ENVIRONMENTAL JUSTICE
Volume 7, Number 4, 2014

DOI: 10.1089/env.2014.0016

# Tools for Addressing Cumulative Impacts on Human Health and the Environment

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## ABSTRACT

''Cumulative impacts'' refers to the total harm to human health and the environment resulting from combinations of stressors over time. Cumulative impacts are creating three kinds of effects: degraded ecosystems (such as oceans and boreal forests), human diseases, and disproportionately burdened communities, which are the hallmark of environmental injustice. At the heart of the problem lie the modern risk-based regulatory systems of the United States and Europe, which are not designed to understand or manage cumulative impacts and which have permitted an accumulation of harmful activities and effects. Alternative, precautionary regulatory approaches have been recommended but not yet widely implemented. Now some communities, planners, and regulators are finding ways to supplement traditional risk-based approaches, using innovative new tools for assessment and decision-making in the face of cumulative impacts, including indexes, mapping, and screening. These efforts both inform policy and serve as exemplary models. Together they point the way toward new, precautionary decision structures aimed at reducing cumulative impacts.

## INTRODUCTION

''Cumulative impact(s)'' refers to the total harm to human health and the environment resulting from combinations of stressors over time. Many environmental, human-health, and social problems are now recognized as being caused by combinations of agents which, considered individually, may seem inconsequential but which, in combination, can give rise to significant harm. Many recent studies emphasize that cumulative impacts are altering global ecosystems, such as oceans, boreal forests, and the atmosphere in ways that are inhospitable to human well-being (Millennium Ecosystem Assessment 2005; OECD 2012). Similarly, chronic human diseases typically arise not from single, isolatable causes but from complex interactions between individual, social, and environmental conditions (Krieger 1994; Schettler 2006; Nordqvist 2013). The same sort of complexity shapes community health and well-being (Etches et al. 2006). Furthermore, environmental injustice typically develops from numerous seemingly insignificant decisions made over decades (Pulido 2000; Brulle and Pellow 2006).

The U.S. regulatory system is not designed to understand or address cumulative impacts. In practice, our laws and decision-making structures have either ignored cumulative impacts or have called for addressing them without specifying how to do it. The National Environmental Policy Act of 1969 (NEPA) mandates consideration of the cumulative impacts of governmental actions, but the mandated analytic procedure exists only in the form of a ''guidance,'' which lacks regulatory teeth (Council on Environmental Quality 1997). In addition, NEPA only requires thorough analysis of ''major'' governmental actions, thus often exempting decisions that, considered alone, may appear insignificant. Furthermore, in practice, NEPA analyses have tended to emphasize impacts on ecological resources, giving short shrift to other kinds of resources, such as socioeconomic, human health, recreational, cultural, historical, and quality of life (USEPA 1999).

In 2003 the U.S. Environmental Protection Agency (USEPA) published a *Framework for Cumulative Risk Assessment*, another guidance document, ''to address all

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the risks or considerations that are needed to adequately inform community decisions'' (USEPA 2003). The document is intended as a platform for future science and policies, recognizing that in many instances risk assessment decisions must be made ''*whether or not the methods or data currently exist to adequately analyze or evaluate those aspects of the assessment*.'' (Emphasis in the original.) The authors are explicit about the need to make risk-based decisions regardless of the ''limitations of current science'' (USEPA 2003).

Since at least the mid-nineteenth century, scientists have tried to comprehend the cumulative impacts of human activities (Marsh 1865; Vogt 1948; SCEP 1970; Goudie 1981). However, only in recent years has attention focused on the failure of the modern risk-based regulatory system to prevent cumulative harm (Travis 1991; Guth 2008; Harremoës 2002; NRC 2009; European Environment Agency 2013). Under the risk-based system, regulators try to calculate the probability that an action, considered in isolation, will result in a specified level of harm to humans (and, sometimes, to ecosystems). If the calculated probability falls below some threshold defined as ''acceptable,'' (say, one cancer in 100,000 individuals exposed for a lifetime) then the action itself is deemed acceptable. As Joseph Guth and others have shown, this approach is based on the tacit (and incorrect) assumption that ecosystems and human populations can tolerate an endless accumulation of innumerable ''acceptable'' insults (Guth 2008; Travis 1991).

In recognition that traditional risk-based approaches have failed to prevent substantial harm (Silbergeld 1993; Montague 2004), in 2009 the National Academy of Sciences recommended a new approach to decision making: instead of calculating the probability of a specified level of harm from an action, the Academy recommended first examining alternative ways to avoid or reduce harm from an action. Then the probability of harm from each alternative could be assessed and compared, to minimize harm (NRC 2009). This embodies a precautionary approach—examining alternatives (including the alternative of doing nothing) to find the least harmful (O'Brien 2000). To date, this new approach has not been widely adopted.

Despite these scientific and regulatory hurdles, environmental justice advocates have pressed for action to understand, mitigate, and prevent cumulative impacts of multiple stressors (Environmental Justice Advisory Committee 2003; NEJAC 2004; Cal/EPA 2014; Morello-Frosch et al. 2002; Pastor et al. 2013). Here we describe some new tools developed by communities, policymakers, and regulators for assessment and decision making while regulatory science tries to catch up with the complex experience of environmental justice communities.

## THE CUMULATIVE IMPACTS WORKING GROUP

In 2010 the Collaborative on Health and the Environment (<http://www.healthandenvironment.org>) and the Science and Environmental Health Network (<http://www.sehn.org>) embarked on a project to examine cumulative impacts on three levels: ecological, community, and individual health. We began by convening a working group of academics, government agency staff, and representatives from nonprofit non-governmental organizations who are addressing cumulative impacts at one or more levels. We then created a cumulative impacts repository (<http://www.cumulativeimpacts.org>), a library of emerging information on all three levels, highlighting relationships among them.

After three years, we observe that considerable progress has been achieved in understanding and assessing cumulative impacts on health and disease on the level of the individual and to some extent the community. The field of environmental health continues to document a complex web of interdependent factors at the root of the most prevalent chronic diseases including cancer, diabetes, cardiovascular disease, obesity, and various neurodevelopmental and neurodegenerative diseases, among others (Schettler 2006). These findings cannot be addressed solely at the individual level, and have led to innovative public health interventions at the community and national levels. There has also been considerable progress in analyzing social and environmental burdens at the community level.

## ANALYTICAL TOOLS FOR CUMULATIVE IMPACTS

A first step in preventing further cumulative impacts is to understand the conditions into which a new stressor (or new relief from a stressor) may be introduced. Inventorying existing conditions is a common first step in both understanding and acting upon any cumulative impacts problem. We present three types of tools that rely on indexes or maps, and sometimes a combination of the two, which are particularly helpful for assessing and addressing community-level cumulative impacts.

### *Indexes*

By definition, an index is an indicator or measure of something. It is then not surprising that several cumulative impacts tools are called indexes. Following are indexes that pertain to various geographic areas:

The Resilience Capacity Index (<http://brr.berkeley.edu/rci/data/ranking>) measures social and economic barriers to health and then scores and ranks 361 metropolitan regions in the U.S. The scores combine a variety of data on economic indicators (e.g., income equality, industrial diversification, housing costs), socio-demographic indicators (poverty, disability, educational attainment) and indicators of community connectivity (how civically active a region's residents are as expressed by voter participation rates, homeownership, organizational density, and metropolitan stability.) While health information is not included in this index, it can be used to estimate a region's capacity to weather acute and chronic stressors ranging from gradual economic decline to rapid population gains, earthquakes, and floods (Foster 2011).

The Green City Index (<http://www.cumulativeimpacts.org/documents/northamerican-gci-report-e.pdf>) is another score and rank approach comparing the environmental

performance of over 120 cities worldwide (e.g., well above average, below average). The index includes 27 major U.S. and Canadian cities, evaluating nine categories of data including $CO_2$ emissions and waste management, energy and land use, the efficiency of buildings, transportation, air and water quality, conservation efforts, and environmental governance. Publicly accessible quantitative data are incorporated with less publicly available, qualitative information on policies in each city. Best practices from each city are profiled in detail and the index is intended to help city leaders learn from each other's experiences (Wander 2011).

The ''Health Matters'' database in San Francisco (<http://www.sfhip.org/index.php>) allows a close look at communities in the San Francisco area, defined by zip code, compared to all counties in California. Rather than a combined ranking, individual scores for particular indicators in a community are shown color-coded (green is good, red not, yellow in between). However, health matters links to a Community Need Index (<http://assets.thehcn.net/content/sites/sanfrancisco/San_Francisco_CNI.pdf>) that scores and ranks areas by need (low to high) on a variety of measures. The Community Need Index (CNI) (<http://www.dignityhealth.org/Who_We_Are/Community_Health/STGSS044508>), created in 2005 by Catholic Healthcare West, is based on a scoring system to rank geographic areas by the severity of barriers to health (related to income, language, education, insurance, and housing). These same scores can then be compared with hospital admission rates for disease outcomes including pneumonia, asthma, and congestive heart failure. Not surprisingly, there is a high correlation between structural, social and economic barriers to care, and hospitalization rates. The CNI is the first standardized index to identify the severity of health disparity for every zip code in the U.S., and the results are used to target community benefits resources (Catholic Healthcare West 2005). A mapping component of the index facilitates public use.

### *Maps*

Maps have been used as community assessment tools in the United States and the United Kingdom since the nineteenth century, most often to display poverty levels and environmental conditions, and to advocate for change (Smith and Miller 2013). Freely available online mapping tools (e.g., Google Earth, Google Maps) and the more frequent use of Geographic Information Systems (GIS) have increased the potential for maps to be powerful public health tools. GIS is used in a diversity of settings and studies to visualize data, including multiple layers of data that can be used to identify disproportionately burdened populations (CDFI Fund 2012; Gao et al. 2008; Gunier et al. 2001; Krieger et al. 2003; Leete et al. 2012; Lefer et al. 2008; Maclachlan et al. 2007; Miranda et al. 2013; Richards et al. 1999; Siegel et al. 1997; Theseira 2002).

The USEPA's website, EnviroMapper with Envirofacts, provides access to several USEPA databases of information about reported activities that may affect air, water, and land. For example, users can generate maps of cities and towns, and also include locations of schools, hospitals, watersheds, and congressional districts (USEPA 2011). The USEPA's EJView website, formerly known as the Environmental Justice Geographic Assessment Tool, allows users to create maps using a variety of data sets including demographic, health, environmental, and facility-level data (USEPA 2010). These data, along with data provided by the U.S. National Library of Medicine TOXMAP (<http://toxmap.nlm.nih.gov/toxmap/main/index.jsp>) (USNLM 2012), have been incorporated into other mapping tools that enable users to view two or more data layers combined. One such example is the Massachusetts Health and Environment Information System (MassHEIS, <http://library.silentspring.org/heis/quickstart.asp>), created by the Silent Spring Institute, which also allows users to view data on multiple cancers (including cancers associated with chemical exposures) and asthma hospitalizations.

### *Combined approaches*

Several online systems have combined scores, ranks and mapping methods into a single tool. After several years of development (Alexeeff 2010), California EPA recently released its Communities Environmental Health Screening Tool: CalEnviroScreen Version 2.0, or ''CalEnviroScreen 2.0'' for short, described as ''a screening methodology that can be used to help identify California communities that are disproportionately burdened by multiple sources of pollution'' (Faust et al. 2014). The system allows users to compare environmental conditions by census tract throughout California (<http://oehha.ca.gov/ej/ces2.html>). In 2009, the New Jersey Department of Environmental Protection began to develop a comparable mapping system intended to identify overburdened neighborhoods but as of May 2014 the system had not been made public (Anderson 2012). Other such efforts at the city and state levels include Philadelphia NeighborhoodBase (<http://cml.upenn.edu/nbase>), Florida CHARTS (<http://www.floridacharts.com/>) and the South Carolina Community Assessment Network (SCAN, <http://scangis.dhec.sc.gov/scan/>).

USEPA's Community-Focused Exposure and Risk Screening Tool (C-FERST) (<http://www.epa.gov/heasd/c-ferst/>) performs functions similar to the California CNI method (Geller, Schultz, and Zartarian 2012), as does the Healthy Development Measurement Tool (<http://www.thehdmt.org/>), developed by the San Francisco Department of Public Health. The latter is a comprehensive evaluation metric to consider health needs in urban development plans and projects in the context of over 100 indicators of social, environmental, and economic conditions; a ''healthy development'' checklist; and a menu of policies and design strategies (Bhatia et al. 2007). Geller et al. from the USEPA (2012) describe why ''screening'' is critical: ''It helps to identify community environmental health issues, incorporating the latest research on the science of estimating human exposure to toxic substances in the environment…[and

make] informed, cost-effective decisions for taking action to improve public health.''

## CUMULATIVE SOLUTIONS

Regulatory agencies are rarely equipped to address cumulative impacts, although the agencies that do tackle the problem are blazing trails in the field of cumulative impact assessment. The 2008 Minnesota Legislature, for example, passed a law requiring the Minnesota Pollution Control Agency to analyze and consider ''cumulative levels and effects of past and current pollution,'' before a permit may be issued for a facility located in a specific area of South Minneapolis (Minnesota Legislature 2013). However, given that many agencies lack a mandate, money, or authority to address cumulative impacts once they are identified, communities are taking matters into their own hands, finding innovative solutions to cumulative impacts. These non-regulatory solutions are replicable, giving people ways to say yes to things that enhance their community rather than binding them to a regulatory agency's decisions. These best practices are crosscutting and reduce harm at multiple levels: individual, community, and ecosystem. We have observed three predominant areas of focus where communities leverage such solutions, each of which we summarize with examples.

### *Food and agriculture practices*

From schools to urban lots to prisons, people everywhere are realizing the power of growing their own vegetables. The Edible Schoolyard Project, founded in 1995 by the chef Alice Waters at the Martin Luther King, Jr. Middle School in Berkeley, CA, has expanded to six other schools and community centers nationwide and linked up with projects in countries including New Zealand, China, and Denmark (Elterman 2012). The aim is to gather and share the lessons and best practices of school gardens, kitchens, and lunch programs worldwide in the hope of supporting new start-up gardens around the globe. The creators hope to democratize edible education and make it accessible to all communities regardless of available resources. Chicago Botanic Garden's Windy City Harvest program operates a boot camp garden at Cook County jail, providing instruction and a certificate in sustainable horticulture and urban agriculture in partnership with the City Colleges of Chicago (Terry 2011). Other urban agricultural efforts such as the for-profit gardens program in Cleveland (Sterpka 2009) and the Flint area farms run by a local karate school (Runk 2009) transform vacant lots and foreclosed property into verdant gardens that help bring fresh produce to neighborhoods where fresh food can be scarce.

According to Harvie et al. (2011) from the Food System and Public Health Work Team of the Healthy Eating Research National Program Office, Robert Wood Johnson Foundation, ''Seemingly disparate issues, obesity and other diet-related disorders, climate change, and the healthcare sector share a variety of linkages, and at the nexus is our current industrial agriculture-food complex.'' Their report, *Common Drivers Common Solutions: Chronic Disease, Climate Change, Nutrition and Agriculture*, concludes that drivers of climate change and chronic diseases could be addressed through changes to our food and agriculture system and associated agriculture policy (Harvie et al. 2011).

### *Greening cities and urban infrastructure*

Researchers from California to New York are accumulating evidence that community health, business success, crime rates, and general satisfaction and well-being are improved when cities choose to incorporate more green space and other eco-friendly infrastructure into neighborhoods. The Urban Long-Term Research Area (ULTRA) is a joint effort of the National Science Foundation and the U.S. Forest Service to understand the nation's cities, home to 80 percent of the population, as functioning ecosystems (Baerwald et al. 2009). Commissioned by the National Recreation and Park Association (NRPA), five scientific monographs (<http://www.nrpa.org/2010researchpapers/>) were released on October 28, 2010 describing the broad and fundamental benefits of parks and recreation for local communities. They focus on: stimulating physical activity, youth development, alleviating stress and reducing crime, improving air quality, and measuring the economic impact of park and recreation services (National Recreation and Park Association 2010). ''The payoff for investing in public parks and recreation sites may be healthier, more physically fit residents and a less strained health care system,'' Penn State researchers stated in a 2010 study (Godbey and Mowen 2010).

The Los Angeles ''green zone'' plan is aimed at low-income, high-pollution areas. According to city planners, ''toxic hot spots,'' such as Pacoima, Boyle Heights, and Wilmington, will get incentives to attract clean industries while polluters will be targeted with tougher inspections and enforcement (Sahagun 2011). The city launched a Cleanup/Greenup website (<http://cleanupgreenup.wordpress.com/>) detailing their efforts and successes (City of Los Angeles 2012).

Idea-sharing resources such as the Best Practices website of Green Cities California (GCC) (<http://www.greencitiescalifornia.org/>) and two websites developed by the University of Washington, Green Cities: Good Health (<http://depts.washington.edu/hhwb/Thm_Place.html>; Wolf 2011) and Human Dimensions of Urban Forestry and Urban Greening (<http://www.naturewithin.info/>; Wolf 2012) are making easily accessible, groundbreaking environmental policies adaptable to other communities (GCC 2012). From bike lanes and micro wind turbines to pneumatic garbage collection and green roofs, there are innumerable ways to ensure ''cities are part of the environmental solution instead of being a part of the problem'' (Karlenzig 2010).

### *Obesity reduction and healthy aging*

A direct correlation between health and physical activity, good nutrition, and a clean environment is indisputable. Researchers are asking how communities can capitalize on

infrastructure to promote these goals. The light rail system in Charlotte, North Carolina was shown to have actually reduced obesity in a 2010 study that explored the effect of light rail transit on body mass index and physical activity. (MacDonald, et al. 2010) Funded by the Centers for Disease Control and Prevention, a three-year environmental change intervention challenged students to ''Eat Smart and Play Hard.'' The program succeeded in preventing obesity among culturally diverse, high-risk, early-elementary school children (Economos 2005).

The USEPA Aging Initiative has published a wealth of presentations (<http://www.epa.gov/aging/publications.htm>) on links between aging, the environment, and health (USEPA 2012), such as the *Growing Smarter, Living Healthier: A Guide to Smart Growth and Active Aging* (<http://www.epa.gov/aging/bhc/guide.htm>), which addresses the basic principles of ''age-friendly'' neighborhoods and town designs that are healthier for people of all ages and the environment (USEPA 2009).

## CONCLUSION

The difficulty of assessing cumulative impacts, characterized by considerable scientific uncertainty, calls for precautionary approaches to prevent and reduce harm. Heeding early warnings, setting goals, looking for better alternatives, and reversing the burden of proof—all elements of precautionary approaches—are logical steps to address cumulative impacts (European Environment Agency 2013).

Similar approaches apply to cumulative risk assessment. The National Research Council's report, *Science and Decisions,* recommends involving the community early and often, beginning with problem formulation, identifying hazards, and looking for ways to reduce harm early in the process rather than waiting for final results of complicated risk assessments before trying to manage risks (NRC 2009; Janssen et al. 2012).

More and more communities are seeking ways to prevent and reduce cumulative impacts. Individual health, community resilience, and ecological integrity represent different aspects of the problem of cumulative impacts and leverage points for addressing them. They also overlap and affect each other. Together they create opportunities for new, precautionary decision structures and initiatives aimed at reducing cumulative harm.

## ACKNOWLEDGMENTS

The authors thank Nancy J. Myers.

## AUTHOR DISCLOSURE STATEMENT

The authors have no conflicts of interest or financial ties to disclose. Carolyn Raffensperger and Peter Montague were supported by the Science and Environmental Health Network. Madeleine Kangsen Scammell was partially supported by National Center for Environmental Research (NCER) STAR Program, EPA grant number RD83458201.

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