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Database Green: Software, Environmentalism and Data Flows in China

Matteo Tarantino* and Basile Zimmermann†

Abstract
Significant efforts towards environmental transparency have been made by the Chinese government since 2008. This paper focuses on the technical decisions shaping a database of official pollution information built and operated by a Chinese NGO known as the Institute of Public and Environmental Affairs (IPE). Issues of standardization, power distribution and institutional fragmentation are discussed. The paper illustrates a case of NGOs integrating enforcement capabilities as data centres amidst the growing reliance on processes of informational governance of environmental issues.

Keywords: pollution; environment; information disclosure; China; software; database; standards; NGOs; IPE

The challenges to the environment presented by China's economic development have been extensively studied in recent decades. Among the main aspects discussed is the role of governmental and non-governmental actors regarding regulatory applicability, enforcement, compliance incentives and litigation mechanisms.[1] Particular attention has been paid to the relationship between the central Ministry of Environmental Protection (MEP) and the local contexts where environmental degradation takes place. Local environmental protection bureaus (EPBs) (*huanbaoju* 环保局) are tied to local interests by their economic dependence on governmental structures which privilege economic development over environmental protection. Their work is also impacted by a lack of autonomy.[2] Countervailing policies by the central government have been questioned in terms of efficacy and participation.[3] In a similar way, the capacity of NGOs to fill in institutional gaps has been questioned because of limitations regarding autonomy and scope of action.[4]

In this broad context, software-based technology is involved at the data collection, dissemination and policymaking levels, where it plays an increasingly central role. Since 2004, state, regional or local "key state-monitored enterprises" (KSME) have been asked to install real-time pollution-monitoring technologies to communicate their emission data to EPBs.[5] Since the 2007 Regulations on Open Government Information[6] and the 2008 Environmental Information Disclosure Decree[7] were brought into force, the central government has been pushing for increased information transparency from local governments by means of Internet-based disclosure.[8] In parallel, the government has also been urging local EPBs to interact with concerned citizens through Weibo 微博, a popular Chinese micro-blogging platform, and it has encouraged the use of air quality indexes (AQI) calculated by software and disseminated through websites and mobile applications. Software-based pollution-forecast tools using big-data approaches are being utilized by institutions such as the municipal government in Beijing.

While the examples listed above have been analysed in the literature in terms of stakeholders, implications and impacts,[9] less attention has been paid to the tools and systems used by the social actors involved in environmental protection. Owing to the sociotechnical specificity of software, the choices embedded within it and the

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constraints it implies have mostly been rendered invisible, inaccessible ("black-boxed") or taken for granted by scholars; this attitude is a core preoccupation for the discipline of software studies.[10]

The project behind this study, undertaken at the University of Geneva, aims to approach environmental protection in China from the perspective of software tools in the context of their use by the Institute for Public and Environmental Affairs (IPE) (*Gongzhong Huanjing Yanjiu Zhongxin* 公众环境研究中心), a well-known environmental NGO. It also attempts to demonstrate the value of studying software artefacts to inform the reading of broader social processes in China.[11]

Data and Method

The project relies on the broad approach of science and technology studies (STS), which treats software as a technical object shaped by various sorts of constraints, as well as by its inventors and users' representations and practices.[12] Drawing from the social construction of technology and the actor-network theory approaches, the analysis focuses on the dichotomy between "human entities" (such as users, producers, policymakers, business owners, environmental officials and activists) and "non-human entities" (software, hardware, databases, computers, mobile phones, rivers, legal texts, etc.) to question the design of technological systems in the IPE's activities in China. We are especially interested in, and hope to contribute to, current theoretical debates in STS about the so-called "materiality of the digital."[13]

In order to reconstruct the relationships between these entities, the project uses an ethnographic approach. This entailed (in the first phase) six months of participant observation of the IPE's day-to-day activities, which involved attending meetings, partaking in non-core tasks (such as editing reports and consulting on specific projects), conducting repeated non-structured and semi-structured interviews with IPE staff and other informants (programmers, officials, members of other NGOs, etc.), and analysing pertinent materials including design documents, sketches, reports, internal communications, source code, databases, content published on the IPE's Weixin (微信, a social media platform also known as Wechat) and Weibo accounts, and press coverage about the IPE.

This paper illustrates some preliminary findings from the first half of the project (June 2014 to November 2015) and focuses on a specific piece of software at the heart of the IPE's activities: its database.

The IPE and its Software System

Founded in 2005 and chaired by Chinese environmental activist Ma Jun 马军, the IPE is headquartered in Beijing and currently works on collecting, disclosing and disseminating information about polluting companies in China. It does so by geo-referencing these companies and rendering this information available to the general public through a website and a mobile application. The IPE's income comes from both Chinese and foreign private foundations including, for instance, the Beijing-based Society of Entrepreneurs & Ecology, the Alibaba Foundation, and the Rockefeller Foundation. As of January 2016, it employed 28 people full-time, making it one of the largest and best-known environmental NGOs in China.

The mission of the IPE fits within the "regulation by revelation" paradigm, or what Arthur Mol describes as "informational environmental governance,"[14] whereby "standard regulatory practices […] are complemented or partly replaced by new informational dynamics in which other non-state actors play a significant role."[15] In the case of the IPE, the NGO complements the regulations of the People's Republic of

China by making environmental violations more visible, thereby increasing social and political pressure on companies to abide by the law.

The lynchpin of the IPE's disclosure activities is an online, dynamic map, launched in 2006, that charts the sources of pollution. The IPE's founders and members believe that the visual perception of the proximity of an environmental risk, through a map of one's own country with pollution issues made visible, can be an impetus for taking action against it. The choices of the Internet and cartography are motivated by ambitions of large-scale accessibility where the target audience is the general public in China.

This vision is powered by a system known as the pollution map (*wuran ditu* 污染地图). It includes a website, a mobile application (app) and social media accounts. Along with a map of environmental violation data (see below for a description), the website includes search pages to access a database, along with indexes ranking transparency performances of cities (PITI index) and brands (CITI index), which are intended to put pressure on local governments and international brands, respectively. Information is also packaged in periodic bilingual reports about specific sectors (for example, IT or textile) or brands (for example, Apple Inc.). The website also includes an encyclopaedia of environmental information and a limited set of functions for user reporting of environmental incidents.

In 2014, the IPE decided to develop a mobile app in order to facilitate access to its data and reach a larger audience. The app relies on real-time emission data from KSMEs, along with maps on air and water quality and environmental information. It includes a photographic function that overlays geo-localized environmental information (such as air quality) relating to the place where the pictures are taken.

Since 2012, interaction with users has mostly been conducted through Weibo. Through its own official account as well as through Ma Jun's account, the IPE publishes and discusses data on polluting factories, news about rectification efforts, and also re-tweets users' reports and institutional reports as well as communications from factories and brands. Since 2015, the IPE has also relied on Weixin to circulate original articles.

Among these functions and features, the IPE's database plays a central role by providing the data that will be visualized on maps, packaged in articles and reports, fed into indexes, and tabulated into webpages. Since the beginning, pertinent data have been collected, formatted and adapted into a specific software form. In the following short case study, we concentrate on the designing, building, maintaining and feeding of this database.

Case Study and Discussion

Throughout its evolution, the IPE's database has gathered a broad variety of data. For clarity, we divide the data into four families: data about environmental violations, based on official records released by EPBs; real-time data on KSME emissions, released hourly by provincial EPBs; data about individual factories, including self-reported emissions, past history and supply-chain data (i.e. whether the factory forms part of a specific brand's supply chains); and data about general environmental quality (air and water). In this discussion, we focus on the first and second families.

Violation data

From the beginning, the IPE made the decision to avoid user-generated data for its database. Most of the information is collected from official sources, which helps the IPE to minimize contentiousness with both polluters and institutions. The core data come from local EPBs, which are obliged to disclose data about environmental violations since the 2002 Cleaner Production Promotion Law.

Among the problems inherent in Chinese environmental disclosure, a common denominator can be found in the lack of enforced standards regulating what kind of data should be disclosed under what circumstances and through which procedures.[16] EPBs release dissimilar amounts of data with different timings, and because their disclosure platforms are non-standardized, access to the data requires different procedures for each website. Such variations make the IPE's task of collecting complete data very challenging. For example, EPB websites are designed in different ways, requiring the user to follow different navigation paths to access the same kind of data (for example, reports of violations).[17] Moreover, data are usually released as printouts within EPB websites or as discrete downloadable documents, which are technically much more difficult to collect than by going through direct connections to online databases.

Further obstacles include the lack of consistency in the reported data. Across different violation records, the same factory names are sometimes spelled differently. This problem often occurs when Chinese characters are transcribed into pinyin, a format on which the IPE relies to allow foreign companies (one of the IPE's main targets) to access its database.

The IPE has dealt with this diverse, irregular dataflow through a manual data-formatting operation. Currently, a division is tasked with the repetitive task of scanning EPB websites, downloading new reports as they are issued, processing them into the proper format, and feeding them into the database.

Although there have been discussions within the IPE about automating this task through the production of "crawlers" (automatic software machines programmed to seek and recover specific online data), the number of pertinent EPB websites (30 provincial and 330 prefecture-level EPBs, generating a total of 4,000–5,000 entries per month), their updates (crawlers need to be reprogrammed to account for changes on websites they are designed to crawl), and the intricacy of their architecture (sometimes the pertinent data are nested inside the website in a way that makes them inaccessible or inconvenient for crawlers, for example, by dispersing data through multiple pages instead of having a single-page list) have discouraged the move to rely on automatic software.

The location of the polluters proved to be an even more challenging problem. The pollution map soon evolved from a custom-made Macromedia Flash-powered index map of China (where the users could click on a province to access a localized list of polluters) (Figure 1) into a dynamic map pinpointing the location of polluters, powered by the external providers Google, Baidu, and Gaode, thus conveying more information through density and proximity. All of these providers need an accurate location, either in the form of GPS coordinates or as an address which their geo-referencing functions can convert into coordinates.

However, the IPE cannot access the exact geo-coordinates of factories, as they are not required information for EPB records. Moreover, the addresses of most of the factories in EPB records cannot be easily converted into coordinates, as some records feature only the name of the village or the county. Sometimes, a new road is built in

order to house a factory and is reported as the address, but the geo-translation functions of map providers cannot process this address because it does not feature in the national road maps. As a result of the lack of standardization in the public geographical information about factories, only a fraction of the polluters in the database can actually be shown on the map.

The IPE has established a procedure to deal with such constraints by enrolling local volunteers to act as location sensors through the use of mobile phones. Individuals take a picture of a factory's insignia and send it to the IPE through Weibo or the mobile app. As smartphones can add coordinates to pictures, the photo can then be processed by the IT staff at the IPE, and the company's record can be updated with proper location coordinates. This is complicated by China's reliance on GCJ-2, an encrypted geo-coordinate standard, which considerably offsets the users' position for security reasons (authorized map providers can correct this offset through an algorithm licensed by the government). Furthermore, to work with the IPE's Baidu-based website maps, coordinates have to be converted into Baidu's own BD-09 standard. To reduce errors, further manual conversions and corrections are entered by IPE personnel.

Overall, the IPE has acknowledged that catching up with the ever-increasing inflow of violation data might prove impossible with such a resource-intensive procedure. An appropriate technical solution has yet to be found.

Figure 1: **IPE Website Maps**

Notes: Since the IPE's website maps moved from static (November 2007, top; screenshot from a cached copy of the website) to dynamic (October 2014, bottom) to maximise "risk perception," the localization of factories has become more important, as now each individual polluter should be visible on the map.

Real-time data

The second type of data in the IPE database is hourly data on the water and air emissions of KSMEs. These data come from sensors installed by factories on their chimneys or wastewater discharges and have been collected since 2004. Since January 2014, the Measures on Self-monitoring and Information Disclosure for Key State-monitored Enterprises have tasked provincial-level EPBs with disclosing such data to the public. Some features of the data are common: results are updated hourly and unsearchable, and no historical series is offered. However, owing again to the lack of shared standards for information disclosure, each province has designed a different online platform. In order to deal with this situation, the IPE has built and updates and maintains 30 different software crawlers to get the hourly data.

In other words, although forced by the 2004 and 2008 laws to disclose information, design choices by the local EPBs can still impede the IPE gaining access. For instance, the infrastructures of some EPBs appear to include network "blacklists" that prevent specific technical entities, including sometimes the IPE's crawlers, from accessing their data. Another technical difficulty occurs when the data are split among multiple pages. The IPE's crawlers have long wait times between two consecutive data requests, thus making the time needed to get all of the data too long and possibly

causing a connection failure. In addition, the EPBs' website layouts change regularly, further complicating the path to reach the necessary data.

Owing to the number of people and machines involved and the complexity of the overall process, it is difficult to know without further research the reasons for such moves by local-level EPBs. Frequent changes and updates of formats, as well as variations among structures with similar needs but without standardization coming from a shared resource (here it would be the state), are a known part of the process of the development of such infrastructures before they reach a technical momentum.[18]

In the absence of any official communication between the IPE staff and the EPBs, when coincidences occur they sometimes make people wonder if design choices could be related to specific interests. For instance, in 2015 a provincial EPB encrypted its data in such a way that it had the immediate effect of blocking the IPE's crawlers. This important design change occurred following the release of the successful documentary on Chinese pollution, *Qiongding zhi xia* 穹顶之下 (*Under the Dome*), which featured the IPE's mobile app. Downloads of the IPE's app increased by 700 per cent in two days, arguably boosting the potential visibility of certain provinces and possibly motivating the encryption. Following the encryption, the EPB's data inflow was blocked, which effectively erased it from the IPE's map. However, after a few weeks, the IPE developed an ad-hoc crawler that was able to work around the limitation, thus restoring the region's visibility, and the data are now displayed as before.

Such technical hurdles do not contravene the EPBs' mandate to disclose environmental data but do force the IPE to undergo costly, weekly revisions of its data-collecting mechanisms. Conversely, some provincial EPBs allow for easier data access by means of APIs (libraries to access data) or easily parseable output formats such as the JSON format.

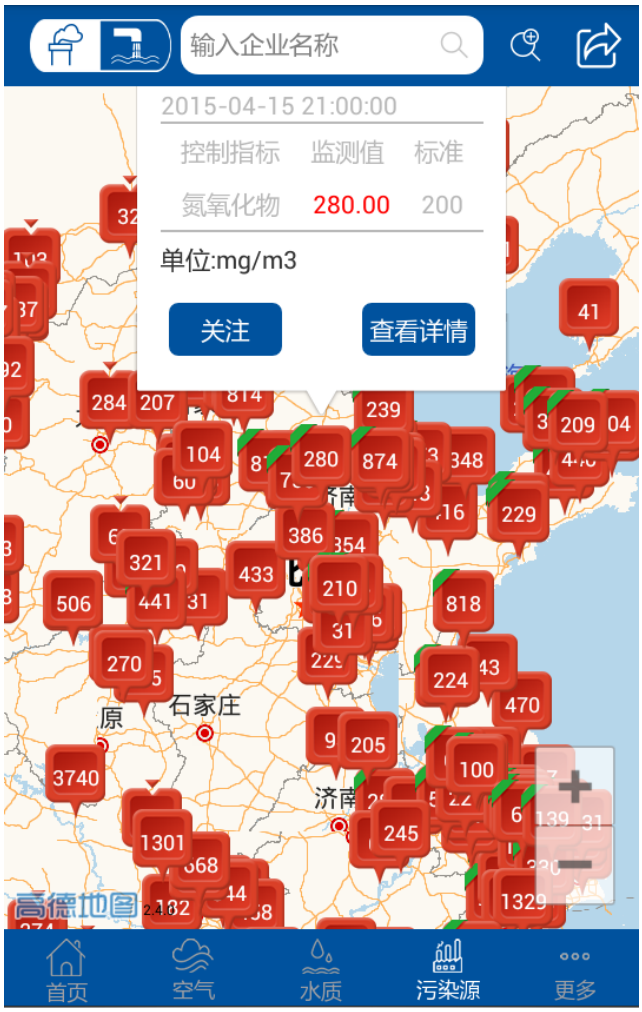
From a methodological and theoretical perspective, technical choices in software design reveal social actors' technical resources as well as potential political relationships, interests and strategies. Changes in these relationships, as reflected in technical choices, are communicated through the logs of crawlers and can be analysed; failures by crawlers to collect data, which appear in logs as error messages, communicate changes in the infrastructure. Even when they are not officially verbalized, they may signal a change in the EPB's infrastructure and/or its attitude toward other entities. Conversely, EPBs can check their server logs to find traces of the activity of the IPE's crawling robots (which can also be tuned to be more aggressive, for example by increasing the frequency of data requests) and attempt to stop or limit this activity. The toing-and-froing between parties shapes all of the involved software objects: crawlers, data flows, databases, filters, websites, etc.

Data assembled by the IPE through its crawling system acquire at the database level an added value of comparability.[19] That is, the data become searchable along both the spatial and temporal dimensions, allowing one to trace emission performances over time for entities such as single factories, districts and regions. Cross-territorial and temporal comparisons thus become possible. This increases the data's relevance, as the data acquire the capacity to expose factories that continue to exceed regional emission standards for significant amounts of time without measures being taken by the pertinent authorities. According to IPE staff, this aspect makes some regional EPBs uneasy at times; however, since their resistance might hinder its work, the IPE always pays special attention to maintaining good relationships with the EPBs where possible.

The IPE's design choices for the disclosure of such data often reflect these perceived tensions with the EPBs, as the limits perceived by the IPE of what it can do are inscribed in the technical choices it makes for data disclosure. For example, the aggregated real-time data are released not as numerical tables (as found on individual regional platforms) but through a map (Figure 2) integrated in the mobile app. This map shows the real-time emission data of KSMEs, indicating in red boxes those that exceed regional pollution standards. Although explicit inter-provincial comparison functions are not offered, the concentration of red icons can be read as an indicator of regional performances. Moreover, those KSMEs whose emissions fall within regional standards can only be seen by zooming into the map. The temporal dimension is partially integrated by including a countdown to the deadline given by EPBs (or through a self-pledge) to polluting factories. While not leveraging the full critical potential of the collected data, these design choices are an attempt to retain the impact of the data for the general public while striking a compromise with other stakeholders.[20]

According to the IPE, its design choices in data disclosure have played an important part in gaining the trust of core institutions. As of 2016, the IPE enjoyed significant support and backing from the Ministry of Environmental Protection, and the organization is more and more frequently called upon for consultation during legislative drafts. An egregious example is the above-mentioned 2014 Measures on Self-monitoring, which followed a 2013 "Total transparency initiative" campaign calling precisely for the kind of disclosure promoted by the IPE and 22 other associations. Besides, as of March 2016, the IPE and MEP are directly cooperating on educational initiatives for the promotion of information disclosure. The IPE's ability to supplement and augment the MEP's enforcement capabilities and the MEP's ability to legitimize the IPE's work vis-à-vis local resistance appear to be the key factors behind this synergy.

Figure 2: **The Mobile App Map (Version 2, 2015)**



Notes: KSMEs whose emissions exceed pollution limits are in numbered boxes. A diagonal band across the top left corner indicates that the factory has been issued with a deadline to curb its emissions. The textbox shows emission data (centre) and deadlines for corrections (top) about a factory.

Conclusions

The attempts of the Chinese central government to foster environmental transparency pivot on software for the collection, management and disclosure of information. At the same time, China's institutional decentralization informs the lack of centralized standards of disclosure, thus enabling the space and autonomy for local actors to choose and enact their own software design choices. This forces social actors involved in information disclosure to articulate complex data-gathering and data-curation efforts that can in turn be facilitated or counteracted at the human and non-human levels by the other involved parties. The software of the IPE and other parties reflects these dynamics in ways that are often not explicitly communicated among the stakeholders but which become comprehensible once design and infrastructural choices are unpacked.

This shows promising developments for software-centred studies on Chinese environmental dynamics, and more generally for the role of software studies within the broader field of Sinology.

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Basile Zimmermann is assistant professor in Chinese studies at the University of Geneva, Switzerland. He is the author of *Waves and Forms: Electronic Music Devices and Computer Encodings in China* (MIT Press, Inside Technology, 2015). His current research projects focus on China studies' methodology and science and technology studies.

摘要：自 2008 年始，中国政府为使环境信息透明做出了巨大的努力。这篇论文主要研究一个官方污染信息数据库的技术发展，以及其信息公开渠道。这个数据库由一个名为"公众环境研究中心"的中国民间组织建立和管理。 此文讨论了标准化、权力分配和机构分割问题。这篇文章论证了民间组织弥补环境制度化执行的可行性；以及在对环境问题"信息管理"重要性增加过程中非政府组织如何作为数据中心获得新的能动力量。

关键词：污染; 环境; 信息公开; 软件; 数据库; 标准化; 民间组织; 公众环境研究中心

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[1] Dasgupta et al. 2001; Wang et al. 2003; Economy 2007; 2011; Lin 2013.

[2] Dasgupta et al. 2001; Lo and Fryxell 2003; Wang et al. 2003; OECD 2006; Economy 2011; He et al. 2013.

[3] For example, Zhu et al. 2015.

[4] Knup 1997; Ho 2001; Schwartz 2004; Yang 2005.

[5] The MEP releases an annual list of key state-monitored enterprises (*Guojia zhongdian jiankong qiye mingdan*), which contains names and identification codes for polluters emitting beyond certain thresholds.

[6] State Council 2007.

[7] Zhang et al. 2010.

[8] Ibid.

[9] Mol 2009; Zhang et al. 2010; Johnson 2011; Mol, He and Zhang 2011; Mol 2014.

[10] Fuller 2008.

[11] Website analysis in China: The China Pollution Map of the Institute of Public and Environmental Affairs (CHIPOMAP) is led by Basile Zimmermann and hosted by the Confucius Institute at the University of Geneva, Switzerland. The project is run in collaboration with Christine Leuenberger (Cornell University, US), Valérie November (LATTS/Ecole des Ponts ParisTech, France), and Li Lulu (Renmin University, China). For details about the research, contact CHIPOMAP's principal investigator, Matteo Tarantino.

[12] Pinch and Bijker 1984; Akrich 1992; Bijker, Hughes and Pinch 2012.

[13] Callon 1986; Latour 1992; Law and Mol 1995; Law 2009. On the materiality of the digital, see Herzogenrath 2015 and the forthcoming *Digital STS Handbook* edited by David Ribes, Janet Vertesi and Morana Alac (Updates on the project can be found at: http://digitalsts.net).

[14] Mol 2008.

[15] Zhang et al. 2010, 1650.

[16] Mol 2009; Zhang et al. 2010; Johnson 2011.

[17] Mol, He and Zhang (2011) also comment on the complicated design of these websites.

[18] See Meyer and Schroeder 2015 for examples of similar technical issues.

[19] Dingwerth and Eichinger 2010.

[20] Historical series have been included in the new version of IPE's website, released in late 2016, signalling a new change in the political climate and IPE's stronger bargaining position (arguably thanks to the backing of players such as the MEP). Also, in February 2016, a new version of the mobile app was released. Our research project's next steps will account for these innovations.