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See table of contents

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ISSUES IN CANADIAN GEOSCIENCE

Carbon Sequestration: Earth Science matters!

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INTRODUCTION

The sobering experience of the last NSERC reallocation exercises should force the Earth Sciences community to review its objectives and reflect upon the perception other public and scientific constituents have of it. For example, Bob McDonald of CBC's 'Quirks and Quarks' aired a feature in June 2003 on the 'Yukon Ice Age' that should be a dramatic reminder that global warming is not a new phenomenon. Yet he was interviewed recently by CBC's Peter Mansbridge on the 'The National' on October 28, 2002, affirming "the skeptics who go against it (global warming), …. medical doctors, geologists, people in other professions … not climate scientists … their arguments, when you look at them closely, just don't stand up." (http://www.cbc.ca/national/trans/index.html). To counter the negative and often confused public perception of Earth Science, and to bolster proposals for increased funding from NSERC, we must develop new research that has relevance for society and that matters scientifically.

The debate about the Kyoto Protocol centres around two alternatives to reduce greenhouse gas (GHG) emissions in the environment: 1) use of low-carbon energy sources such as hydroelectric or eolian power; and 2) reduction in energy consumption and increase in energy efficiency. The use of low carbon energy sources instead of hydrocarbons will require a major industrial shift that cannot occur quickly. In addition, these alternate sources of energy do not necessarily have the flexibility of the GHG-emitting energy sources, and they have their own impact on the environment. Reduction of energy consumption has many advantages, including cost savings for individuals. There is, however, a limit to the reduction that can be reached, and it is an alternative that most appeals to people in developed countries that consume a disproportionately large amount of the world's energy supply. Energy reduction has little appeal to societies that seek rapid development from economic conditions few of us would deem adequate. This is where most of the world's population resides and where major increases in GHG emissions will occur in the future, because of population increase and rise in per capita use of energy. In addition to the sheer volume of emissions from developing countries, they are commonly produced from what are considered dirty energy sources such as coal, which may emit sulphur and metals.

CARBON SEQUESTRATION

Carbon sequestration is a third alternative to reduce GHG emissions. This process begins with carbon capture either from the atmosphere or from point sources such as industrial complexes and energy producers. Captured carbon must then be stored in a reservoir and prevented from reaching the atmosphere. Here Earth Science matters! We have the broadest and most applicable scientific knowledge to tackle carbon sequestration. We must assume a leadership role in carbon sequestration research and establish the Earth Sciences as the leading authority in Canada by including carbon sequestration as a major project for the next NSERC reallocation exercise. There are three major reservoirs that can store carbon with short- to long-term residence, and each of them offers challenging research opportunities for Earth scientists.

Sequestration in Terrestrial Biomass

Terrestrial biomass is a huge short-term carbon reservoir (~2000 Gt C) that uses photosynthesis and plant respiration to exchange carbon with the atmosphere. This exchange sequesters 1.9 Gt C/a in terrestrial biomass, an amount that is almost counterbalanced by emission of 1.7 Gt C/a from deforestation, thus yielding a small positive sequestration gain of 0.2 Gt C/a. Considerable controversy exists on the exact carbon flux values, which is being addressed by research such as the FLUXNET-CANADA network. Because terrestrial biomass is a short-term storage solution for carbon, only increases in biomass can lead to increased carbon sequestration. Terrestrial biomass sequestration has some additional virtues such as revegetation of abandoned lands or protection of swamps, thus improving biodiversity and the environment. Earth scientists have shown, however, that SO_2 pollution slows biomass growth thus reducing its capacity to capture carbon (Savard et al., 2002). We can also determine past storage of biomass carbon in the geological record: could what it tells us impact carbon sequestration policies? We have to be part of this debate, because Earth Science matters!

Sequestration in the Oceans

The ocean is also a vast reservoir of CO_2. The concentration of dissolved CO_2 in the upper part of the ocean has increased over time, remaining in equilibrium with atmospheric CO_2 concentration, and therefore absorbing a vast quantity (1.9 Gt C/a) of anthropogenic carbon emissions. One scheme to sequester CO_2 tests fertilizing the photic zone, causing an algal bloom. Phytoplankton may then be consumed by other organisms, or settle to the bottom of the ocean, thereby sequestering carbon away from the atmosphere. One such experiment using iron sulphate fertilizer yielded troubling results such as release of isoprene, another GHG (Dalton, 2002). Unlike surficial oceanic water, the deep ocean is not in equilibrium with atmospheric CO_2 and could store huge amounts of anthropogenic carbon for hundreds of years. Sequestration involves either dissolving gas bubbles into seawater, or direct injection of liquid CO_2 to the seafloor, where solid clathrates are stable at the ambient pressure and temperature conditions. One major impact of CO_2 injection is a decrease in the pH of water near the injection site. New alternatives are being developed, including dissolution of CO_2 in a calcium bicarbonate solution, akin to limestone weathering, and then pumping this solution in the ocean to dilute it (Rau et al., 2003). There are many objections to CO_2 storage in the ocean, which will need to be addressed to make it acceptable to society. Earth scientists need to take a leadership role in assessing the long-term stability and environmental impact of ocean sequestration. We also have unique and vital geochemical expertise, which can help us understand and forecast the role of the oceans in past and future carbon absorption.

Sequestration in Geological Formations

Geological storage involves sequestering CO_2 in rocks. The most advanced concept and one that has commercial application in terms of oil and gas fields is to inject CO_2 into geological reservoirs for enhanced oil recovery (EOR) or storage of dry acid gas. In fact, Canada hosts the International Energy Agency EOR test site at Weyburn, Saskatchewan. Injection of CO_2 into geological reservoirs is quite similar to the natural gas distribution network that relies on natural, engineered reservoirs to stock gas for peak consumption periods. Another alternative is to adsorb CO_2 onto organic matter in deep coal beds unsuitable for mining. By this process, CH_4 is displaced by injected CO_2 thus producing natural gas. Obviously, EOR and CH_4 production from coal beds have economic value, but the positive impact on Canada's CO_2 emissions is reduced by the amount of oil and gas eventually produced and combusted. The CO_2 can also be injected and dissolved into a confined aquifer, a method used by Norway's Statoil in the Sleipner gas field to avoid emission of CO_2 into the atmosphere as a by-product of natural gas production. Finally, CO_2 can be sequestered as carbonate minerals. For example, olivine or serpentine react naturally with CO_2 to form magnesite ($MgCO_3$). There are more than enough magnesium silicate rocks in ophiolite belts and in asbestos mine waste in Canada to store Canada's CO_2 emissions for centuries. A collateral and environmentally friendly effect of the use of mineral carbonation is the recovery of mining waste in asbestos production districts such as the Eastern Townships in Quebec and the Cassiar district in British Columbia. The most significant advantage of mineral carbonation by magnesite is that it is the only permanent form of carbon sequestration. Mineral carbonation is thermodynamically favoured, but the rates of reaction present a challenge when one considers sequestering the CO_2 emissions from an average power plant. In addition, magnesite manufactured from carbon sequestration processes could become a magnesium ore: magnesium metal production from magnesite releases CO_2 but increased use of magnesium in vehicles would help reduce GHG emissions. Geological storage represents the most advanced of the alternatives for CO_2 sequestration, and has a track record of industrial implementation and review by international panels in instrumented test sites. It is also the only long term to permanent form of CO_2 sequestration. Earth Sciences clearly matters!

CONCLUSIONS

Hydrocarbons will remain a major energy source for several decades and carbon sequestration is a valid and important means of reducing our GHG emissions. The Earth Sciences are at the heart of the carbon sequestration concept and we must therefore be at the centre of the debate, providing facts and figures for a scientifically and environmentally sound decision. For all these reasons, the development of carbon sequestration research programs should be addressed by Earth Scientists for the next NSERC reallocation exercise. It has appeal for most disciplines in Earth Sciences, it is scientifically relevant and challenging, and it has significant importance for Canadian society and its economic development.

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