S.A.P.I.EN.S

8.1 (2015)
Vol.8 / n°1

Rodolfo Andres Hernandez

Prevention and Control of Air Pollution in China: A Research Agenda for Science and Technology Studies

Electronic reference
Rodolfo Andres Hernandez, « Prevention and Control of Air Pollution in China: A Research Agenda for Science and Technology Studies », *S.A.P.I.EN.S* [Online], 8.1 | 2015, Online since 15 December 2015, connection on 15 January 2016. URL : http://sapiens.revues.org/1734

Publisher: Institut Veolia Environnement
http://sapiens.revues.org
http://www.revues.org

Document available online on: http://sapiens.revues.org/1734
This document is a facsimile of the print edition.

INSTITUT
Veolia Environnement

S.A.P.I.EN.S
Volume 8 issue 1 2015

Perspectives

Prevention and Control of Air Pollution in China: A Research Agenda for Science and Technology Studies

Rodolfo Andres Hernandez

RAH, Institute of Science, Technology and Society,
Tsinghua University, Beijing 100084, China,
Correspondence address:
Room 246, Building Mingzhai, Tsinghua University, Beijing 100084, China,
Email : adr12@mails.tsinghua.edu.cn

Abstract

China's air pollution has reached a critical state, and is characterized by heavy coal smoke and a wide presence of ozone and particulate matter (PM2.5). From 2011, through the 12th five year plan, the prevention and control of air pollution entered a new 'transition stage' guided by the principles of sustainability and energy conservation, and also intensified by pressure from the society. This article is divided into two parts: first, it introduces the most important changes, problems and advances during this transition, including a brief explanation of the policy mechanisms. Second, it illustrates how research in the area of Science and Technology Studies (STS) can bring about new ways to understand the problems of the knowledge-policy and public engagement of air pollution in China.

Keywords: air pollution, China, 12th FYP, Science and Technology Studies, STS

TABLE OF CONTENTS

Published: 15 december 2015
Edited by: Nicolas Renard. This manuscript was reviewed by two anonymous referees.

1. INTRODUCTION

In recent years, China's air pollution has attracted the world's attention for the images of its main cities shrouded in haze and heavy smog. In fact, a recent official report[1] shows that in 2014, only 8 of 74 cities monitored by China's Ministry of Environmental Protection met air quality standards.

The origins of China's modern air pollution problem can be linked to the "Reform and Open Policy" of 1978, which introduced a new era of rapid and ambitious economic development. During more than three decades, continued economic growth has been accomplished at the expense of an excessive use of energy that has placed an enormous burden on the ecological system (Fang *et al.*, 2009).

Parallel to the evolution of its economic policy, China's environmental governance, and more specifically, its air pollution management, were adopted in the decade of the 1970s and have since been continuously updated. Large reforms on the modernization of environmental protection institutions, the standards to control pollutants, and the work on legal framework, among others, have expressed the will of the central government to advance in the prevention and control of air pollution (PCAP). More recently, the 12th Five-Year Plan (FYP) of 2011-2015, which sets out both economic and political guidelines, represents a change of vision regarding environmental pollution as a problem related to the entire system (Wong & Buckley, 2015). A call has been made for a "new development model and a new green governance approach" (He *et al.*, 2012). Accordingly, PCAP has been reoriented during these transitional years, and much of the scope of the policy measures are still under 'improvement phase' (Feng & Liao, in press).

With this transition in mind, the country is today dealing with economic and energy reforms to address the environmental problems and the demands of a new middle-urban class. In part, these reforms demand multiple roles, including: China being a key actor of climate change, seeing as it is the world's largest emitter of carbon dioxide (CO_2)[2]; as a developing country that heavily relies on fossil fuel (where coal represents about 70% of primary energy production and consumption (IEA, 2009); and as a market economy society, where new circumstances, such as private car ownership, have created the major sources of air pollution in the largest cities (MEP, 2013).

Contemporary research about the topic has focused on policy approach (Lin & Elder, 2014; He *et al.*, 2012), legal framework (Feng & Liao, in press; Alford & Liebman, 2001), energy (Li & Wang, 2012), and the use of models to interpret pollution data (Wang *et al.*, 2014). However, little attention has been placed on how knowledge about air pollution is transformed to policy, and how different communities interact in the governance process. This is interesting, because the popularization of the internet and mobile devices has facilitated the dissemination of information regarding air pollution (Kay *et al.*, 2014). Furthermore, it is not a secret that academic communities have been supportive of this process, and have relied on independent data and peer review work in order to check and balance the official approach (Ho & Nielsen, 2013).

This article has a dual purpose: to introduce the main changes in China's PCAP, and to propose a research agenda that places the knowledge-policy disconnect and the role of public engagement at the center of the discussion. While the former is based on policy analysis from the fields of law, policy, and environmental engineering, the latter has developed from the discipline of Science and Technology Studies (STS) concerning environmental governance and policy.

2. PREVENTION AND CONTROL: AIR POLLUTION IN CHINA

In the 1970s, China adopted a modern management of environmental problems, which was modeled on the approaches of the western world. Since the country's participation in the Stockholm Conference on the Human Environment in 1972, the "management of the physical environment has evolved from a focus on eliminating existing pollution to preventing it all together [*sic*]» (He *et al.*, 2012 :29).

China's PCAP is illustrative of this evolution which, according to Feng and Liao (in press), passed through three phases: beginning (1979-1999), development (2000-2013) and improvement (2014-present). The 'beginning phase' was characterized by efforts to situate PCAP in the legal system. Both the Environmental Protection Law of 1979 (trial version) and the Air Pollution Prevention and Control Law (1987) stipulated general provisions and guidelines for supervision and management. During the 'development phase', initiatives such as 'Two Control Zones', which involved "a region ... affected by high sulfur dioxide (SO_2) concentrations and/or acid rain, and a system to collect emission fees from all polluters" (Feng & Liao, in press: 5), attempted to move towards a more regulated and realistic regional approach. The 'improvement phase' (2014-present), represents a turn in the governance of air pollution, becoming strengthen after national episodes of high PM2.5 in 2013 (Feng & Liao, in press: 5). The most notorious initiative until now has been the amendment of the Environmental Protection Law 2015 (EPL), a decision which was postponed for years. According to Qin (2015) the new EPL introduced changes in "almost every major article, after passing through three separate hearings and doubling in length from its original version". Although it is too soon to assess its effects on the overall PCAP, EPL is "perceived as the most progressive and stringent law in the history of environmental protection in China" (Zhang & Cao, 2015: 433).

1 MEP news release, 2nd February 2015: "MEP releases air quality status of key regions and 74 cities in 2014. MEP website." URL: http://english.mep.gov.cn/News_service/news_release/201502/t20150209_295638.htm

2 Retrieved on October 26, 2015 from http://www.wri.org//blog/2014/05/history-carbon-dioxide-emissions

2.1 PCAP POLICY FRAMEWORK

PCAP policy frameworks in China are constituted of laws, standards, regulations and action plans. Five-Year Plans (FYPs) are especially relevant for the definition of guidelines for economic and social policy, including environmental protection.

Specifically regarding air pollution, some "FYPs mandate overall directions for the revision of laws, regulations, standards, and other measures and instruments for air pollution" (Lin & Elder, 2014: 15). Before the 12th FYP in 2012, some of the most crucial initiatives promulgated included: Prevention and Control of Atmospheric Pollution Law (1987, 1995, 2000), the National Ambient Air Quality Standards (GB3095-1996) and the Emission Standards of Air Pollutants for Thermal Power Plants (GB13223-2003) (Chan & Yao, 2008).

In general terms, the execution of the policy framework is the responsibility of the Ministry of Environmental Protection (MEP) and the local Environmental Protection Bureaus (EPBs) in different jurisdictions. Other ministries and agencies (*e.g.*, Ministry of Science and Technology) have specific roles when the policy incorporates varied aspects such as energy, industry, and technology.

2.2 AIR QUALITY LEGISLATION

In China, the legal framework has different levels in which the National People's Congress has the main role of producing laws. It corresponds to the State Council and the ministries to formulate policies, regulations and standards that usually guide the provincial and local governments.

The main national laws directly concerning PCAP are: the Environmental Protection Law (2015), the Air Pollution Prevention and Control Law (2015), the Environmental Impact Assessment Law (2003), the Law on Promoting Clean Production (2012), and the Energy Conservation Law (2007). It is important to note that the Air Pollution Prevention and Control Law has followed a long path to become the principal guiding law in the area today. Promulgated in 1987, the Air Pollution Prevention and Control Law contributed to the reduction in concentration of total suspended particulates (TSP) (Florig *et al.,* 2002). It was later revised in 1995 and amended in 2000 (Alford & Liebman, 2001) to aid the reduction of SO_2 and provide mechanisms to control cross-boundary pollution (Wang *et al.*, 2014). Finally, after fifteen years of political indecision, the law has been updated to support the changes in the 12th FYP.

2.3 AIR QUALITY MONITORING

In the 1980s, China established a national air quality monitoring system divided into national- and local-level networks. Both networks share common features, such as the type of stations, namely: i—monitoring, ii—assessment, iii—control, and iv—background.

In 2000, monitoring data was linked to the Air Pollution Index (API), which read the concentration of SO_2, nitrogen dioxide (NO_2), and particulate matter (PM10) in 42 cities. The API was classified in the following grades: industrial, urban, and natural (Wan & Patdu, 2013).

Since 2012, an hourly and daily Air Quality Index (AQI) was introduced, which for the first time reported PM2.5. In that year, a regional air quality management system paved the way to address transboundary pollution between provinces (Lin & Elder, 2014:10).

3. PROBLEMS

3.1 PARTICULATE MATTER CONTROL

Coarse and fine particulate matter (PM10 and PM2.5 respectively) are particles 30 to 100 times thinner than a human hair, and are found in the air, often in the forms of dust, dirt, soot, smoke, and liquid droplets[3]. PM2.5 poses a greater risk to humans because they can penetrate deeply into the lungs, and are associated with lung cancer, cardiovascular, and respiratory diseases.

Because China has one of the highest PM concentrations in the world, it has quickly become a matter of urgency. Recent evidence has shown that about 1.2 million premature deaths were linked to air pollution (Wong, 2013b). Moreover, a shorter life expectancy and higher rates of mortality are associated with exposure to PM, as documented in several studies (Chen *et al.*, 2013) and global reports (Yang *et al.*, 2013).

At present, many experts have demonstrated that the complexity of PCAP in China is related to the control of PM2.5. In contrast to 'primary pollutants' (SO_2 or nitrogen oxides [NO_X]), which are emitted from a specific source, PM is a secondary, non-point-source pollutant. Thus, PM can interact with other elements including energy structures, climatic conditions, and living habits across the nation (Fang *et al.*, 2009). Also, due to the association of PM2.5 with "mixing pollutants from coal combustion, vehicular emissions and biomass burning" (ibid.: 81), the management employs various administrative levels, industrial and socio-economic sectors.

During the 2000s, PCAP focused on primary pollutants, which led to a reduction in the average concentrations of SO_2 and NO_2 (Fig. 1). There are a number of scientific and political explanations for this. On the one hand, there was a grounded understanding of the physical and chemical behavior of these types of pollutants. On the other hand, any attempts to regulate or control emissions were facilitated by the association of the emitter and its geographical location. The command and control approach, which was the most common type of pollution management, permitted the control of primary pollutants under the official plans.

3 Retrieved on October 2 2015 from: http://www3.epa.gov/pmdesignations/faq.htm

Since the 2000s, PM control has been depicted in two different ways. At the time, the only available data related to PM10, which in fact showed a significant reduction (Fig. 1). As Ho and Nielsen (2013) explain, the average concentration above 95 μg/m^3 (micrograms per cubic meter) was still very high compared to the WHO recommendations for developing countries of a sequence of 'interim' annual average targets of 70, 50 and 30 μg/m^3 (WHO, 2006 in Ho & Nielsen, 2013). On the other hand, PM2.5 data began to be publicly released from 2011, and 74 cities have since been tracked under a trial program to update the standards of air quality. To date, only eight cities have been in compliance[4], and almost half of the cities reported unhealthy average concentrations (Fig. 2).

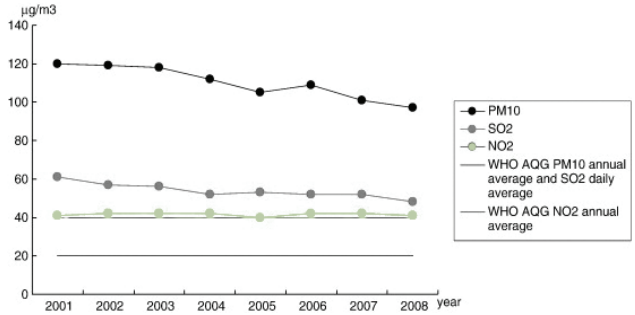

Figure 1. Ambient air pollution levels in 31 provincial capitals of China (μg/m3, 2001–2008) - (Kan *et al.*, 2012).

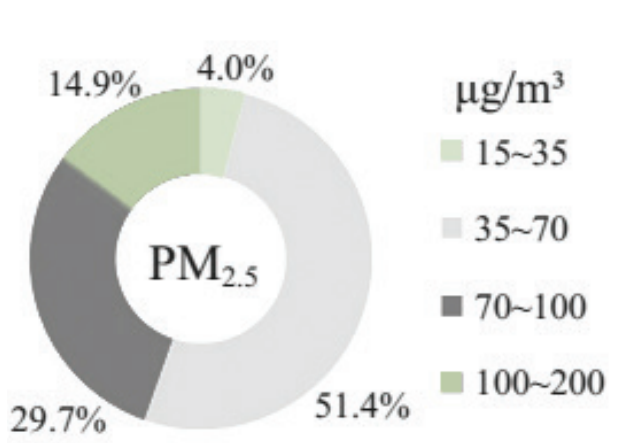

Figure 2. Concentrations of PM2.5 and PM10 in 74 cities for the year 2013 - (MEP, 2013)

3.2 DATA

Despite the developments of air quality management over recent years, China still faces problems related to: a—the use and dissemination of information, b—the link between air quality management data and policy making, and c—the credibility of data. Mol describes China's as an "information poor" environment (Mol, 2008), characterized by "inconsistencies in the available monitoring systems and technical capacity; political factors that limit information flows and processes; and institutional and organizational constraints that hamper information collection, processing, and dissemination" (Mol, 2009 in Hsu *et al.*, 2012: 40).

In 2012, the public release of a new AQI highlighted the existing data management problems. Over the years, data collection has been undertaken by monitoring departments without history databases (Wan & Patdu, 2013). It is challenging for not only the public, but also the scientific community and policy makers to access, use, and understand a broader spectrum of air pollution. Moreover, the links between data and PCAP policies were less efficient than expected. According to Wan and Patdu:

"Raw monitoring data, emission inventories, air pollutant concentrations, potential health impacts, and source control measures are not particularly useful unless translated into judgments on comparative advantage, or raised in the context of socio-political trends." (ibid.: 25)

The credibility of data, as various authors explain, constitutes a threat to both the official plans and also to making an urgent decision regarding health policy (Wen & Gu, 2012; Chen *et al.*, 2011). Common practices includes altering data (Andrews, 2008), changing the position of monitoring stations, or producing bias statistics (Ghanem & Zhang, 2014) could all undermine the scope of present plans.

3.3 ADVANCING IN PUBLIC PARTICIPATION AND MEDIA COVERAGE

From the 2000s, Chinese media started covering environmental issues with a varying degree of independence (Wong, 2013a). The public also has canalized their concerns through online social networks. For the government, the participation of the new actors represents a challenge. In general terms, policies and legislation such as the Open Government Information regulations of 2008 and the EPL 2015 have extended the rights of society and NGOs to participate in the environmental governance and obtain environmental information; however, it has been made clear that if their activity harms the economy, social stability, or state secrets, then punitive measures will be taken.

Two examples illustrate the contradictions. In 2011, the Beijing government started publicly reporting an API, in the same way as the US embassy had been doing for over three years with its own index. The readings showed obvious differences; Beijing's were frequently lower than those of the U.S., lacking a description of the health effects. Online citizens expressed their distrust and criticisms of the Beijing index. The issue spurred a diplomatic protest from China, but soon after the government advanced the adoption of a new standard (GB 3095-2012), adopting a similar index to the U.S. Embassy.

The second example occurred in February 2015, when journalist Jing Chai released her independent documentary 'Under the Dome'[5] online. This work was the result of years of reports about the most accurate problems facing China's air pollution management. After a few days, the video had received more than 200 million views, leading the minister

4 MEP news release, 2nd February 2015: "MEP releases air quality status of key regions and 74 cities in 2014. MEP website." URL: http://english.mep.gov.cn/News_service/news_release/201502/t20150209_295638.htm

5 Original title "Qióng dĐng zhĐ xi"; released on 28th February 2015.

of environmental protection to compare it to Rachel Carson's 'Silent Spring' (1962). Such national attention was considered dangerous for some sectors of the government, and the video was removed and banned until the present.

4. IMPROVEMENTS

Paradoxically, China's advances in PCAP are part of the problem. Experts have expressed concern about the strategies to control airborne pollutants (Wang *et al.*, 2010), the disclosure of information (Mol, 2009), and the adoption of cross-boundary and interregional management (Lin & Elder, 2014). Although there are key steps to a new governance of PCAP, however, all plans are currently under construction, with a view to accomplishing them in the long-term.

There is a consensus that the advances have been accelerated with the 12th FYP, which inaugurated a period of transition (He *et al.*, 2012) and improvement (Feng & Liao, in press). For instance, the inter-regional plans have been instrumental in coping with the transboundary character of PM2.5 and ozone (O_3) (Lin & Elder, 2014). This innovation, introduced in the Air Pollution Prevention and Control in Key Regions of 2012, incorporates the lessons from the 10th and 11th FYPs.

The 12th FYP also implemented the National Ambient Air Quality Standards (NAAQS), which have a mandatory PM2.5 standard in 74 cities (GB 3095-2012), and the public reports of Air Quality Index (AQI). An AQI logs hourly and daily values of six pollutants (SO_2, NO_2, CO, O_3, PM10, and PM2.5) and their associated health risks, which were not present in the previous version (API).

Two more initiatives, namely, the Total Emission Control Program, which sets energy policies and targets, and the Air Pollution Prevention and Control Action Plan (2013), which strengthens the implementation of the 12th FYP, are significant for this new era in management (Lin & Elder, 2014).

5. DISCUSSION: PCAP FROM AN STS PERSPECTIVE

One of the central research topics in the field of science and technology studies (STS) is the intersection between environmental policy, scientific knowledge, and public engagement[6]. The body of research includes environmental modeling, innovative institutions (*e.g.* the Intergovernmental Panel on Climate Change), political ecology, and environmental management and research, among others (Yearley, 2008). Air pollution has also brought specific attention to the works of Jasanoff (1990), Yearley (2006) and Lidskog and Sundqvist (2011). This section proposes two specific research agendas based on the main questions that these authors have previously discussed regarding the scientific knowledge-policy problem and public engagement. Due to a lack of research about the topic in PCAP in China, I suggest some questions as a form to apply to the understanding of its evolution and the transition witnessed from the 12th FYP, all of which are described in this article.

5.1 CHINA'S PCAP AS A KNOWLEDGE-POLICY ISSUE

STS studies on environmental policy are motivated by the fact that some of the ideals of science (independency, objectivity, authoritative) are undermined or transformed when entering into the democratic stage of decision making. This concern poses some questions to similar debates in the policy studies arena, where a normative approach is expected (Haas & Stevens, 2011; Funtowiczs & Ravetz, 1991). A classic explanation of how policy and knowledge can merge together was offered by Sabatier (1987), through the framework that considers different levels of the government involved in policy changes, and how different actors and knowledge are integrated. In this framework, changes occur over long time periods, and can be seen through different actors and "subsystems" of values, beliefs and coalitions.

Based on STS research, China's air pollution governance could be viewed as the result of the interaction between knowledge and public policy, opening a new way to understand PCAP evolution. Until now, the main focus of PCAP research in China has been on legal and policy areas, which offer a substantial but also 'fixed' position about its evolution based on policy momentums. China is still shown as both a successful and unfinished case with regard to the application of Western policy and technical recipes for PCAP.

With this in mind, STS research can help to explain the political rationales regarding knowledge and the scientific community in China's PCAP. At a basic level, the reason is that STS understands the relation of science and government as being political. Knowledge for policy purposes is never 'pure' in the sense of directly meeting the needs of policy makers. This has been demonstrated by recent research on the policy–knowledge interface that explains the dynamic process of policy making and the diversity of knowledge producers (Jones *et al.*, 2013). From the STS corner, Jasanoff (2004) quoted the term "co-production" to indicate how scientific knowledge within policy agendas configures the social order. The process implies that scientists provide content to (some) decisions in policy making, while decision-makers then validate (or reject) this knowledge to solve specific social problems. In the interaction, it is not always scientists who provide evidence-based assessment (Juntti *et al.*, 2009; Shackley & Wynne, 1996), but they also rely on their position, informal judgement (Collins in Sundqvist *et al.*, 2015), and values (Elliot, 2011; Douglas, 2009).

China's scientific community has always been part of the PCAP policy advisor framework, however, from the period of the Beijing Summer Olympics of 2008, their contribution has gone beyond the formal channels of traditional policy making in China. Before 2008, scientists were asked to provide research, models, and data to legitimize or readdress policy decisions.

6 Recently, these kinds of debate have provoked cross-disciplinary research problems, including works from environmental sociology, social theory, and the philosophy of science. For a comprehensive review see Evans & Collins (2008).

After 2008, the contribution of peer-review research based on universal values of science has been the key to developing 'independent' evidence that views official data with objectivity (Ho & Nielsen, 2013). One example is the application of satellite observation to estimate PM2.5, to address the problems inherent in gathering data in a country like China (van Donkelaar *et al.,* 2010). The new position of scientists, however, does not undermine the previous role (to legitimize and readdress policy decision) but rather adds a new angle, one of independence. Timidly but increasingly, non-governmental initiatives such as the Clean Air Alliance of China, which groups together experts in air pollution, are becoming crucial in creating a sense of community that interacts with policy makers through the traditional political channels, but also adding peer review and scientific research as tools of participation.

Jasanoff's (1990) work on the role of scientists as political agents and researchers explains some of the contradictions when scientific activity is carried out for policy making. During the 1970s, scientific advisors of the U.S. regulatory policy of air quality found themselves mixed up in political decisions that undermined their research assessment. Whitehead (2009) on UK air pollution control complements the idea of governance based on scientific knowledge, and is guiding in a broader sense. The author provides a history of the relationship between atmospheric science and the State, where air pollution governance is constructed from a scientific basis.

In that order of ideas, a first agenda of STS concerning PCAP could be explaining how scientific knowledge has contributed to the construction of a specific type of governance of air pollution in China. As in both the works of Jasanoff and Whitehead, specific directions might be expected when applying this type of research to China's PCAP. For instance, which role does China assign to scientists at different stages of the PCAP policy? Which types of practice legitimize their role, and which undermine the government's legitimacy?

5.2 PCAP AND PUBLIC ENGAGEMENT

The second topic of the research agenda concerns the public engagement to PCAP in China. As described earlier in this article, the role of the public and the media has become both essential and problematic when challenging the official position on air pollution, especially where data bias and poor management have arisen. From the side of STS, in general, the study cases occur in democratic settings, and the question about 'which role should the engaged public have', is not as important as 'the methods that should be used to capture the public's contribution' (Yearley, 2011). China's case is apparently different.

First, China's public is an entity that does not operate legitimately in opposition to the government, or at least is not recognized officially as such. Although in previous years the number of demonstrations on environmental problems has increased (Gardner, 2014), they seldom become a movement and are usually dissipated either through police force or governmental solutions. The potential of air pollution as a threat to social instability is an open official concern (Wong & Buckley, 2015), though not a response to social participation. Secondly, the initiatives on air pollution have become less sound and mediatic, seemingly after the government updated the Air Quality Index and established monitoring stations in most of the cities.

A research agenda from STS should consider the elements connected to China's political and social system, but also the triggers that contribute to citizens engaging in the problem, including the practices and tools they use. The example of the US Embassy in Beijing provides a clue to the type of sound participation that is preferred in main cities and urban classes (Huang, 2015). The interest in using online social networks arises from transparency, data accuracy, and health effects. NGOs such as Green Beagle and Friends of Nature, both based in Beijing, have integrated this approach, supporting citizen science to understand and appropriate the language of science on air pollution. At some point, there were small initiatives to construct independent monitoring data, but it soon became known that the government would possibly condemn this.

In this regard, a successful STS approach should be critically applied to China's example. Before exploring whether the public could become a peer-review of environmental (scientific) knowledge (Funtowicz & Ravetz, 1991), there should be some consideration about what constitutes the public in China, with regards to the PCAP. A clue of how this has taken form is to explore the fact that in other latitudes, the skepticism on data was resolved. As an example, in the 1990s, at an early stage of the implementation of air quality monitoring stations in the U.K. (Yearley, 2006; 2011), there was a strong connection to the kinds of questions, concerns and tools that people embraced. China's recent outrage through online participation highlighted that the 'timid citizen science' approach has the potential to explain the governance of air pollution at different levels.

References

Alford, W.P. & B. Liebman (2001). Clean air, clear processes? The struggle over air pollution law in the People's Republic of China. Hastings Law Journal 52 (3): 703-748.

Andrews, S.Q. (2008). Inconsistencies in air quality metrics: 'Blue Sky' days and PM10 concentrations in Beijing. Environmental Research Letters 3(3): 1-14.

Chan, C. & X. Yao (2008). Air pollution in mega cities in China. Atmospheric Environment 42: 1–42.

Chen, B., H. Kan, R. Chen, S. Jiang & C. Hong (2011). Air pollution and health studies in China—policy implications. Journal of the Air & Waste Management Association 61(11): 1292–1299.

Chen, Z., J. Wang, G. Ma & Y. S. Zhang (2013). China tackles the health effects of air pollution. The Lancet 382 (9909): 1959–1960.

Douglas, H. (2009). Science, Policy and the Value-Free Ideal (1st Ed.). Pittsburgh: University of Pittsburgh Press.

Elliot, K. (2011). Is a Little Pollution Good For You? Incorporating Societal Values in Environmental Research. New York: Oxford University Press.

Evans, R. & H. Collins (2008). Expertise: from attribute to attribution and back again? In: Hackett, E., O. Amstersdamska, M. Lynch & J. Wajcman (Eds.) The Handbook of Science and Technology Studies, pp.609–630. Cambridge, MA: MIT Press.

Fang, M., C. Chan & X. Yao (2009). Managing air quality in a rapidly developing nation: China. Atmospheric Environment 43: 79–86.

Feng, L. & W. Liao (in press). Legislation, plans, and policies for prevention and control of air pollution in China: achievements, challenges, and improvements. Journal of Cleaner Production: 1-10.

Florig, H.K., G. Sun & G. Song (2002). Evolution of particulate regulation in China-- prospects and challenges of exposure-based control. Chemosphere 49: 1163-1174.

Funtowicz, S. & J. Ravetz (1991). A new scientific methodology for global environmental issues. In: Costanza, R. (Ed.) Ecological Economics: The Science and Management of Sustainability, pp.137-52. New York: Columbia University Press.

Gardner, D (2014, 15 September). China's environmental awakening. New York Times. Retrieved from: http://www.nytimes.com/2014/09/15/opinion/chinas-environmental-awakening.html?_r=0

Ghanem, D. & J. Zhang (2014). 'Effortless perfection:' do Chinese cities manipulate air pollution data? Journal of Environmental Economics and Management: 68(2): 203–225.

Haas, P. & C. Stevens (2011). Organized science, usable knowledge, and multilateral environmental governance. In: Lidskog, R. & G. Sundqvist (Eds.) Governing the Air. The Dynamics of Science, Policy, and Citizen Interaction, pp.125-61. Cambridge, MA: The MIT Press.

He, G., Y. Lu, A. Mol & T. Beckers (2012). Changes and challenges: China's environmental management in transition. Environmental Development 3: 25-38.

Ho, M. & C. Nielsen (2013). Clearer Skies Over China. Reconciling Air Quality, Climate, and Economic Goals. London, Cambridge (MA): The MIT Press.

Hsu, A., A. de Sherbinin & H Shi (2012). Seeking truth from facts: The challenge of environmental indicator development in China. Environmental Development 3: 39-51.

Huang, G. (2015). PM2.5 opened a door to public participation addressing environmental challenges in China. Environmental Pollution 197: 313–315.

IEA [International Energy Agency] (2009). Cleaner Coal in China. Paris, France: OECD/IEA. URL: https://www.iea.org/publications/freepublications/publication/coal_china2009.pdf

Jasanoff, S. (1990). The Fifth Branch. Science Advisers as Policy makers. Cambridge, MA: Harvard University Press.

Jasanoff, S. (Ed.) (2004). States of Knowledge: The Co-Production of Science and Social Order. London: Routledge.

Jones, H. *et al.* (2013). Knowledge, Policy and Power in International Development: A Practical Framework for Improving Policy, Background Note. London: ODI.

Juntti, M., D. Russel & J. Turnpenny (2009). Evidence, politics and power in public policy for the environment. Environmental Science & Policy 12(3), 207–215.

Kan, H., R. Chen & S. Tong (2012). Ambient air pollution, climate change, and population health in China. Environment International 42: 10–19.

Kay, S., B. Zhao & D. Sui (2014). Can social media clear the air? A case study of the air pollution problem in Chinese cities. The Professional Geographer 67(3): 351-63. DOI: 10.1080/00330124.2014.970838

Li, J. & X. Wang (2012). Energy and climate policy in China's twelfth five-year plan: A paradigm shift. Energy Policy 41: 519-528.

Lidskog, R. & G. Sundqvist (2011). Governing the Air: The Dynamics of Science, Policy, and Citizen Interaction. Cambridge, MA: MIT Press.

Lin, X. & M. Elder (2014). Major Developments in China's National Air Pollution Policies in the Early 12th FiveÐYear Plan (No. 2013-02). Institute for Global Environmental Strategies (IGES). Retrieved from http://pub.iges.or.jp/modules/envirolib/view.php?docid=4954

MEP [Ministry of Environmental Protection] (2013). Report on the state of the environment in China 2013. Chinese version: zhongguo huanjing zhuangkuang gongbao 2013. Ministry of Environmental Protection of People's Republic of China. URL: http://www.mep.gov.cn/gkml/hbb/qt/201407/W020140707500480541425.pdf

Mol, A. (2009). Urban environmental governance innovations in China. Current Opinion in Environmental Sustainability 1: 96-100.

Mol, A. (2008). Environmental Reform in the Information

Age: The Contours of Informational Governance. Cambridge: Cambridge University Press

Qin, L. (2015, 4th September). China's new Air Pollution Law omits key measures in war on smog. China Dialogue. Retrieved from: https://www.chinadialogue.net/article/show/single/en/8156-China-s-new-Air-Pollution-Law-omits-key-measures-in-war-on-smog

Sabatier, P. (1987). Knowledge, policy-oriented learning, and policy change. An advocacy coalition framework. Science Communication 8(4): 649-692.

Shackley, S. & B. Wynne (1996). Representing uncertainty in global climate change science and policy: boundary-ordering devices and authority. Science, Technology, & Human Values 21(3): 275-302.

Sundqvist, G., I. Bohlin, E. Hermansen & S. Yearley (2015). Formalization and separation: A systematic basis for interpreting approaches to summarizing science for climate policy. Social Studies of Science 45(3): 416-440.

van Donkelaar, A. *et al.* (2010). Global estimates of ambient fine particulate matter concentrations from satellite-based aerosol optical depth: development and application. Environmental Health Perspectives 118(6): 847-855.

Wan W. & K. Patdu (2013). A new era in air quality monitoring in China. Asian Environmental Technology: 24–25.

Wang, L. *et al.* (2010). Assessment of air quality benefits from national air pollution control policies in China. Part I: Background, emission scenarios and evaluation of meteorological predictions. Atmospheric Environment 44(28): 3442–3448.

Wang, S. *et al.* (2014). Effectiveness of national air pollution control policies on the air quality in metropolitan areas of China. Journal of Environmental Sciences 26(1): 13–22.

Wen, M. & D. Gu (2012). Air pollution shortens life expectancy and health expectancy for older adults: the case of China. Journals of Gerontology: Medical Sciences 67(11): 1219–1229.

Whitehead, M. (2009). State, Science and the Skies: Governmentalities of the British Atmosphere. Oxford: Wiley-Blackwell.

Wong, E. (2013a, January 15). China lets media report on air pollution crisis. New York Times, p. A.6. New York, N.Y..

Wong, E. (2013b, April 2). Early Deaths Linked to China's Air Pollution Totaled 1.2 Million in 2010. New York Times, p. A.9. New York, N.Y.

Wong, E. & C. Buckley (2015, March 15). Chinese Premier Vows Tougher Regulation on Air Pollution. New York Times, p. A8. New York, N.Y..

Yang, G. *et al.* (2013). Rapid health transition in China, 1990-2010: findings from the Global Burden of Disease Study 2010. The Lancet 381 (9882): 1987–2015.

Yearley, S. (2006). Bridging the science-policy divide in urban air-quality management: evaluating ways to make models more robust through public engagement. Environment and Planning C: Government and Policy 24: 701–714.

Yearley, S (2008). Nature and the environment in Science and Technology Studies. In: Hackett, E., O. Amstersdamska, M. Lynch & J. Wajcman (Eds.) The Handbook of Science and Technology Studies, pp.921–948. Cambridge, MA: MIT Press.

Yearley, S. (2011). Citizen engagement with the politics of air quality: lessons for social theory, science studies, and environmental sociology. In: Lidskog, R. & G. Sundqvist (Eds.) Governing the Air. The Dynamics of Science, Policy, and Citizen Interaction, pp.253–271. Cambridge, MA: The MIT Press.

Zhang, B. & C. Cao (2015). Policy: Four gaps in China's new environmental law. Nature (Comment) 517: 433–434. Retrieved from: http://www.nature.com/news/policy-four-gaps-in-china-s-new-environmental-law-1.16736