Information behaviors at the edge of reason: the role of uncertainty, science, and culture on environmental policy

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ABSTRACT
We all expect government agencies to use high quality evidence when creating public policy; however, in a democratic society, cultural values also play a role. For example Europe and America have different policies with respect to genetically modified foods and nuclear energy. Our goal is to explore information behaviors that surround the process of transforming scientific evidence into public policy in order to uncover where (and how) cultural values might be embedded. We analyzed more than a thousand citations from three scientific reviews that were conducted by scientists based in the EU and US on di(2-ethylhexyl) phthalate (DEHP), a plastic softener that is controversial because of potential impacts for industry and public health. Our analysis suggests that culture may influence public policy by establishing the initial scope of a review, by determining which evidence should be included, and by framing how evidence is presented.

Keywords
Information behavior, science policy, information use.

INTRODUCTION
We all expect public policy to be based on the best available scientific evidence. In some countries the use of evidence is legally mandated, such as in the US Safe Drinking Water Act that states “… the Administrator shall use (i) the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices; and (ii) data collected by accepted methods or best available methods ….”

The key challenge in setting public policy about chemical exposure is that ethical reasons prevent us from exposing someone to a potentially harmful chemical in order to determine definitively if the chemical is harmful. In the absence of a controlled experiment, evidence from animal and epidemiological studies are used to estimate risk. In a legal setting this is best captured in the precautionary principal that states: “Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.” ("Rio Declaration on Environment and Development," 1992).

Even if evidence was perfect and complete, people who live in a democracy can influence public policy. For example a recent review of the Integrated Risk Information System (IRIS) program at the US Environmental Protection Agency (EPA) states that “public input and peer review as integral parts of the IRIS process” (NRC, 2014, p4).

Our goal in this paper is to explore information behaviors against this backdrop of uncertainty as science and culture meld to form public policy (see Figure 1). We present a case study of a plastic softener called di(2-ethylhexyl) phthalate (DEHP), that has been prohibited from toys, but further controls has been proposed (and then withdrawn) from policy makers and scientists in the EU and US. We analyzed three DEHP reports produced by the European Chemicals Bureau, the (US national) EPA and the Californian EPA that together contain more than a thousand citations. We report the number and type of articles cited and describe our manual inspection of journal articles that are cited in both the EU and US reviews. Our results suggest that there are several potential avenues where public policy might be influenced by cultural differences.

BACKGROUND
Over the last decade, phthalates, a widely used plasticizer have prompted heated discussion about potential toxicity in humans (see Table 1). One chemical, di(2-ethylhexyl) phthalate, (DEHP) has received considerable attention because of its prevalence and thus a ban would result in large economic losses for the chemical industry.

The scope of the DEHP debate is not limited to financial interests. Tension also exists between EU scientists and EU policy makers. One report claims that the EU policy maker’s proposed ban on phthalates in toys, was surprising
and went against the opinion of its own scientific committee (CSTEE) (Callapez, 2006). Although the European Commission tasked the SCENIHR committee with formulating an opinion in order to inform the Medical Devices Directive, the Directive was passed (Sep 2007) before the Opinion was complete (Feb 2008). Lastly, opinions from EU and US scientists differ where a Danish author argued for tighter restrictions (Rank, 2005), while an American author argued that DEHP has no harm on humans (Kamrin, 2009).

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>May 2009</td>
<td>Draft recommendation that four phthalates (DEHP, DBP, BBP and DIBP) should be added to the list of priority substances that should be reviewed.</td>
</tr>
<tr>
<td>Nov 2011</td>
<td>Endocrine disruptor expert advisory group formed.</td>
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<tr>
<td>July 2012</td>
<td>Public consultation launched on SEAC (Committee for Socio-economic Analysis)’s draft opinion on restricting phthalates.</td>
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<tr>
<td>Nov 2012</td>
<td>Denmark publishes a national ban on the import and sale of products containing any of the four phthalates DEHP, DBP, BBP and DIBP at a concentration greater than 0.1% by weight.</td>
</tr>
<tr>
<td>May 2013</td>
<td>Denmark postpones the phthalates ban by 2 years.</td>
</tr>
<tr>
<td>Oct 2013</td>
<td>Scientist claim that endocrine disruptor framework “is based on virtually complete ignorance of all well-established and taught principles of pharmacology and toxicology” (Dietrich et al., 2013)</td>
</tr>
</tbody>
</table>

Table 1 - EU legislative actions concerning phthalates.

The importance and amount of debate surrounding DEHP, provides an interesting test-bed in order to explore information behaviors that surround the policy making process including how scientific articles are initially selected, how the results from individual studies are presented, and how conflicting evidence is reconciled.

**METHOD**

Figure 1 depicts the process whereby science and culture influence public policy. In this paper we focus on the first step of that process where evidence from empirical studies are collected and organized, and on potential differences in DEHP policy between Europe and America.

Three reviews were identified. The European review (EU) is a risk assessment that was commissioned by the European Union (ECB, 2008). The standard process by which chemical risk is assessed in the US is IRIS (NRC, 2014), where both carcinogenic and general effects are reported. There is a US DEHP review in IRIS for carcinogenic effects, but interestingly, no general risk assessment has been conducted. However we did locate a review (NTP, 2006) outside of IRIS that focused on human reproductive and developmental effects, which are the main health concern around DEHP. We will refer to this report as the 2006 US review. Lastly, we consider a state level review conducted by the Californian EPA (Carlisle, et al, 2009) (subsequently referred to as the CA EPA) because Californian laws tend towards providing consumers with more information about potentially hazardous chemicals than other US states.

References from each review were extracted from the pdf, and scripts were used to identify author, title, journal, and year. The total number of articles cited by each report was calculated. Journals cited in each of the US reviews and the EU review were identified and the citing text was manually inspected. We annotated the sections of the review (the citing text) that discussed the original article (the cited text) with respect to the results and evaluation of scientific study: strengths, weaknesses, utility, result, and interpretation. This scheme relates closely to earlier work that focused on core scientific concepts within an article (the hypothesis, motivation, goal, object, background, method, categories used in (Liakata & Soldatova, 2008)), how claims are reported (the explicit, implicit, comparisons, correlations and observation categories used in (Blake, 2010)), and how an article contributes to scientific knowledge (the aim, basis, background, contrast, other, and own categories used in (Teufel, et al, 1999)). We then explored the nuances between different ways the citing texts from the EU and US referred to the same cited study.

**RESULTS**

**Overall review conclusions**

The 2008 EU review does not cite recent human studies, but arrives at the same conclusion as the US reviews because the human studies are insufficient with respect to reproductive and developmental effects. In contrast, all

![Figure 1 – Process of transforming scientific evidence into public policy.](image-url)
three reviews found that there was sufficient evidence from animal studies (mainly rodents) to conclude that DEHP is a developmental and reproductive toxicant in animals.

**Number, timeframe and type of citations**

The 2008 EU risk assessment included 923 citations, the 2006 US risk assessment included 195 citations and the 2009 CA NTP included 192 citations. As shown in Figure 2, most articles cited in the 2008 EU review were published before 2000 and the most current article was published in 2004. In contrast most articles cited in the 2006 US review were used in only 50.5% of the citations from the EU review. Specifically journals were cited in 92.8% of the citations from the EPA review (181/195) and 96.8% of the citations in the CA EPA review (186/192) whereas journals were used in only 50.5% of the citations from the EU review (466/923). Instead, the EU review cited reports. The EU and the US reviews shared 17 citations and the EU review cited 6 journals in the UK while the US cited 5 UK based journals and 1 Indian journal.

In order to see if access to particular journals might explain the difference in the proportion of journals cited in the EU review, we identified the ten most frequently cited journals in the EU review (Wolfe, 2003) that was subsequently published as two NTP reports in 2004 and 2005. As shown in Figure 2, most articles cited in the 2008 EU review were published before 2000 and the most current article was published in 2004. In contrast most articles cited in the 2006 US review were used in only 50.5% of the citations from the EU review. Specifically journals were cited in 92.8% of the citations from the EPA review (181/195) and 96.8% of the citations in the CA EPA review (186/192) whereas journals were used in only 50.5% of the citations from the EU review (466/923). Instead, the EU review cited reports.

In order to see if access to particular journals might explain the difference in the proportion of journal articles cited, we identified the ten most frequently cited journals in the EU and CA EPA reviews. Both reviews cited 4 US based journals. The EU review cited 6 journals in the UK while the US cited 5 UK based journals and 1 Indian journal. Many of the frequently cited journals overlap, which suggests that access alone does not explain the lower proportion of journals cited in the EU review.

**Analysis of shared citations**

The EU and the US reviews shared 17 citations and the EU and CA EPA shared 34 citations. Examples here are drawn from either review. Tracing studies can be difficult because different articles describe the same study and different versions of the same article can be cited. For example, the EU review cited (Wolfe, 2003) that was subsequently published as two NTP reports in 2004 and 2005. The reviews evaluated each article with respect to adequacy (strengths, weaknesses and utility of the design) and the fit for purpose (useful, of some utility, of minimal utility, not useful, etc.). Although many of the EU and US assessments resulted in the same action (most often that a study would not be further considered), interpretations were often nuanced. For example US described the (Colon, et al, 2000) study as “unreliable” and “not useful” whereas the EU described it as “unclear”.

In some cases different assessments of evidence lead to different actions with respect to including or excluding a study results from further consideration. For example the US stated that the (Moore, et al, 2001) study was “not appropriate” and although the EU recognized that the study was “not statistically significant”, the EU review included the actual study result. This difference could be due to the difference in the scope (the EU review was more comprehensive) but also speaks to the role that a reviewer plays in teasing out when evidence does and doesn’t count.

In general, we found the US report more transparent with respect to articulating the rationale as to why an article was excluded. In several cases the US mentioned an article and stated explicitly that it was excluded, whereas the EU review rarely cited and then excluded an article so it was not clear if the EU reviewers identified, but excluded the study, or if they did not consider the study.

As with any review, all information from the original article cannot be included, thus it is not surprising that each review included different facts from the same study; however some of the review text initially seemed inconsistent. The most illustrative example is the no-observed-effect-level (NOEL) and lowest-observed-effect-level (LOEL), two critical data points in chemical toxicity from (Akingbemi et al., 2001).

**US**: “Leydig cells isolated from rats after DEHP treatment on PND 21 – 34 showed a decrease in basal and LH-stimulated testosterone production in vitro (LOAEL 100 mg/kg bw/day). Leydig cells isolated from rats after DEHP treatment on PND 35 – 48 displayed decreased basal and LH-stimulated testosterone production in vitro (LOAEL 10 mg/kg bw/day) and decreased activities of enzymes in the testosterone synthesis pathway." ... Leydig cells isolated from prepubertal rats that had been treated on PND 21 – 48 showed an increase in basal and LH-stimulated testosterone production with a LOAEL of 10 mg/kg bw/day ... They identified 1 mg/kg bw/day as a NOAEL in their experiments and 10 mg/kg bw/day as a LOAEL.”

**EU**: “The LOAEL for effects of DEHP on the serum concentration of testosterone in very young rats is 100 mg/kg and day”

The Akingbemi article actually reported four different studies and supports each of the LOAEL values above, but this example illustrates how even objective science requires interpretation.

After adjusting for different units, the CA EPA and EU reports still have a discrepancy (between 800 and 346) when referring to (Tsumura et al., 2001) where the US review stated that DEHP levels ranged “from 346 to 11,800 ng/g” and the EU stated that “the concentration of DEHP
was 0.8-11.8 mg/kg". Both of these statements are supported by the original article, but the EU reviewers calculated the value by combining data from a table with information from the article narrative.

CONCLUSION
Further work needs to be done to explore the impact of different articles that discuss the same study (and different versions of the same article), but our analysis thus far revealed several interesting differences between the EU and US reviews. The EU review tended to cite older and non-journal sources and the US reviews were more consistent in evaluating the study design and in providing a rationale for why a study should be excluded from further consideration.

Although the US and EU reviews both focused on DEHP, only a small proportion of journals were cited in both reviews. We attribute this in part to differences with respect to the scope of the review (the EU review is more comprehensive), which can influence policy by restricting (or allowing) certain studies to be excluded (or included). In both cases, the review scope was established by elected officials, the European Union commissioned the EU review and the US congress initiated the US review. Thus establishing the scope is the first place where culture may play a role in the process of transforming results reported in scientific literature into public policy.

The second place where culture may influence public policy is in determining the adequacy of study designs reported in the published journal articles. The US review referenced citations, even if the actual results were not further considered due to study design issues. In contrast it was not clear from the EU review if studies were specifically excluded or never considered. The third place where culture may influence subsequent policy is in deciding which of the many results from an article is included in the summary.

We observed each of the differences above, but arguably the conclusions are most important part of a review. The debate concerning DEHP continues, but all three reviews reached the same conclusion: there is insufficient evidence to determine if DEHP is harmful to humans and DEHP is a developmental and reproductive toxicant in animals.

Setting environmental policy is ultimately an information problem where the majority of the work involves collecting and organizing information. Given the potential impact on society, we hope that this poster motivates other information scientists to work towards a better understanding of the information behaviors that surround this process and to develop systems (manual, automated or both) that would help with this important activity.

ACKNOWLEDGMENTS
This research is made possible in part by a grant from the U.S. Institute of Museum and Library Services (IMLS), Laura Bush 21st Century Librarian Program Grant Number RE-05-12-0054-12 Socio-technical Data Analytics (SODA)

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