HEALTH EFFECTS OF ACUTE AND PROLONGED CO_2 EXPOSURE IN NORMAL AND SENSITIVE POPULATIONS*

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INTRODUCTION

Human health effects of CO_2 have been examined in the scientific and medical literature as a prerequisite to health risk assessment for releases of CO_2 from CO_2 capture, transport, and sequestration (CT&S) sites. Atmospheric CO_2 at ~0.037% (370 ppm) poses no threat to human health, however, considerably higher concentrations produce adverse effects. Human health effects associated with CO_2 exposure (~1 atm) are presented for selected normal and sensitive populations. Although occupational standards exist, they may not be protective for environmental exposure of the general population.

Table 1: NIOSH Occupational Exposure Standards[1]

REL	5,000 ppm (0.5%)	TWA, 10-hr day, 40-hr week
STEL	30,000 ppm (3%)	15-minute TWA
IDLH	40,000 ppm (4%)	Immediately dangerous to life/health

CO_2 IN HUMAN PHYSIOLOGY

CO_2 is produced by cellular metabolism. It can also enter the body during respiration when the atmospheric concentration exceeds the alveolar concentration. Complex mechanisms control CO_2 levels in the body. CO_2 is transported in blood both in solution and in multiple chemically bound forms, but only the physically dissolved CO_2 diffuses across the alveolar-capillary membrane. CO_2 reversibly reacts with two major components in the blood: H_2O and proteins (plasma proteins and hemoglobin). Reaction with H_2O forms carbonic acid (H_2CO_3) relatively slowly in plasma. In erythrocytes, H_2CO_3 is rapidly formed due to enzymatic action. It then dissociates into bicarbonate (HCO_3^-) and H^+, which is buffered by hemoglobin.

$$\mathbf{CO_2 + H_2O \rightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+}$$

CO_2 is a potent stimulus to ventilation by increasing inspiratory drive (↑ TV, ↑ expiratory drive, ↓ T_E). Stimulation, mediated by medullary and peripheral arterial chemoreceptors (probably due to ↓ pH), begins within seconds of inhalation; maximal stimulation is usually attained <5 min. The respiratory rate (RR), however, is not significantly elevated below a 2% CO_2 concentration unless the O_2 concentration is depressed. In normal humans, CO_2 increases cardiac output (CO), HR, BP, and dilates cerebral blood vessels.

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EFFECTS OF CO_2 IN HUMAN POPULATIONS

The commonly cited effects of CO_2 that can be found in most text books are shown in Table 2. These effects are primarily for the healthy working population and generally have no duration attribution.

Table 3 gives a selected summary of studies under normoxic conditions, except where indicated, from the medical and scientific literature that provide duration of exposure when given and specific effects experienced by various human populations. The table is not comprehensive, but gives the reader an idea of the range of effects that can be experienced with CO_2.

Table 4 gives a selected summary of studies of prolonged exposure of healthy volunteers to CO_2 under normoxic conditions. The acute effects of CO_2 are often mitigated during prolonged exposure by the homeostatic mechanisms for maintenance of acid-base balance.

In addition to its physiological effects, CO_2 can also act as an asphyxiant by displacing atmospheric O_2. Signs of asphyxia will be noted when atmospheric $O_2 \leq 16\%$. Unconsciousness leading to death will occur when the atmospheric oxygen concentration is reduced to ≤ 8%, or at higher concentrations with strenuous exertion. Four stages of asphyxiant effects are described in Table 5, which depend on the arterial O_2 saturation (P_aO_{2sat}).[17]

The effects of CO_2 in any given situation will depend on the concentration of CO_2, the duration of exposure, and the concentration of O_2. The evaluation of all these factors are important to understand the potential impact of CO_2.

Table 2: Commonly Cited Effects of CO_2[2-5]

CO_2	Effects
1%	Respiratory rate (RR) ↑ 37%
1.6%	$\dot{V}$ ↑ ~100%
2%	RR ↑ ~50%; brain blood flow ↑
3%	Exercise tolerance ↓ in workers when breathing against inspiratory & expiratory resistance
5%	$\dot{V}$ ↑ ~200%; RR ↑ ~100%, dizziness, HA, confusion, dyspnea
7.2%	RR ↑ ~200%, HA, dizziness, confusion, dyspnea
8-10%	Severe HA, dizziness, confusion, dyspnea, sweating, dim vision
10%	Unbearable dyspnea, followed by vomiting, disorientation, hypertension, & loss of consciousness

Table 3: Effects of Acute CO_2 Exposure

CO_2	Min.	Population	Effects
2.5%	150 trials	Healthy volunteers	Temporary ↓ visual stereoacuity (detection of coherent motion)[6]
2.5%	≥30	Healthy volunteers	Visual stereoacuity ↓ Resting energy expenditure ↑ 2.8%[7]
4%	30-60	Healthy volunteers	At 29°C ambient: rectal & forehead temp ↓. ~14% of extra heat losses from respiration[8]
4%	30-60	Healthy volunteers	At 5°C ambient: rectal & forehead temp ↓. ~14% of heat losses from respiration; balance skin conduction, evaporation, & convection[8]
3 or 5%	20	No CV or pulmonary disease controls	$\dot{V}$ ↑ 153%; $\dot{V}_{O2}$ ↑ 13%; $P_aO_{2\ sat}$ ↑ 0.5% to 100% MABP ↑ 10%; pulmonary blood flow unchanged MPAP (S/D) 21/8 mm Hg unchanged CI ↑ 7% (3.68 L/min/m^2)[11]
3 or 5%	20	Chronic pulmonary emphysema patients	$\dot{V}$ ↑ 100%; $\dot{V}_{O2}$ ↑ 13% (considerable variation) $P_aO_{2\ sat}$ ↑ 4% to 93%; CI ↑ 13% (3.13 L/min/m^2); CO ↑ 14% MABP (S/D) 147/84 ↑ 10% MPAP (S/D) 48/21 ↑; large ↑ in pulmonary blood flow MPAR ↑ 14%; ↑ 136% over no disease control[11]
5%	5	Panic disorder patients	$\dot{V}$ ↑ 110%; TV ↑ 140%; RR ↑ 24% [9]
5%	5	Non-panic controls	$\dot{V}$ ↑ 130%; TV ↑ 60%; RR ↑ 7% [9]
5%	10-20	Normotensive stroke patients	MABP ↑ 17%; MPAP ↑ 34%; HR ↑ 24%; CI ↑ 22%; CW ↑ 44%; CBF (hemispheric) ↑ 51%; CVR ↓ 18% [10]
5%	10-20	Hypertensive stroke patients	MABP ↑ 19%; MPAP ↑ 68%; HR ↑ 12%; CI ↑ 33%; CW ↑ 51%; CBF (hemispheric) ↑ 48%; CVR - ↓ 21% [10]
6%	5	Healthy, young volunteers	Body sensations: SOB ↑ 50%; heart palpitations ↑ 16%; sweating ↑ 28%; pressure in chest ↑ 56%[12]
8%	5	Healthy, young volunteers	RR ↑ 73%. Body sensations: SOB ↑ 72%; heart palpitations ↑ 44%; sweating ↑ 72; pressure in chest ↑ 38%; wobbly or rubber legs ↑ 34%; dizziness ↑ 28%; blurred or distorted vision ↑ 22%[12]
10%	5	Healthy volunteers	CSF pressure ↑ ≥ 250 mm H_2O for all subjects BP_S ↑ 18 mm Hg; BP_D similar[13]
30% in 70% O_2	2	2 Healthy volunteers	PR & QT intervals ↑; QRS complex ↑; Other ECG abnormalities; Venous blood pH 7.12-7.16; BP ↑ marked & progressive; 35-40 respirations to narcosis[14]

Table 4: Effects of Continuous or Repeated CO_2 Exposure

CO_2	Exposure	Population	Effects
0.5 - 1.5%	Repeated daily	Healthy individuals	Well tolerated
1%	22 days	Healthy volunteers	Serum Ca and urinary P output ↓ progressively throughout exposure; Ca deposition in body tissues ↑
1.2%	25 days	Healthy volunteers	Serum Ca, total & active ↓; bone formation sl ↓; bone resorption sl ↑[15]
1.5%	42 days	Healthy volunteers	$\dot{V}$ ↑ 35% by Day 5; TV ↑ 200 mL by Day 42; RR peaked on Day 1; normal by Day 28[16]

Table 5: Effects of Simple Asphyxiants

Stage	P_aO_{2sat}	Effects
Indifference	90%	Night vision ↓
Compensatory	82 - 90%	RR ↑; PR ↑; night vision ↓; performance ability sl ↓; alertness sl ↓. Symptoms may begin in those with significant pre-existing cardiac, pulmonary, or hematologic diseases
Disturbance [hypoxemia]	64 - 82%	Compensatory mechanisms inadequate. Air hunger, hyperventilation, fatigue, visual acuity ↓, tunnel vision, dizziness, HA, belligerence, euphoria, numbness and tingling of extremities, poor judgment, memory loss, cyanosis.
Critical	< 60 - 70%	≤3-5 minutes: deterioration in judgment & coordination; total incapacitation & unconsciousness follow rapidly

SENSITIVE POPULATIONS

The following is a preliminary identification of some human populations potentially sensitive to the effects of CO_2. The CO_2 concentration and the O_2 concentration can interact in these and other human populations to alter responses to CO_2.

Cerebral Disease & Trauma Patients. CO_2 is a very potent cerebrovascular dilator. For each 1 mm Hg change in P_aCO_2, CBF globally increases by 1-2 mL/100 g-min. CO_2 exposure can seriously compromise patients in coma or with head injury, increased intracranial pressure or bleeding, or expanding lesions. Elevation of P_aCO_2 can further dilate cerebral vessels already dilated by anoxia.

Individuals Performing Complex Tasks. CO_2 can significantly diminish performance on tasks requiring psychomotor coordination, visual perception, attention, and rapid response.

Infants & Children. Infants and children breathe more air than adults relative to their body size and thus they tend to be more susceptible to respiratory exposures.[20] The vasodilator effects and enhanced ventilation could contribute to rapid loss of body heat.

Medicated Patients. Respiratory center stimulation by CO_2 is depressed by anoxia and by various drugs such as alcohol, anesthetics, morphine, barbiturates, etc.[3] In these cases, compensatory mechanisms do not protect and symptomology does not alert the individual to the presence of high CO_2 levels.

Panic Disorder Patients. Panic disorder patients experience an increased frequency of panic attacks at 5% CO_2. Anxiety and somatic symptoms also are significantly increased and are similar to those experienced by healthy subjects exposed to 7.5% CO_2.[19] Panic attack and significant anxiety can affect the ability of the individual to exercise appropriate judgment in dangerous situations.

Pulmonary & Coronary Disease Patients. CO_2 exposure can increase pulmonary pressure as well as systemic BP and should be avoided in individuals with systemic or pulmonary hypertension. The rise in CW during CO_2 inhalation could jeopardize patients with coronary artery disease and those with heart failure.[18]

SUMMARY

The release of CO_2 from CT&S sites that produce relatively low ambient concentrations of CO_2 for prolonged periods, high concentrations of CO_2 in relatively anoxic environments (such as could result from a catastrophic release) for short periods, and intermediate concentrations of CO_2 (under normoxic or hypoxic conditions) could pose health risks for sensitive and normal human populations.

The release of CO_2 in a significant amount is especially hazardous because CO_2 is colorless and is generally considered odorless unless present at very high concentrations > 40%. Identification of CO_2 intoxication is generally by the exclusion of other toxicants and disease conditions because symptomology is not unique to CO_2.

Preliminary evaluation of CO_2 effects in human populations suggests that acute exposure to CO_2 concentrations $\leq$3% and prolonged exposure to concentrations $\leq$1% may significantly affect health in the general population. Site specific risk assessments using these and other health effects data are necessary to determine potential health risks for a given sensitive or normal population.

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Key

BP	blood pressure (S/D) systolic/diastolic	MPAP	mean pulmonary arterial pressure
BP_S	systolic blood pressure	MPCP	mean pulmonary capillary pressure
BP_D	diastolic blood pressure	P_aCO_2	arterial blood partial pressure CO_2
CBF	cerebral blood flow	$PetCO_2$	end tidal CO_2 partial pressure
CI	cardiac index (L/m^2/min)	R_E	respiratory exchange ratio
CO	cardiac output (L/min)	RR	respiratory rate
CV	cardiovascular disease	SOB	shortness of breath
CVR	cerebral vascular resistance	T_E	expiratory time
CW	cardiac work (kg-M/min)	TV	tidal volume (normal breath)
HA	headache	TWA	time weighted average
HR	heart rate	$\dot{V}$	minute ventilation (L/min)
MPAR	mean pulmonary arterial resistance	$\dot{V}O_2$	O_2 uptake/min
MABP	mean arterial BP	TWA	time weighted average

Carbon Sequestration: Who's Talking? What are the Issues?[1]

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Abstract

In support of the on-going Ohio River Valley Project, the authors reviewed 154 media articles that specifically mention carbon capture and geologic sequestration and that were issued between November 20, 2002 and April 11, 2003. The purpose of the review was to develop a preliminary understanding of issues being raised concerning this new technology. The expectation is that this preliminary analysis will be followed by discussions with the public to confirm perspectives on the issues and to address and incorporate them into project plans. The dates the articles were issued on tend to cluster around specific precipitating events, such as the announcement that launched the carbon sequestration research project in the Ohio River Valley (frequently referred to as the Mountaineer project). The media articles are overwhelmingly either positive or neutral in their characterization of this rather new class of carbon management technologies, and the discussions were frequently set within the broader context of climate change policy issues. Positive attributes include its promise to be widely deployable over many decades and its ability to help transition the energy infrastructure to a low- or non-emitting system. Concerns raised are primarily focused on the need for additional policy decisions such as mandated emissions cuts and possible uncertainties surrounding carbon retention. Most persons cited in these articles are federal government spokespersons, especially from the U.S. Department of Energy (DOE), or researchers affiliated with or sponsored by DOE. This result is likely because the DOE is the largest sponsor of research in geologic sequestration. However, representatives from industry, state governments and nongovernmental environmental organizations are also active in the discussion.

Introduction

As part of a groundbreaking DOE-FE NETL-funded field research project on geological sequestration in the Ohio River Valley,[3] the authors are conducting a systematic study of publicly stated views about this particular research project as well as sequestration and carbon capture, as expressed in media references. The purposes of the research are to (a) gain insight into some of the key issues being articulated, and (b) use this insight to assist in stakeholder interactions. As this technology is new, this preliminary analysis represents an initial step in seeking to understand issues that must be addressed if the technology is to be implemented successfully. The intent is to follow up with in-person discussions to confirm stakeholder issues and perspectives at a sufficiently early stage to address and incorporate them into project planning.

This paper provides a summary of findings to date, as our research is still ongoing. Following an overview of the approach, findings are presented under the following headings: precipitating

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[1] This paper was presented at the Second Annual Confernce on Carbon Sequestration held in Alexandria, VA on May 5-8, 2003.
[2] The authors can be reached via email at judith.bradbury@pnl.gov and dooleyj@battelle.org
[3] The Ohio River Valley Project is a geologic study being conducted at the Mountaineer Plant by Battelle Memorial Institute under sponsorship form American Electric Power (AEP), which owns the Plant, the U.S. Department of Energy, BP, and Schlumberger. The Ohio Coal Development Office of the Ohio Department of Development is also providing support to the project, given the potential to address future carbon emissions form the many coal-fired electricity power plants in Ohio, and the jobs that these plants and the Ohio coal mines support.

event and monthly distribution of the articles over the time period under study; overall portrayal; specific issues raised; and affiliation of persons quoted in the article.

Approach

The sources of the articles analyzed in this paper range from the *New York Times*, *Los Angeles Times*, *USA Today*, and various newswire services to U.S. Department of Energy (DOE) "Techlines," press releases from Battelle and AEP, to international newspapers such as the London Financial Times. Using the LexisNexis news service which searches over 4,000 articles daily, the authors compiled articles that specifically included mention of capture and geologic sequestration of carbon dioxide. Additional keywords were supplied to the search service, for example, carbon or CO_2 capture, storage, burial and/or disposal. The search was initiated in mid-November, 2002, immediately prior to the announcement of the Ohio River Valley Project being conducted by researchers from the Battelle Memorial Institute at the AEP Mountaineer Plant in West Virginia. Findings reported are from mid-November 2002 until mid-April 2003.

A total of 153 articles were recorded over the study period. Articles were divided into four categories and recorded in four separate matrices: (1) specific mention of the Mountaineer Plant research project; (2) general discussion of carbon capture and sequestration, including discussion of related projects in the United States; (3) international projects; and (4) related legislative and political activities. Of the 153 articles recorded, slightly more than half (79 articles) were focused on the Mountaineer Plant research project or were general discussions of carbon capture and sequestration in the United States. Although there is no reason to believe that this is an exhaustive listing of all articles written on sequestration during this time period, the data set is broad enough to allow a preliminary analysis.

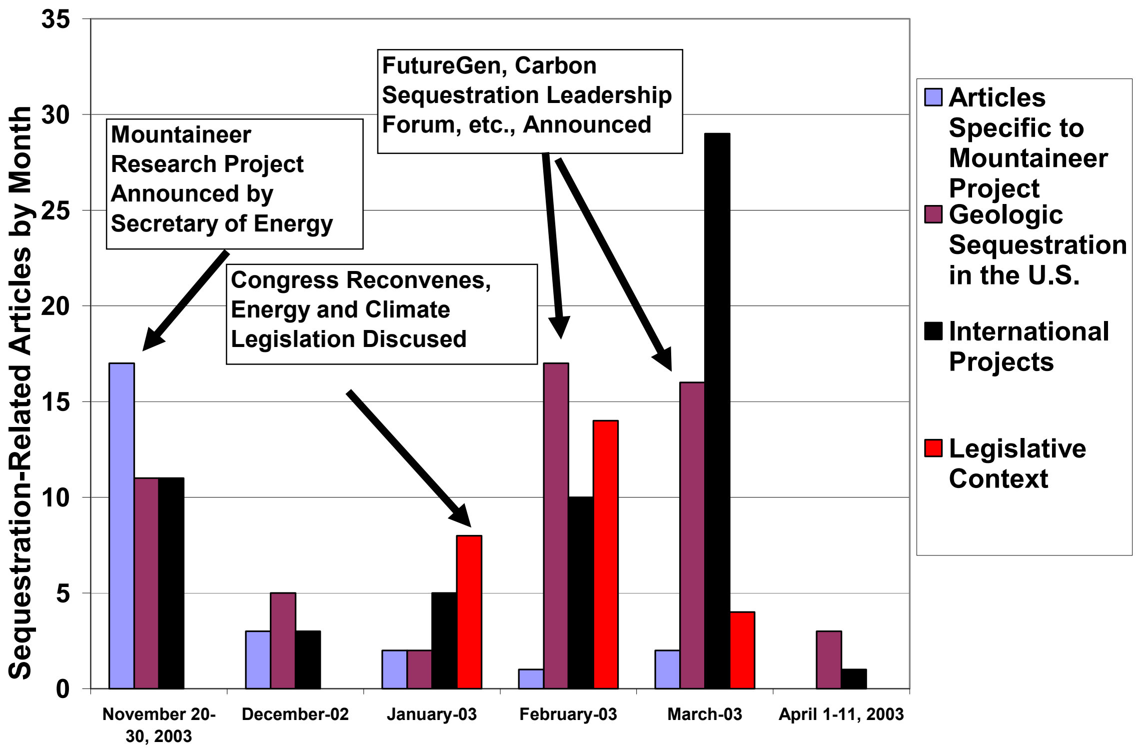
Data for each matrix were recorded under the following headings: date, source, title, precipitating event, article focus, overall portrayal or orientation toward geologic sequestration (positive, negative or neutral); specific issues raised about the technology; and the name and affiliation of persons quoted in the article.

With the exception of Figure 1, which examines the distribution over time of articles in all four categories, the focus of our analyses is on 79 articles included in the first two categories, i.e., articles that mentioned the Ohio River Valley Project (also known as the Mountaineer project) or discussed carbon sequestration in the United States. Since articles in the third and fourth categories (international sequestration research projects and energy/climate legislative activities) were compiled primarily to provide context for the sequestration research project's efforts to communicate effectively with stakeholders, we will only briefly touch upon articles in these categories.

Precipitating Events and Distribution over Time

The monthly distribution of articles over this initial five-month study period is largely explained by a relatively small number of precipitating events. Figure 1, which includes all 153 articles in each of the four categories, shows that the number of articles mentioning the research at the Mountaineer Plant peaked in November, immediately following the announcement of the project. Articles that discussed geologic CO2 sequestration in the U.S. more broadly increased in February and March. For these articles, the February announcement of the Administration's FutureGen project was the most significant precipitating event that accounts for a significant increase in articles centered on geologic sequestration in general in the United States. Other precipitating events that could be identified for this category were other sequestration-related announcements from the DOE (e.g., Regional Carbon Sequestration Partnerships, the Carbon Sequestration Leadership Forum, cooperative research agreements with the European Union and China). The increase in the category of international articles in March is attributable to projects/decisions being taken abroad; for example, an increase in Australian articles during March is attributable to the launching of a new sequestration research program in Australia.

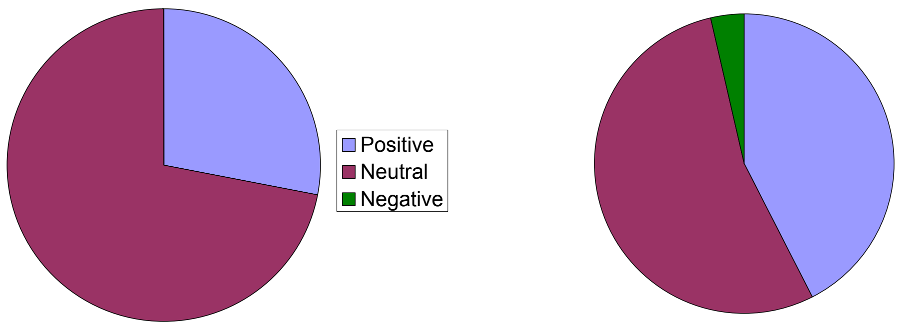
Figure 1: Sequestration Articles by Major Focus with Key Precipitating Events



Overall Portrayal

Figure 2 reports on the portrayal of the technology: overall, was the article positive, negative or neutral in orientation? For this and subsequent figures, articles are included only for those mentioning the Mountaineer Project or carbon sequestration in the United States. Articles were classified "positive" if the statements made were predominantly positive, "neutral" if there were both positive and negative statements, and "negative" if the statements made were predominantly negative. The figure indicates that the overwhelming majority of articles was either positive or neutral—some of the neutral articles constituted brief announcements, while others presented a more detailed overview of geologic carbon sequestration, including comments from both spokespersons supportive of the research or technology and those who raised concerns. Possible explanations for the relatively favorable or balanced portrayal include the high proportion of DOE or project proponent announcements and also the tendency of the media to provide "balance" in the more detailed presentations. Interestingly, two of the detailed articles that were more negative in tone were those reporting on the annual meeting of the American Association for the Advancement of Science—perhaps attributable to the speakers' tendency to focus on issues, or "problems," of scientific interest.

Figure 2. Overall Portrayal of Carbon Sequestration Technology in Media Articles Mountaineer Specific Articles (left hand panel), General Sequestration in the US Articles (right hand panel)



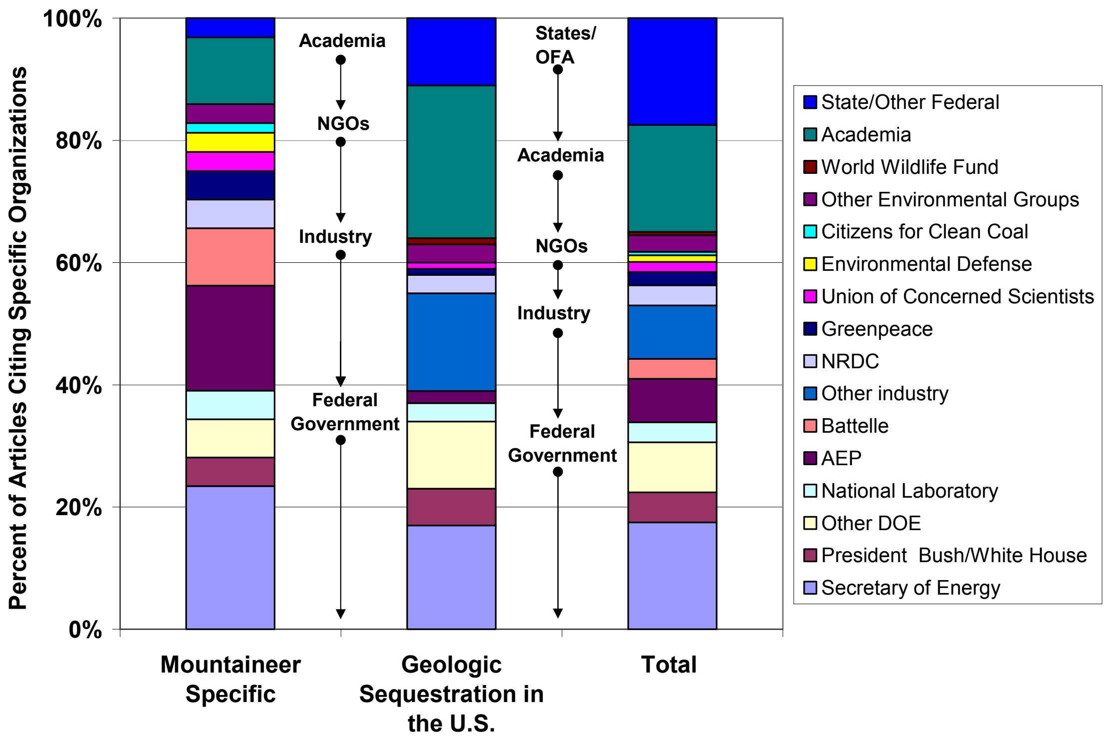
The Thought Leaders

Figure 3 graphically represents spokesperson cited—or who the "U.S. Geologic Carbon Sequestration Thought Leaders" are by organizational affiliation (as with Figure 2, data are included only for articles mentioning the Mountaineer Project or sequestration in the U.S.). Significant sources of information for the media include DOE, other parts of the federal government including the White House, researchers located at National Laboratories and universities, and representatives of large industrial firms and nongovernmental environmental organizations.

Several particular types of sources are worth noting. First, the federal government and in particular DOE, appear to be the primary sources of media information on geologic sequestration and are cited in roughly 40% of the articles, regardless of whether the article is specific to the Mountaineer project or is more general. Second, as one would expect with AEP being the host site and Battelle being the prime contractor for the Mountaineer research project, these two firms are significant sources of information for this specific research project. Third, academic researchers appear to be predominantly used by the media as sources of information about geologic sequestration in general. Fourth, environmental nongovernmental organizations are also significant sources of information about both the Mountaineer project and geologic carbon sequestration in general.

Significantly, there are currently no local public stakeholders cited in these articles (where a stakeholder is defined as a person who is interested in or affected by a project). Examples of such stakeholders include persons from local civic groups or local residents. For the purposes of this paper, AEP spokespersons from the local community where the study is being carried out are not viewed as "local public stakeholders" since the company is one of the study sponsors. The lack of local public stakeholders cited in these articles indicates that the current discussion about geologic sequestration is being conducted at the conceptual and national level. That is, to date, no local publics are seeing geologic sequestration projects as being "in their backyards," and therefore these local stakeholders have yet to use the media as a means of expressing their opinions about this class of technologies and how these technologies may affect them.[4]

Figure 3: Sources of Information for Media Articles on Sequestration By Type of Organization



Issues Articulated

Having discussed timing, overall portrayal, and spokespersons in the initial sample of articles, we turn to examining some of the key themes identified in the articles that mentioned the Mountaineer Project or carbon sequestration in the United States. Not surprisingly, issues raised concerning the technology were raised within in the broader context of climate change and energy policy. Table 1 identifies favorable statements about geologic sequestration; Table 2 identifies concerns about the new class of technologies.

Table 1 clearly shows that one of the predominant themes is "the promise" that carbon capture and geologic sequestration technologies hold for helping the nation successfully mange its emissions of CO_2. Various attributes of this potential promise relate to the technology's ability to:

- be a key component (or one of the options) of a larger and balanced suite of emissions abatement options
- serve as a long-term solution (i.e., has deployment potential that stretches over 100s of years) that is capable of being deployed over a very large section of the United States

[4] One example of local publics expressing themselves about ocean sequestration is documented in M.A. de Figueiredo, D.M. Reiner, and H.J. Herzog, "Ocean Carbon Sequestration: A Case Study in Public and Institutional Perceptions," presented at the Sixth International Conference on Greenhouse Gas Control Technologies, Kyoto, Japan, October 1-4 (2002).

- help transition the current energy infrastructure to a low- or zero-emitting energy system, including allowing coal to be the backbone of a hydrogen economy.

Table 1. Issues Raised In Favor of Carbon Sequestration Technology

Issue	Articles Mentioning the Mountaineer Project (n=25)	Articles Discussing Geologic Sequestration in the U.S. (n=54)
Support expressed for carbon sequestration	-	9
Support expressed for carbon sequestration research (total)	10	9
- Research is needed	-	4
- Promising/more than a blue-sky concept	4	1
- Will help answer technical questions	4	3
- Will help address cost issues	2	1
Carbon sequestration can transform coal into an environmentally benign source	2	10
Renewables and efficiency are not enough to solve the global energy problem (total)	8	4
- Renewables are not enough	4	1
- Sequestration will buy time, allow a gradual transfer to a green fuels/ hydrogen economy	4	3
Sequestration has the potential to store CO_2 power plant emissions for 100 years/has enormous market potential	5	5
Options are needed (total)	4	5
- A suite of options is needed	2	3
- Sequestration is one viable option/can make a contribution	2	2
This is a good area for research because of the geology/ saline formations are quite common	5	1

Table 2. Issues/Concerns Expressed Concerning Carbon Sequestration Technology

Issue	Articles Mentioning the Mountaineer Project (n=25)	Articles Discussing Geologic Sequestration in the U.S. (n=54)
Carbon sequestration research is not enough (total)	5	17
- It is too costly	2	4
- Tax incentives/a market approach is needed	3	4
- Mandated emissions cuts/caps also needed	-	9
Carbon sequestration should not be the sole policy focus (total)	4	7
- It should not be developed at the expense of other solutions	2	4
- It should be part of a three-part strategy: energy efficiency, renewables, and rapid deployment of gasification plants	-	1
- It is a short-term solution	-	2
- It is an end-pipe solution	1	-
- It is the coal industry's last hope	1	-
Carbon should not be sequestered in the ocean where it could cause damage to marine life	2	2
Serious uncertainties exist (total)	7	8
- Need to be sure CO_2 stays where it is put	2	1
- It could leak/cause health and safety problems	2	3
- There could be rapid release of gas	3	-
- There could be large releases of salty water	-	2
Sequestration has a way to go (total)	1	3
- More time is needed	-	1
- Focus should be on large-scale scale projects that produce sequestration-ready CO_2	-	2

Among issues or concerns raised in these articles and summarized in Table 2, the most frequently issue raised was the need to supplement research on breakthrough technologies like carbon capture and geologic sequestration with additional policy measures such as tax incentives and mandatory emissions caps or cuts. Concerns were also expressed about the permanence of sequestered carbon and the costs of deploying this class of technologies. Ocean disposal was clearly identified as a concern in these articles. Interestingly, and as a parallel to the above positive point about capture and geologic sequestration being a valuable component of a larger carbon management portfolio of options, there was concern expressed in some articles that funding for carbon capture and geologic sequestration might come at the expense of support for other emissions mitigation technologies such as renewable energy. Many of these identified concerns may be addressed as field experiments like the Mountaineer Project start to produce information on the fate of injected CO_2 and other key performance characteristics of these technologies.

Summary

Our analysis indicates that, to date:

- Discussion of carbon sequestration in the U.S. is largely being conducted at the national level. The viewpoints of local publics are not yet evident.
- The media portrayal of carbon sequestration in the U.S. is primarily favorable or balanced.
- In part, this favorable or balanced portrayal is attributable to the large number of articles related to DOE announcements and the predominance of DOE and DOE-related spokespersons. In part, also, it appears that some thought leaders are “sitting on the fence” until more is known about how this technology performs in the real world.
- Supportive comments about carbon sequestration appear to view the research as “promising,” with the potential to provide a solution to greenhouse gas emissions—transforming coal into an environmentally benign source and/or buying time while the transition to a “green” economy takes place.
- Comments indicating concern are focused primarily on the broader context of climate change policy. A large number of comments noted that additional policy decisions such as tax incentives and mandated emissions cuts are needed, and the technology should not be the sole policy focus or be developed at the expense of other solutions. However, a significant number of issues were also raised about possible uncertainties with the technology itself.

The pros and cons that have been voiced about this specific class of technologies may be viewed as part of the larger energy policy debate. On the one hand, there appears to be broad recognition that CO_2 emissions should be reduced and there is provisional support for carbon sequestration to assist in bringing about these reductions. On the other hand, there is also support for additional measures—tax incentives and mandated emissions cuts, as well as pursuing other technology alternatives. This finding indicates that the public will likely seek to place discussions of carbon capture and geologic sequestration technologies in a broader context that includes discussions of what climate change is and what the broad portfolio of climate change actions looks like.

Second, as highlighted above, the discussion to date appears to be occurring solely at the national and conceptual level. There is, as yet, no comment by local publics. However, as the history of facility siting has shown, local publics may become increasingly vocal as time goes on. In addition, uncertainties that are interesting issues of debate for scientists may become issues of contention among local publics who are asked to host a new technology in their own backyards. Thus, issues related to health and safety that are currently being raised at the national level and mainly as scientific issues, may be viewed as likely issues to be raised by local publics as projects become more imminent in their localities. They serve as a reminder to project managers of the need to engage local publics in addressing issues like these at an early stage and to get on with the research needed to resolve these scientific issues.

Third, representatives of several NGOs are currently serving as the public voice in articulating the issues surrounding this new technology. This analysis, albeit preliminary, suggests that project managers will benefit from more in-depth discussions to explore these stakeholders’ issues and perspectives at a sufficiently early stage to address and incorporate them into project planning.

Appendix Table 1. Monthly Distribution of Carbon Sequestration Articles

Date	Mountaineer	Geologic Sequestration in the U.S.	International Projects	Legislative Context	Total
November 20-30, 2002	17	11	11	-	39
December, 2002	3	5	2	-	10
January, 2003	2	2	5	8	17
February, 2003	1	17	10	14	42
March, 2003	2	16	29	4	42
April 1-11, 2003	-	3	1	-	4
Total	25	54	48	26	154

Appendix Table 2. Affiliation of Persons Quoted in the Media

Affiliation	Mountaineer	Geologic Sequestration in the U.S.	Total
DOE, Total	25	37	62
Secretary of Energy	15	17	32
President Bush/White House	3	6	9
Other DOE	4	11	15
National Laboratory	3	3	6
Industry, Total	17	18	35
AEP	11	2	13
Battelle	6	-	6
Other industry	-	16	16
Environmental Groups, Total	13	9	22
NRDC	3	3	6
Greenpeace	3	1	4
Union of Concerned Scientists	2	1	3
Environmental Defense	2	-	2
Citizens for Clean Coal	1	-	1
No name/Other	2	3	5
World Wildlife Fund	-	1	1
Academia	7	25	32
State/Other Federal	2	11	13
Total	64	100	164