Factors that influence environmental health literacy from returning polycyclic aromatic hydrocarbon exposure results

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Abstract

Reporting personal environmental exposure data back from researchers to study participants is becoming more common, however there are few tools to assess whether report back increases environmental health literacy (EHL). This study assessed whether sociodemographic or environmental characteristics were associated with changes in EHL after receiving personal air monitoring results. This study was conducted in a New York City based pregnancy cohort wherein participants were assessed for exposure to polycyclic aromatic hydrocarbons during the third trimester of pregnancy. Participants (n = 168) received their results two to five years after participation and a subset (n = 47) completed a survey evaluating perspectives on their results and subsequent behaviors. Using these results, we created a quantitative scale of EHL, with higher scores indicative of higher EHL. We found that participants with a college degree were significantly more likely to be surprised by their results than those with less than a high school degree (OR = 5.60, p ≤ 0.05) and that higher naphthalene levels were associated with decreased odds of being surprised about receiving the results (OR = 0.37, p = 0.02). There were no observed associations between demographic or exposure characteristics and our dichotomous EHL indicator; however, those with more education and higher income tended to have higher EHL scores. Additionally, participants who reported being surprised by or glad to receive their results had higher EHL scores. Open-ended text responses indicated that while some participants felt worried after receiving their results, participants reported being glad to have received the report.

Keywords: Children, environmental health, pregnancy, report back, polycyclic aromatic hydrocarbons, United States

Introduction

Environmental health literacy (EHL) is an emerging field that combines elements from different disciplines, including health literacy, risk communication,
environmental health, communications research, and safety culture (1, 2). Building on the concept of health literacy (3), as EHL increases, it is anticipated that informed individuals can take control of their own health and be aware of how their actions may reduce exposure or mitigate risk from environmental hazards (1, 2). These are valuable skills to have in a culture that is more aware of environmental exposures and changes including climate change (4). One potential route to increase EHL is through personal exposure report back (5-8).

Personal exposure report back is intended to return a research participant’s own data and provide information about their study results. Previously, it was commonplace to return results to participants only if there was clinical guidance on the exposure levels (5). However, in the last two decades, there has been a shift towards giving participants the option to receive their results back, even in the absence of a clinical cut point (5, 9, 10). To give guidance on how best to report back personal exposure monitoring, the Silent Spring Institute developed a handbook on report back (11). It includes sections on how to get started, methods for reporting back both environmental monitoring and biomonitoring results, and evaluation of the report back. With the ethical shift regarding research participants’ right to know and a handbook on best practices, reporting back results has become more commonplace, and is now recommended (9).

At the most basic level, the return of personal results addresses a commitment to scientific transparency, as it also addresses a core element of EHL: recognition of environmental exposures. Finn and O’Fallon adapted Bloom’s taxonomy of educational objectives to environmental health knowledge, which outlines gradual steps of increased literacy around environmental health issues with concepts including recognition, understanding, application, analysis, evaluation, and creation (2). While the EHL taxonomy is a useful framework for demonstrating how individuals learn and progress in EHL, it does not provide an indicator to measure EHL.

To date, there have been few tools developed to assess EHL. Studies have looked at qualitative changes associated with return of data and seen increases (6-8), but quantitative measures are less common. Some of the current methods to measure EHL rely on concepts from health literacy, which is not necessarily the same as EHL (12-14). Our goal in this study was to determine whether sociodemographic or environmental characteristics were associated with both quantitative and qualitative changes in EHL among research participants after receiving report back on personal results.

In this study we look at a New York City based pregnancy cohort with personal chemical exposure monitoring conducted for polycyclic aromatic hydrocarbons (PAH) in the third trimester of pregnancy. The cohort comes from an urban area, is primarily Hispanic, and is often an understudied research population. Participants received their personal results back between two and five years after the monitoring was conducted. The time between participation and return of results was included as a potential predictive variable. The motivating factor for this research is to find a way to break the cycle of children’s environmental health disparities, utilizing report back to increase recognition and understanding of how environmental exposures impact health.

Methods

Pregnant individuals enrolled in the Fair Start cohort of the Columbia Center for Children’s Environmental Health (CCCEH) participated in this study. Recruitment of the Fair Start cohort began in 2013 at New York Presbyterian Ambulatory Care clinics in New York City. The cohort was established with the goal of characterizing the association between prenatal and early life environmental exposures on childhood development. Recruitment into the Fair Start Cohort remains ongoing, with a planned sample size of at least 750 participants. This study was conducted with a subset of participants that were enrolled between November 2015 through March 2019. Participants primarily reside in the neighborhoods of Northern Manhattan and the South Bronx and 90% self-identify as Hispanic, as previously described (15). As part of participation in the cohort, individuals completed prenatal visits during the third trimester of pregnancy, which included completing questionnaires.
to collect information on demographics, occupation, environmental exposures, and personal product use. Following the prenatal visit, participants wore a passive sampling silicone wristband for 48 hours, to assess their personal exposure to semi-volatile and volatile organic compounds. The wristbands were analyzed at Oregon State University for 63 PAHs.

Return of data to study participants development

Personalized reports were created for a total of 168 participants summarizing their PAH exposure, as measured by the wristbands. The report included a personalized cover letter, infographics summarizing how PAHs are generated, where they are found and ways to reduce PAH exposure. Though the wristbands measured 63 PAHs, and all data was returned, the reports focused on n = 18 PAHs, which have been identified as priority chemicals by the United States Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease Registry (ATSDR). The EPA identifies 16 PAHs as priority PAHs, operating under the rationale that these 16 are representative of environmental exposures, although this assumption has been questioned (16). The ATSDR highlighted PAHs as a chemical group on their Priority Substance list (17), with the toxicological profile for PAHs identifying 17 specific PAHs (18). These 17 PAHs were selected based on the availability of health and toxicity data, probability of human exposure, and potential for adverse health outcomes following exposure (18). When the EPA and ATSDR lists are combined, there are 18 unique PAHs.

Individual plots were generated comparing each person’s individual exposure to naphthalene and phenanthrene, which are two priority PAH that were selected, as they were the most commonly detected PAHs in the wristbands; both were detected in >75% of samples. Plots compared each participant to the other participants in the study and each report included a personalized table showing which of the priority PAHs were detected along with common environmental sources of these chemicals, the total number of PAHs detected in the individual’s wristband, and a table detailing the concentration of each PAH found in the individual’s wristband and the range of exposure across the study population.

This report was based on a previously developed report (9), then piloted and tested in focus groups within the cohort. Feedback and revisions from the focus group were incorporated prior to utilizing the report with the participants for this study (Riley et al. manuscript in preparation). Reports were generated in English and in Spanish, and paper copies were sent to the participants’ homes in June 2021, with electronic versions emailed upon request. A short (04:48 min) video (19) was developed to walk participants through the report, with English and Spanish closed captioning. This study was approved by the Columbia University Irving Medical Center IRB (#AAAK6753) and Oregon State University IRB (IRB-2021-1048) and individuals were consented prior to their prenatal visit.

Survey

Following receipt of the results in July of 2021, participants (n = 168) were sent a link to an electronic survey to gather feedback on the report using the REDCap system of the Data Coordinating Center at the Mailman School of Public Health, Columbia University. The survey was available in both English and Spanish, with the option for participants to select the language they were [most?] fluent in. All individuals who received a report were eligible to complete the survey, which consisted of 18 questions regarding socio-demographics, report readability, time spent reviewing the report, level of interest in receiving their results, and whether the participants were surprised by the results. Survey questions were chosen to assess environmental health literacy, and included questions adapted from the Silent Spring Institute Report Back Handbook (11). The survey questions are included in the supplemental material. A total of N = 47 participants completed the questionnaire, resulting in a 28% completion rate. Prior to analysis, open ended questions with responses in Spanish were translated into English by a native Spanish speaker.
Development of the EHL scale

We developed a numeric scale to assess EHL based on the information collected in the survey. First, we selected appropriate questions from the survey based on their applicability to the EHL taxonomy (2). A total EHL indicator was created by selecting Likert questions from the survey that were associated with different levels of the EHL framework (2). Table 1 includes a full list of questions used, which include a measure of participant likelihood to change behavior in response to exposures, a key tenet of EHL (2, 20). Responses to each of these questions were categorized and coded based on Likert responses—where higher numbers indicate higher EHL. Scores for each question were summed to create an EHL scale with a minimum of 0 and a maximum possible score of 26. The median value was 14 (range 8-20).

Table 1. Demographic characteristics and exposure summaries of participants included in the research study

<table>
<thead>
<tr>
<th>Level</th>
<th>No Survey</th>
<th>Completed Survey</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>121</td>
<td>47</td>
<td>0.82</td>
</tr>
<tr>
<td>Maternal Age (mean (SD))</td>
<td>28.96 (6.43)</td>
<td>28.71 (5.25)</td>
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</tr>
</tbody>
</table>

Categorical Characteristics

<table>
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<th>Maternal Education (%)</th>
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<th>Completed Survey</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
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<td>&lt;High School</td>
<td>23 (20.9)</td>
<td>12 (26.7)</td>
<td>0.50</td>
</tr>
<tr>
<td>High School Diploma</td>
<td>48 (43.6)</td>
<td>15 (33.3)</td>
<td></td>
</tr>
<tr>
<td>2- or 4-Year College Degree</td>
<td>39 (35.5)</td>
<td>18 (40)</td>
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</tbody>
</table>

<table>
<thead>
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<th>Marital Status</th>
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<th>Completed Survey</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never Married</td>
<td>56 (50.9)</td>
<td>17 (37.8)</td>
<td>0.20</td>
</tr>
<tr>
<td>Married/ Living with Partner</td>
<td>48 (43.6)</td>
<td>23 (51.1)</td>
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</tr>
<tr>
<td>Divorced/ Separated</td>
<td>6 (5.5)</td>
<td>5 (11.1)</td>
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</table>

<table>
<thead>
<tr>
<th>Income</th>
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<th>Completed Survey</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
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<td>$0-$20,000</td>
<td>58 (52.7)</td>
<td>29 (64.4)</td>
<td>0.25</td>
</tr>
<tr>
<td>&gt;$20,000</td>
<td>52 (47.3)</td>
<td>16 (35.6)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>No Survey</th>
<th>Completed Survey</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic or Latino</td>
<td>105 (95.5)</td>
<td>45 (100.0)</td>
<td>0.34</td>
</tr>
<tr>
<td>Not Hispanic or Latino</td>
<td>5 (4.5)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PAH Exposure</th>
<th>No Survey</th>
<th>Completed Survey</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene (mean (SD))</td>
<td>4.54 (0.89)</td>
<td>4.57 (1.19)</td>
<td>0.84</td>
</tr>
<tr>
<td>Phenanthrene (mean (SD))</td>
<td>5.61 (0.61)</td>
<td>5.67 (0.50)</td>
<td>0.62</td>
</tr>
<tr>
<td>Total PAH Count (mean (SD))</td>
<td>11.49 (4.52)</td>
<td>11.09 (5.59)</td>
<td>0.63</td>
</tr>
<tr>
<td>Count of Priority PAH (mean (SD))</td>
<td>5.01 (2.14)</td>
<td>4.38 (2.33)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

*Utilized Fisher’s Exact test for comparisons.
*Categorical characteristic data is only available for 155 participants (data were unavailable for 13 participants).
*Unit = log pmol/wristband.
*Total number of PAH found in wristband, wristbands were analyzed for 63 PAHs.
*The PAH method includes 18 Priority PAHs, as defined by ATSDR and the EPA.

Text mining

Data was collected for 47 participants. A total of 33 participants answered the question “What are your feelings after viewing your results?”. Standard text processing steps were taken to convert to lower case text, remove punctuation, remove standard English stop words using the Snowball stemmer project (21), and remove white space. A sentiment analysis (22) was conducted on each participant’s answer. The presence of words corresponding to 6 different emotions (“anticipation,” “fear,” “joy,” “sadness,” “surprise,” “trust”) was tabulated along with the overall sentiment (“negative,” “positive”). A predicted probability was calculated for the sentiments: positive, negative, and neutral. For each participant, the predicted sentiment was taken to be the sentiment with the highest respective probability.

Data analysis

To determine the representativeness of those who completed the survey versus those who did not, we
used Fisher’s exact test to account for the small sample size. Quantitative data analysis focused on potentially modifiable factors that influenced how participants perceived their report back information. Child age at report (as a proxy for time between exposure monitoring and receipt of report), maternal education, marital status, and income were all examined as predictors in the analysis.

Exposure to naphthalene and phenanthrene were also considered as potentially modifiable factors that might be associated with EHL. Given the high detection frequency, these two chemicals were specifically highlighted in the report and more detail was provided about them for the benefit of the participants. Values were log adjusted and treated as predictors in the models. Additionally, we evaluated the total number of PAHs detected and the number of priority PAHs found in each person’s wristband as predictors of exposure.

Linear and logistic regression models were used, as appropriate, to assess whether the potentially modifiable lifestyle and exposure factors listed above were associated with indicators of EHL. Supplementary Table 1 summarizes the development and scoring of the variable. In addition to multivariate models, we also compared the reaction to the results (e.g., surprised, glad) by EHL score using t-tests. All analyses were completed in R statistical software (R version 4.1.2) (18).

A thematic analysis was conducted on participant responses to the question “What were your feelings after viewing the results?” Each response was manually reviewed and coded. Three themes were identified: worried, reassured, and wanting to learn more. One respondent noted not having any feelings after the return of results, and their answers were excluded from this analysis.

Results

Participants who completed the survey (n = 47) were not statistically different from participants who received their report but did not complete the survey with respect to maternal age, education, marital status, income, ethnicity, and PAH exposure. While not statistically significant, participants who completed the survey were more likely (p = 0.20) to be married or living with their partner for >7 years than participants who did not complete the survey (see Table 2).

General response to the report

Respondents were asked simple questions to gauge their response to the report. Specifically, participants were asked if they were glad to have received their results, and if they were surprised by their results. N = 47 participants (28% of the study population who received their reports) responded to these questions, and a majority were glad to have received their data (94%) and were surprised by any of their results (69%).

Table 2. Average environmental health literacy score by demographic characteristics

<table>
<thead>
<tr>
<th>Level</th>
<th>Average EHL Score Mean (SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal Education (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;High School</td>
<td>14.70 (3.33)</td>
<td>0.56</td>
</tr>
<tr>
<td>High School Diploma</td>
<td>15.86 (2.85)</td>
<td>0.10</td>
</tr>
<tr>
<td>2 or 4 Year College Degree</td>
<td>16.94 (2.13)</td>
<td>0.50</td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never Married</td>
<td>15.67 (2.99)</td>
<td></td>
</tr>
<tr>
<td>Married/ Living with Partner</td>
<td>16.14 (2.85)</td>
<td>0.63</td>
</tr>
<tr>
<td>Divorced/ Separated</td>
<td>17.00 (1.63)</td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0-$20,000</td>
<td>15.62 (2.91)</td>
<td>0.19</td>
</tr>
<tr>
<td>&gt;$20,000</td>
<td>16.75 (2.46)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>16.05 (2.78)</td>
<td></td>
</tr>
<tr>
<td>Not Hispanic or Latino</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Summary of model summary data

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Surprised Results1</th>
<th>Glad to have learned Results1</th>
<th>Time Reading2</th>
<th>Total EHL Score2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>P Value</td>
<td>OR</td>
<td>P Value</td>
</tr>
<tr>
<td>Child Age</td>
<td>1.59</td>
<td>0.27</td>
<td>1.24</td>
<td>0.78</td>
</tr>
<tr>
<td>Maternal Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school diploma</td>
<td>3.30</td>
<td>0.16</td>
<td>1.27</td>
<td>0.87</td>
</tr>
<tr>
<td>2- or 4-year degree</td>
<td>5.60</td>
<td>0.05*</td>
<td>1.55</td>
<td>0.77</td>
</tr>
<tr>
<td>Marital Status</td>
<td>1.04</td>
<td>0.96</td>
<td>2.93</td>
<td>0.40</td>
</tr>
<tr>
<td>Income</td>
<td>1.30</td>
<td>0.71</td>
<td>17.41</td>
<td>0.99</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.37</td>
<td>0.02*</td>
<td>0.87</td>
<td>0.72</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>1.88</td>
<td>0.31</td>
<td>22.08</td>
<td>0.24</td>
</tr>
<tr>
<td>Total PAH</td>
<td>1.01</td>
<td>0.37</td>
<td>1.03</td>
<td>0.12</td>
</tr>
<tr>
<td>Priority PAH</td>
<td>0.90</td>
<td>0.48</td>
<td>0.94</td>
<td>0.26</td>
</tr>
</tbody>
</table>

*Indicates significance at a level of p < 0.05. 1logistic regression model. 2linear regression model.

Figure 1. Distribution of naphthalene and phenanthrene by participant response to whether they were surprised by their results.

Figure 2. Distribution of environmental health literacy (EHL) indicator score. Maximum possible score = X. Scores ranged from 8-20.
We found that mothers with a college degree were significantly more likely to be surprised by their results than mothers with less than a high school degree (OR = 5.60, p ≤ 0.05). We did not observe that income, marital status, and child age was associated with participants being surprised by their report, whether they were glad to have received their report, or the amount of time spent reading their report (see Table 3).

We observed that naphthalene levels were associated with a decreased odds of being surprised about receiving the results (OR = 0.37, p = 0.02) (see Figure 1). Phenanthrene, total number of PAHs detected, and the number of priority PAHs detected were not associated with being surprised by the report, being glad to have received the results, or time spent reading the report (see Table 3).

**Environmental health literacy**

A total of 44 participants (94% of all who completed the survey) answered all the questions used to create the EHL indicator score. The highest possible EHL score was 26. Scores ranged from 8-20, with a mean and median of 14 (see Figure 2). When examining EHL score by demographic characteristics, EHL score increased with increasing education, marital status, and income, although these trends were not statistically significant (see Table 2). When looking at measures of PAH exposure, naphthalene has an inverse association with total EHL score (β = -0.85, p = 0.02). Phenanthrene, total PAH, and priority PAH count were not associated with total EHL score (see Table 3). We observed that those who reported being surprised by their results had higher EHL scores than those who were not surprised (mean EHL = 17.2 (SD = 1.9) vs. 13.9 (SD = 2.9), p < 0.01) and those who were glad to receive their results had higher EHL scores than those who were not glad (mean EHL = 16.5 (SD = 2.4) vs. 11.3 (SD = 3.5), p < 0.01) (models not shown).

**Reception of the report back**

A total of 33 participants (70% of those who completed the survey) provided free-form responses to the question, “What are your feelings after viewing your results?” Responses in Spanish were translated to English. Open-text responses ranged from one word to 23 words, with a median word count of three words. The responses are visualized in supplemental Figure 1.

![Figure 3](image_url)

Figure 3. Total number of words corresponding to one of six emotions (“anticipation,” “fear,” “joy,” “sadness,” “surprise,” “trust”) across 33 open-ended responses in answer to the question, “What are your feelings after viewing your results?”
A sentiment analysis was conducted to evaluate the overall feelings reported by the participants. Words associated with six different emotions were characterized, with the most prevalent emotion being associated with the response being characterized as fear, followed by surprise, and then joy and anticipation (see Figure 3). The responses were further assessed for overall predicted sentiment (negative, neutral, positive). There were equal numbers of positive and negative associations, with slightly more responses being identified as neutral (see Figure 4).

Thematic analysis of the short answers resulted in three shared themes: wanting to learn more; being worried, and feeling reassured. There were six responses that referenced wanting to know more about their exposures. For example, one participant wrote: “I want to know more because I already know that I do not know anything about my exposures.”

The majority of responses (n = 16) were coded as indicating worry, with responses either directly using the word “worry” or obliquely referencing worry, as indicated by this participant: “Second thinking what items I surround myself with.”

There were also several participants that referenced a feeling of reassurance (n = 8). As one respondent wrote, “Feeling more tranquility and gratitude for the information.”

Discussion

The role of report-back is posited to help increase EHL, thereby facilitating individual knowledge gain and potential behavior changes (20,23,24). We returned individual data within the context of the study population to 168 individuals in the Fair Start Cohort, approximately 2-5 years after data collection. Over one-quarter of the participants completed a survey describing their reaction to the report. The survey respondent population was representative of the study population when assessed across socio-demographic variables.

Here, our data indicates that participants who are more educated (college degree +) and those with lower environmental exposures to common PAHs are more likely to be surprised by their results. Being surprised about receiving personal exposure monitoring information is indicative of being able to Recognize and Understand environmental health concepts, based on the EHL taxonomy by Finn and O’Fallon (2). In the taxonomy, the ability to Recognize and Understand a concept are at the most basic levels of EHL. An individual could progress through higher levels that include being able to Apply, Analyze, Evaluate, and eventually Create. College educated individuals may have been exposed to these concepts previously or be able to apply them.
Environmental health literacy

To their daily life more easily. However, the question was binary (yes/no) and did not allow us to query the direction of surprise, (e.g., we do not know whether the participants were surprised that their levels were higher versus lower than they expected).

The negative association between naphthalene exposure and being surprised by the results is noteworthy and was unchanged after accounting for income and/or education. Naphthalene is a common air pollutant that is formed through several sources leading to exposure in ambient air including gasoline and oil combustion, as well as biomass burning, but also has several indoor exposure sources including mothballs, plug-in air fresheners, fumigants, and deodorizers (19). Individuals may be more familiar with these indoor sources of PAH, and naphthalene has a characteristic ‘chemical’ smell.

Beyond assessing the impact of individual return of results on participant reaction to the reports, we developed a measure of EHL using survey questions. There are few tools for measuring EHL (12-14, 24-26). Given the distribution, we did not set parameters of high versus low literacy like other tools (11, 21), yet looked at EHL as a continuous variable. We saw a positive trend between maternal education and EHL, although this relationship was not statistically significant, possibly due to the small sample size. Some tools have found significant associations between EHL and education (13), yet this has not been replicated in other EHL tools (14, 27). We may have not seen this in our data because of the small sample size (n = 44) or because the categories chosen to group the data were slightly skewed with a smaller proportion of mothers not completing high school. Additionally, education status alone may not be the driver of EHL, compared to topic-specific knowledge. For example, a study looking at specific environmental exposures found that one component of EHL “willingness to engage in protective behaviors” was significantly associated with knowledge of the exposure as opposed to general educational attainment (27), yet in another study, content-specific knowledge was not associated with health-protective behaviors (13). In our study, we did not assess knowledge about PAH exposure explicitly so could not assess whether our indicator of education represents the contribution of educational attainment or knowledge specifically about PAH.

We saw that people were glad to have received the report, despite having participated in the research two to five years prior. The use of text mining for semantic analysis indicated equivalent negative and positive feelings across six emotions. Another study evaluated eight feelings (“curious,” “Informed,” “Interested,” “Empowered,” “Helpless,” “Scared,” and “Worried”) across a cohort of 295 women viewing results from blood tests, which included levels of flame retardants, PFAS, and lipids (28). Following structured interviews, most participants reported positive feelings before and after viewing their results, with a minority of participants reporting feeling helpless, scared, or worried (28). However, the authors noted that a more stratified analysis by race showed that the level of worry may differ by race, although this was complicated by the chemical results, as Black participants had higher levels of chemicals and noted higher levels of worry (28). Our cohort predominantly identified as Hispanic or Latino, and thus stratification of results by race was not possible. Beyond the semantic analysis, our qualitative analysis indicated that while participant responses referenced “worry”, they also identified potential behavior changes, i.e., selecting different products to reduce exposures. Unfortunately, our survey characterized “worry” on a binary scale (yes/no) and did not allow for a more nuanced understanding.

Despite referencing fear upon viewing the results, participants overwhelmingly reported they were glad to have received their data (94%). In addition, eight of 30 responses expressed reassurance and gratitude for the report. This is borne out by other studies that have returned individual results, wherein participants were glad they had received their data (5, 8, 29-32). In particular, this is supported by prior data, wherein parents received information on children’s exposures to asthma triggers (32). Here, participants in low income, public housing with lower socioeconomic status, similar to our cohort, found that the return of data was positively received and there was evidence that the reports facilitated greater understanding of environmental exposures (32). Here, our cohort is somewhat homogenous when looking at socioeconomic status, and thus we were not able to probe connections between socioeconomic status and EHL. Of note, the link between socioeconomic status and
EHL has been found to be null in a study evaluating EHL levels and connections to adoption of health protective behaviors (27).

EHL is a complex concept that merges background information on environmental health, risk communication, public health, and behavioral science (6). The complex interplay between demographics, foundational environmental health knowledge, and perceptions of self-efficacy/knowledge sufficiency has been previously explored (14, 27). We were unable to probe into self-efficacy and knowledge sufficiency in this research; our survey included one question regarding likelihood to make changes (supplemental material: Questionnaire, Q8), yet was not designed to probe knowledge sufficiency as a co-variante for EHL, and thus was integrated into the overall measure rather than a standalone metric. While this data supports continued efforts to return individual data, the null associations between EHL and sociodemographic variables, as well as exposure predictors, suggest we need to better understand predictors of EHL to ensure reports are appropriate. It is frequently assumed that EHL and Health Literacy (HL) are similar, so the same predictors will apply to both concepts, but preliminary research suggests the relationship is more complicated (27). Indicators of HL include demographics such as age, gender, and marital status (33). When thinking about developing report back tools, we need to determine drivers specifically of EHL, rather than assuming drivers of HL.

Strengths of this study include conducting the report back in a longitudinal cohort study where participants remain engaged many years following data collection. CCCEH partnered with collaborators at Oregon State University who have previous experience returning results (8, 34), to generate a report that was meaningful and culturally sensitive. Additionally, the version of the report that was used in this study had previously been piloted in the Fair Start cohort and undergone focus group feedback to improve the readability. Limitations of this research include having a small sample size (n = 47 completed the survey, n = 44 had all questions answered for EHL indicator variable). While the sample was representative of the larger cohort, more respondents may have allowed identification of predictors of EHL. Additionally, this data is collected in a primarily Hispanic urban cohort, and the generalizability of these results may not be applicable to other groups or locations.

This works helps to Break the Cycle of environmental health disparities by breaking the link between limited education/limited empowerment leading to increased exposure then to negative health outcomes (see Figure 5). Reporting back data, following established ethical guidelines (5, 9, 30, 35), can increase EHL (6-8). Increased EHL is tied to increased knowledge, either general (12, 13) or topic-specific (27), leading to increased willingness to engage in behaviors to reduce exposure (27, 30, 32). In this way, the link leading to increased exposure is broken. Within the larger Fair Start cohort, previous work has shown that participants used information from their report to make informed decisions about reducing exposures, and became vocal in their community to raise awareness about environmental exposures (36). This is shown in other studies, wherein return of results can lead to behavior change, or willingness to change behavior, to reduce exposures and improve health (30, 32).

Figure 5. Cycle diagram.
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Supplemental Material

Questions from the report back questionnaire

The survey included some questions from the *Handbook for Reporting Results to Participants in Biomonitoring and Personal Exposure Studies* and are marked with an asterisk* or a double asterisk** if adapted.


1. How long did you spend reading your report?
   a. Less than 5 minutes
   b. 5-15 minutes
   c. More than 15 minutes
   d. I did not read it

2. What information were you MOST interested in reading about in the newsletter?
   a. Page 1 introductory letter
   b. Information about PAHs (human health, sources)
   c. Reducing exposure to PAHs
   d. Type of PAHs found in your wristband
   e. Your results
   f. The results of the whole study

3. How easy or hard to read and understand was each part of the report? (very easy, somewhat easy, neutral, difficult, very difficult, did not read)
   a. Page 1 introductory letter
   b. Information about PAHs (human health, sources)
   c. Reducing exposure to PAHs
   d. Type of PAHs found in your wristband
   e. Your results
   f. The results of the whole study

4. Before you received this report how much did you know about PAHs and the risk they pose to people?
   a. I knew a lot about PAHs
   b. I knew a little about PAHs
   c. I did not know anything about PAHs
5. How much did this report add to your knowledge about PAHs?
   a. A lot
   b. A moderate amount
   c. A little
   d. None at all

6. How easy or difficult was it for you to find what YOUR levels of PAHs were?
   a. Very easy
   b. Easy
   c. Neutral
   d. Difficult
   e. Very difficult
   f. I did not find this information
   g. I did not read the report

7. How easy or difficult was it for you to figure out how YOUR levels of PAHs compared to the whole group?
   a. Very easy
   b. Easy
   c. Neutral
   d. Difficult
   e. Very difficult
   f. I did not find this information
   g. I did not read the report

8. Which of the suggested steps to reduce PAH exposures are you most likely to take?
   a. Ventilate when cooking or using a wood-fired stove/fire (run fans or open windows). Grill or smoke outdoors.
   b. Limit exposure to gasoline and diesel fumes
   c. Replace pest control methods like mothballs with alternatives like cedar shavings
   d. Avoid e-cigarettes and cigarette/cigar smoke
   e. Rotate smoked, grilled and charbroiled foods with baked, steamed, and/or canned foods
   f. If you use a wood stove, make sure the opening and chimney do not leak smoke
   g. I am going to do something else:
      i. Other
   h. I am not going to do any of these things

9. Do you plan to talk about this study and/or your PAH exposure with a doctor, nurse, or public health professional?**
   a. I definitely will
   b. I probably will not
   c. I may or may not
   d. I probably will not
   e. I definitely will not

10. Please tell us a little about your experience receiving your study results. Was the report helpful to you, and are you glad you received this information about PAHs and the levels of PAHs we found in the wristbands you wore?

11. Did the description of how to read your results (see example graph) help you better understand your results? (1 = not easy, 10 = very easy)
12. Overall, how interesting was it to see your chemical exposure results? (1 = not interesting, 10 = very interesting)
13. Are you glad to have learned about your own results?* (yes/no)
14. What are your feelings after viewing your results?**
15. Were you surprised by anything in the results? What was surprising?**
16. Did the study change your views about what role you think chemicals might play in your health?**
17. What additional resources or information would you like to have as a result of this study?*

Supplemental Table 1. Coding for the environmental health literacy indicator variable

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Corresponding EHL Taxonomy</th>
<th>Scoring Summary</th>
</tr>
</thead>
</table>
| How long did you spend reading the report?                                   | General EHL indicator       | 1 = Less than 5 minutes
|                                                                                |                             | 2 = 5-15 minutes
|                                                                                |                             | 3 = More than 15 minutes
|                                                                                |                             | 0 = I did not read it                     |
| Before you received this report how much did you know about PAHs and the risk they pose to people? | Recognize                  | 2 = I knew a lot about PAHs
|                                                                                |                             | 1 = I knew a little about PAHs
|                                                                                |                             | 0 = I did not know anything about PAHs    |
| How much did this report add to your knowledge about PAHs?                   | Apply                       | 3 = A lot
|                                                                                |                             | 2 = A moderate amount
|                                                                                |                             | 1 = A little
|                                                                                |                             | 0 = None at all                          |
| How easy or difficult was it for you to find what YOUR levels of PAHs were?  | Understand                  | 3 = Easy
|                                                                                |                             | 2 = Neutral
|                                                                                |                             | 1 = Difficult
|                                                                                |                             | 0 = I did not find this information      |
|                                                                                |                             | 0 = I did not read the report            |
| How easy or difficult was it for you to figure out how YOUR levels of PAHs compared to the whole group? | Understand                  | 3 = Easy
|                                                                                |                             | 2 = Neutral
|                                                                                |                             | 1 = Difficult
|                                                                                |                             | 0 = I did not find this information      |
|                                                                                |                             | 0 = I did not read the report            |
| Which of the suggested steps to reduce PAH exposures are you most likely to take? | Analyze                     | Sum of 8 options (range 0-8)             |
| Do you plan to talk about this study and/or your PAH exposure with a doctor, nurse, or public health professional? | Evaluate                    | 4 = I definitely will
|                                                                                |                             | 3 = I probably will not
|                                                                                |                             | 2 = I may or may not
|                                                                                |                             | 1 = I probably will not
|                                                                                |                             | 0 = I definitely will not                |

Survey questions were coded to the EHL taxonomy, described by Finn and O’Fallon (Finn, S. and O’Fallon, L., 2017. The emergence of environmental health literacy—from its roots to its future potential. Environmental health perspectives, 125(4), pp.495-501.).
Supplemental Figure 1. Word cloud of words seen in open-ended question, “What are your feelings after viewing your results?”

References


between wristbands and urine for assessment of personal PAH exposure. Environ Int 2022;163:107226.


