and disaster risk education, the second and third years of the project will be devoted to making this knowledge more accessible to outsiders. At the same time, the project will ensure that local people's voices are heard in policy debates. In 2012, the project will develop educational materials for schools and communities that draw on local and indigenous knowledge. This material will then be tested at pilot sites in 2013. The same year, the project will see to it that the documented local knowledge is woven into national and local policies.

The project will involve three local partners, the Indonesian Society for Disaster Management, the Center for Disaster Preparedness in the Philippines and the Haburas Foundation in Timor Leste, but it will rely on local communities as the primary source of information. By ensuring that local and indigenous knowledge is integrated with scientific knowledge and Western strategies for disaster risk reduction, the project should ultimately strengthen communities' resilience to hazards.

Lisa Hiwasaki[16]

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14. See the account and photos here (in Japanese): www.bo-sai.co.jp/chirijisintunami.html

15. On the Indian Ocean earthquake and tsunami and the knowledge that saved the Moken, see A World of Science*, April 2005*

16. Programme Specialist for Small Islands and Indigenous Knowledge, UNESCO Regional Bureau for Science in Asia and Pacific, based in Jakarta: l.hiwasaki@unesco.org

International Year of CHEMISTRY 2011

Diary

4–5 July
STI global assessment programme
Meeting to define methodology of proposed programme. UNESCO Paris: *l.brito@unesco.org*

19–21 July
Indigenous peoples, marginalized populations and climate change
Two workshops run by UNU, IPCC, CBD Secretariat, UNDP, UNESCO. Mexico City: *j.rubis@unesco.org*

25–29 July
Coastal and marine atlases
3rd ODINAFRICA workshop. Vacoas (Mauritius): *m.odido@unesco.org*

26–28 July
Protecting structures, saving lives
4th session of Intl Platform for Reducing Earthquake Disasters. Intl workshop and members' meeting. Santiago de Chile: *y.katusmi@unesco.org*

30 August – 1 September
Intl Quiet Ocean Experiment
Open science meeting on impact of sound on marine organisms, to develop 10-year science plan for large-scale intl research project. UNESCO Paris: *t.gross@unesco.org; http://ioc.unesco.org*

31 August – 2 September
Intl Coastal Atlas Network
UNESCO-IOC Project Office for IODE. Oostende (Belgium): *p.pissierssens@unesco.org; www.iode.org*

5–8 September
CoastGIS
UNESCO-IOC Project Office for IODE. Oostende (Belgium): *p.pissierssens@unesco.org; www.iode.org*

12–30 September
OceanTeacher Academy courses
On marine data management (12–16 and 19–23), grant writing (12–16), data curation for info professionals (26–30). UNESCO-IOC Project Office for IODE. Oostende (Belgium): *p.pissierssens@unesco.org; www.iode.org*

18–21 September
Eco-friendly farms for cash crop halophytes
And biodiversity conservation with seawater irrigation. Expert workshop. UNESCO Doha and Environment Agency Abu Dhabi (United Arab Emirates): *b.boer@unesco.org*

19–22 September
Chemistry, science and society
23rd annual conf. of Academia Europaea, under auspices of Intl Year of Chemistry. UNESCO Paris: *r.sigamoney@unesco.org*

26–28 September
Re-invigorating IOCINDIO
UNESCO-IOC Regional Commission for Central Indian Ocean. UNESCO Doha and General Directorate of Nature Reserves (Qatar): *b.boer@unesco.org*

Corrigendum
On page 15 of the April 2011 issue of *A World of Science*, the GERD/GDP ratio for Qatar should have read 0.33%.

New **Releases**

A Teaching Resource Kit for Mountain Countries

A Creative Approach to Environmental Education
Man and the Biosphere series. UNESCO Publishing, ISBN: 978-92-3-104159-4, €22.00. Exists in English and French, 176 pp.
Combines a teacher's manual in three chapters with an activity book for pupils. It teaches 10-15 year-olds about soil erosion and other issues specific to mountainous regions, using a fun and engaging approach. It contributes to the UN Decade of Education for Sustainable Development (2005-2014). The kit is being distributed by the UNESCO Associated Schools Network, which comprises nearly 9000 schools in 180 countries.
Download: *http://unesdoc.unesco.org/images/0019/001918/191873e.pdf*

Chemistry and Life

Jasmina Sopova (ed). UNESCO Courier. *Exists in Arabic, Chinese, English, French, Russian and Spanish, 56 pp.*
Download: *http://unesdoc.unesco.org/images/0019/001906/190645e.pdf*

Application of Satellite Remote Sensing to Support Water Resources Management in Africa

Results from the Tiger Initiative
UNESCO-IHP. Technical Documents in Hydrology, No. 85. English only, 152 pp.
The European Space Agency launched the TIGER initiative as follow-up to the World Summit on Sustainable Development in 2002. The initiative assists African countries in overcoming problems faced in the collection, analysis and dissemination of water-related geo-information by exploiting the advantages of Earth observation technology. In recent years, ESA, UNESCO and the Canadian Space Agency have contributed to TIGER, in collaboration with UNECA and the African Development Bank and under the leadership of the African Ministerial Council on Water.
Download: *http://unesdoc.unesco.org/images/0018/001880/188045m.pdf*

The Arab Recycling Initiative

Website devised by 2B Communications and UNESCO Doha office.
This new website features news on recycling of plastic, mobile phones and other materials. For example, the European green company Zonzoo recycled nearly 2 million mobile phones in 2009 and is on course to treble that figure this year across its existing territories in Europe and now also the Middle East. Go to: *www.arabrecycling.com*; for details (in Doha): *m.sutcliffe@unesco.org*

The Impact of Global Change on Water Resources

Brochure produced by UNESCO-IHP. English only, 24 pp.
Describes how the UNESCO-IHP is responding to this challenge.
Download: *http://unesdoc.unesco.org/images/0019/001922/192216e.pdf*

Tectonic Map of Africa

Map published by the Commission of the Geological Map of the World and UNESCO. Second edition, €15.00. Bilingual English and French.
See page 12 for details. Order a print or digital version from *www.ccgm.org*

Savoir des femmes

Médecine traditionnelle et nature
By Laurence Pourchez. Local and Indigneous Knowledge Series. UNESCO Publishing, ISBN: 978-92-3-204197-5, €15.00. French only, 120 pp.
From the late 17th century onwards, the islands of Reunion, Mauritius and Rodrigues in the Indian Ocean were gradually populated by migrants from Europe, Madagascar, Africa, India, China, Polynesia and Australia, generating a cross-fertilization of medical traditions transmitted largely by women. This book focuses largely on childbirth.

Current Challenges in Basic Science Education

Produced by the Education Sector, English only, 92 pp.
Examines issues such as how to promote equality and equity; collaboration across borders in a globalizing world; hands-on learning, the use of clowns and other innovative teaching techniques; preparing for the world of work and; the role of ICTs. For details: *b.macedo@unesco.org*; download: *http://unesdoc.unesco.org/images/0019/001914/191425e.pdf*

Al-Zubarah – Pearl of the Past

By Tobias Stössel and Yaser Al Huthi. Film on DVD narrated by John de Bono. Produced by UNESCO Doha, supported by the Qatar Museums Authority, Qatar Ministry of Culture, Arts and Heritage, Katara: Valley of Cultures, and the Qatar Marine Festival. Contact: b.boer@unesco.org

Hydrology and Water Resources

DVD produced by UNESCO's Delhi office in 11 000 copies with funding from Netherlands Permanent Delegation to UNESCO. English only.
Contains all reports published by UNESCO's International Hydrological Programme and many by other international water-related organizations, including UN-Habitat, UN-Water, the UNESCO-IHE Institute for Water Education, World Water Council and Intergovernmental Panel on Climate Change. Presented by UNESCO to an international workshop at the Institute of Technology and Management (India) on 14-15 March 2011. Request a copy of the DVD (UNESCO Delhi): *b.neupane@unesco.org; water@unesco.org;* or through *ihp@unesco.org*

The Water Channel

Portal supported by UNESCO-IHP, UNESCO-IHE Centre for Water Education, Cap-Net and International Fund for Agricultural Development. In English.
Hosts short articles, discussions and numerous videos on water-related issues. As of April, the portal hosted 670 videos. It invites 'creative people tuned into water to join in, explore and add to it!' Access: *http://www.thewaterchannel.tv/index.php*; contact one of the founders: *a.pham@unesco-ihe.org*

Glossary of Glacier Mass Balance and Related Terms

UNESCO-IHP' Technical Documents in Hydrology series, no. 86. Prepared by the Working Group on Mass-balance Terminology and Methods of the International Association of Cryospheric Sciences. English only, 124 pp.
Download: *http://unesdoc.unesco.org/images/0019/001925/192525e.pdf*

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Cover photo: Cleaning up a Kolontar street in protective gear – Photo: Flickr