Assessing health impacts in complex eco-epidemiological settings in the humid tropics: Modular baseline health surveys

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Abstract
The quantitative assessment of health impacts has been identified as a crucial feature for realising the full potential of health impact assessment (HIA). In settings where demographic and health data are notoriously scarce, but there is a broad range of ascertainable ecological, environmental, epidemiological and socioeconomic information, a diverse toolkit of data collection strategies becomes relevant for the mainly small-area impacts of interest. We present a modular, cross-sectional baseline health survey study design, which has been developed for HIA of industrial development projects in the humid tropics. The modular nature of our toolkit allows our methodology to be readily adapted to the prevailing eco-epidemiological characteristics of a given project setting. Central to our design is a broad set of key performance indicators, covering a multiplicity of health outcomes and determinants at different levels and scales. We present experience and key findings from our modular baseline health survey methodology employed in 14 selected sentinel sites within an iron ore mining project in the Republic of Guinea. We argue that our methodology is a generic example of rapid evidence assembly in difficult-to-reach localities, where improvement of the predictive validity of the assessment and establishment of a benchmark for longitudinal monitoring of project impacts and mitigation efforts is needed.

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1. Introduction
Health impact assessment (HIA) entails the systematic analysis of potential impacts on public health due to policies, programmes and projects, and aims to optimise the health interests in the decision-making process (Kemm et al., 2004). HIA usually embraces an interdisciplinary approach, combining quantitative and qualitative methods, to guide evidence-based mitigation measures (Krieger et al., 2003; Lock, 2000; Scott-Samuel, 1998). HIA has progressively developed over the past 20 years with continued diversification in approaches, methods, tools and guiding frameworks (Harris-Roxas and Harris, 2011; Krieger et al., 2010). The salient issues in natural resources and industry development projects in the developing world are quite different from those associated with an advanced economy policy or programme. Given the enormous, resource-driven (i.e. biofuels, mining, oil/gas, water and timber) development that is occurring in low-income, but resource-rich countries (Erlanger et al., 2008a), there is a need to identify the most useful approaches and techniques for characterising the baseline situation. Defining the baseline is a crucial exercise, as subsequent monitoring and evaluation (M&E) activities and documentation of positive and negative effects will be dependent on the accuracy of the baseline determination. In a developing country setting, obtaining relevant baseline data in an efficient and cost-effective manner is a complex, yet important undertaking.

In general, HIA practitioners draw on epidemiological evidence that is readily available, and critically assess its relevance for particular circumstances of a specific proposal (Mindell et al., 2004). In a developing country context, population-based surveys such as demographic health surveys (DHS), multiple indicator cluster surveys (MICS) and health statistics reported by the World Health Organization (WHO) and other organisations typically provide epidemiological data on a national or regional level. While such data are relevant for impact assessment of national policies and programmes, they...
are often inapplicable for M&E of a specific project at a community level. Settings that are characterised by profound micro-environmental differences (e.g. altitude, humidity, land-use patterns, rainfall and temperature), and large disparities of access to health care, have important ramifications on local burdens of disease (Eisenberg et al., 2007; Listorti and Doumani, 2001; Prüss-Ustün et al., 2008; Schellenberg et al., 2003; Utzinger and Keiser, 2006). Regional or national data typically obscure or overtly miss critical small area morbidity/mortality differences. Hence, for robust risk appraisal and documenting changing patterns of health, wellbeing and equity following project implementation, adequate tools for quantification at a local level are required (Bhatia and Seto, 2011; Utzinger et al., 2005; Winkler et al., 2010).

The baseline analysis is tied to, and sequentially follows, the initial scoping analysis. Scoping identifies the range of potential health impacts and determines, by means of a gap analysis, whether sufficient data are available in order to proceed directly with the risk/impact analysis and mitigation phase (Winkler et al., 2011). In case of inadequate or insufficient data, there is a need to collect additional baseline health data. In low-income countries, critical data gaps are the norm rather than the exception (Adrien et al., 2008; Thamilkithuk, 2006). Hence, it is essential to develop a standardised, rapid and inexpensive baseline health survey methodology that incorporates a broad set of practical and readily reproducible key performance indicators (KPIs) that can be adapted to the magnitude and complexity of myriad project settings. In this context, we have developed a modular, cross-sectional baseline health survey methodology that has been successfully applied in a number of projects, countries and environmental settings across sub-Saharan Africa and elsewhere. In the present paper, our methodology is illustrated by a baseline health survey carried out in 14 sentinel sites located within the concession area of a mining project in West Africa.

2. Methods

2.1. Key performance indicators (KPIs)

KPIs are measures of project inputs, outputs, outcomes and impacts that are monitored during project implementation (Mosse and Sontheimer, 1996). From a practical point of view, three data collection levels exist, each of which offers a set of specific indicator groups: (i) individual level (e.g. age and sex, indicators of knowledge, attitude and practice (KAP) and biomedical indicators); (ii) household level (e.g. structural indicators, such as durable housing characteristics, asset indicators (e.g. possession of a radio or bicycle) and environmental indicators); and (iii) community level (e.g. health systems, infrastructure indicators and environmental indicators).

For the data collection per se, different data collection tools and methods (referred to as ‘modules’) are at our disposal. Fig. 1 shows the interlinkages between the different data collection levels, the indicator groups and the data collection modules, including a broad, but focused set of potential KPIs. Importantly, the aforementioned indicators need specificity in terms of the final dimension unit and the precise manner of assessment.

2.2. Study design

The design of a HIA baseline health survey is governed by the fact that it should reflect the heterogeneity of health characteristics and potential project-related impacts (beneficial or detrimental) among different communities and/or population groups. Hence, a central feature of baseline health surveys for industrial projects is that data collection methods need to be fine-tuned to local small-area conditions. A broad-based tool kit is essential. In our view, the standardised sampling methodologies advertised for large-scale national and regional surveys are, for the most part, inapplicable to typical industrial project settings (United Nations, 2008). Against this background, we developed a three-stage sampling strategy, which is purposive at the first two stages and randomised at the third stage (see Fig. 2).

In the frame of a baseline health survey as part of a HIA of a project, stratified sampling is recommended at the first stage. The population is stratified into so-called potentially affected communities (PACs). We define PAC as a community within a well-defined geographical boundary under the assumption that it will be equally exposed to the project in terms of the magnitude and nature of the anticipated impacts (Winkler et al., 2010). Examples of PACs are communities along a major access road of a project, communities to be resettled, or communities in directly affected by a project. The definition of PACs is project specific, and thus based on available socioeconomic and environmental baseline data, supplemented with findings from the scoping study.

At the second stage, primary sampling units are defined and selected within a PAC and referred to as sentinel sites. A sentinel site is defined as a geographically constructed area (e.g. sentinel village), or a part of an area (e.g. neighbourhood in a town), with up to 300 households. The number and selection procedure (i.e. purposive or random) of sentinel sites is governed by the magnitude and heterogeneity of the project area, financial and human resources, operational issues and technical considerations.

At the third stage, when data collection occurs at sentinel site level, a diverse array of options must be considered on a site-specific basis. Ideally, a complete list of households or residential dwellings serves as sampling frame for simple random sampling (Aliaga and Ren, 2006). In rural areas of the developing world, where household lists may not be readily available, the following alternatives exist. First, compact segment sampling is a useful technique (Turner et al., 1996). Here, a sketch map is drawn of the sentinel site, showing dwellings, which is then split into a small number of segments, such that the number of dwellings per segment is roughly the same (e.g. 30 households). One segment is then chosen at random from each sentinel site and all households in the segment are included in the sample. Further, a quota sample method lends itself when no mapping material is at hand. For this, a top with a marked cross on it is spun at a central point within a sentinel site to determine four perpendicular directions. Subsequently, the households along these directional lines to the edge of the cluster area are counted, and one in each direction selected at random. Proximity sampling is then pursued with interviewers moving from one household to the next nearest household until the pre-determined number of households is reached. These sampling methods may be augmented by purposive selection of key sites not located on transects, but which have the potential for high impacts.

The optimal sample size at sentinel site level is usually a trade-off between the available budget and the desired survey precision. DHS experience suggests that, for an average cluster size of 100–300 households, to achieve moderate intra-cluster correlation and an acceptable cost ratio, the optimal second-stage sample size is about 20–30 women per cluster for gathering data on most of the survey indicators (Aliaga and Ren, 2006). DHS are similar in terms of field procedures and measured indicators, and thus this range is utilised as reference for the number of individuals and households selected per sentinel site.

2.3. Data collection modules

The final setup of a baseline health survey is determined by the selected KPIs of interest, as they indicate which of the 10 data collection modules presented in Fig. 1 should be used. The selection of the modules to be employed is governed by the data needs, whereas human resources and equipment required are carefully determined. The set of modules depends on the sample size, sampling strategy and available data. For example, to gather community-level information on structural and institutional indicators, module 2 is employed...
(service and infrastructure assessment), whereas for obtaining environmental indicators, modules 6–10 are used, which require special equipment and specific considerations regarding sampling procedures. A questionnaire survey (module 1), end-user water quality testing (module 6) and a clinical field unit (module 3) may be linked by using the household as the common unit of sampling. This means that the assessor collects a drinking water sample after conducting an interview and subsequently refers household members to a clinical field unit where they are examined by a medical team for clinical investigation. While in some cases there is an advantage to linking different modules, the opposite may apply for modules such as a parasitological survey in schoolchildren (module 4) or an entomological survey that focuses on disease vectors (module 10). These surveys are preferably led by independent and specialised teams, as they do not have a common sampling unit with other teams and also the daily schedule may differ.

3. Case study

3.1. Study area and compliance

Our case study pertains to a baseline health survey carried out for the Rio Tinto Simandou project in May 2010. This project is a large iron ore mining exploration currently at feasibility stage, located in the south-eastern part of the Republic of Guinea (Rio Tinto, 2010). An estimated 60,000 people reside in the administrative area around the mine concession, affecting four sub-districts with 31 settlements (ranging from small hamlets with less than 40 individuals to a town with 22,000 inhabitants) (Rey, 2008; SNC-Lavalin, 2009). Details of this project, together with our approach for, and key findings from, the HIA scoping have been presented elsewhere (Winkler et al., 2011).

In collaboration with the socioeconomic baseline study team and the community relations team, the project area was stratified into eight PACs, within which 14 sentinel sites were selected (Fig. 3). In the absence of household lists and mapping material for the remote communities, households were selected using the quota sample method described in section 2.2. An estimated 26,000 people live in the 14 sentinel sites, in approximately 3,500 households (La Granada Enterprise, 2008; SNC-Lavalin, 2009). Overall, 451 households (13.3% of the total estimated households) participated in the questionnaire survey. Clinical field unit investigation focussed on 1,511 individuals (813 children aged 6–59 months and 698 adolescents and adults aged ≥15 years), which represents 7.7% of the estimated population in these age groups. Table 1 provides further details on sampling, stratified by sentinel site and module.
3.2. Study setup and equipment

Use of module 1 (questionnaire survey), module 2 (service and infrastructure assessment), module 3 (clinical field unit), module 4 (parasitological survey in schoolchildren), module 6 (end-user water quality testing) and module 8 (water source quality testing) covered approximately 60 specific KPIs. The surveys were conducted by three teams: (i) six interviewers administering a questionnaire survey at household level (module 1), (ii) three medical doctors accompanied by two nurses performing clinical investigations at the clinical field unit (module 3), and (iii) two epidemiologists together with five laboratory technicians conducting parasitological surveys in schoolchildren (module 4). As preparatory steps for the surveys, the locally recruited staff were trained in interview techniques, laboratory procedures and quality control. Questionnaires were pre-tested in a village that was not selected for the survey. Prior to the surveys, the 14 sentinel sites were visited by a community consultation team to inform community leaders, traditional village chiefs and community members about the purpose and procedures of the study.

For this paper, a selection of results will be presented, following standard protocols. First, the extent of malaria was assessed from a finger prick blood sample using a rapid diagnostic test (RDT) for appraisal of *Plasmodium* infection (ICT malaria combo cassette test; ICT Diagnostics, Cape Town, South Africa). Second, a stool sample was collected and subjected to the Kato-Katz thick smear technique for diagnosis of *Schistosoma mansoni* and common soil-transmitted helminths (*Ascaris lumbricoides*, hookworm and *Trichuris trichiura*) (Katz et al., 1972). Third, urine samples were examined for *Schistosoma haematobium*, using the centrifugation method (Hodges et al., 2011). Finally, the presence/absence of coliform bacteria and *Escherichia coli* were determined, using a Colitag™ water test (CPI International; Santa Rosa, CA, USA).

3.3. Ethical considerations and treatment

The study was approved by the ethics committee of the Ministry of Health and Public Hygiene (MHPH) of the Republic of Guinea (Ref. no. 07/CNERS/10). The study is registered at Current Controlled Trials (identifier: ISRCTN88762301). Written informed consent was obtained from all the study participants, and the parents/legal guardians of children below the age of 16 years. Individuals who were found positive for *Plasmodium* infection by a RDT, were infected with soil-transmitted helminths or *S. mansoni*, as determined by parasite eggs in a Kato-Katz thick smear, showed *S. haematobium* eggs in their urine, had severe anaemia or other ailments were treated according to national policies, free of charge.

4. Results

To illustrate the methodology, we present selected KPIs pertaining to malaria, helminth infections, sanitation and drinking water, and access to health care. Of note, due to unforeseen circumstances, one of the sentinel sites (i.e. Lamandou) could only be sampled by the parasitological school survey team. Hence, complete data sets are available for 13 of the 14 selected sentinel sites.

4.1. Malaria

Overall, 813 children aged 6–59 months were examined for *Plasmodium* infection at 13 sentinel sites by means of a RDT. A total of 536 children tested positive, owing to an overall prevalence of 65.9%. Stratified by sentinel site, the prevalence ranged from 53.6% (Traoréla, 54 children tested) to 92.6% (Piyaro, 64 children tested) (Fig. 4). For comparison, according to data presented by the much more coarse-grained malaria atlas project (MAP) (Hay and Snow, 2006), the prevalence of malaria is 50–60% for the current study area. At the sentinel sites, boys were significantly more often infected with *Plasmodium* than girls (70.4% vs. 61.4%, p = 0.007). Those children who slept under an insecticide-treated net (ITN) the night before the survey took place were selected as a KPI for malaria prevention. The lowest rate was observed in Banankoro (22.0%) and...
Table 1: Population estimates and study compliance of questionnaire survey (module 1), clinical field unit (module 3) and parasitological survey in schoolchildren (module 4) during a baseline health survey conducted in 14 sentinel sites of a mining project in the Republic of Guinea in mid-2010.

<table>
<thead>
<tr>
<th>Sentinel site</th>
<th>Estimated number of households (male:female)</th>
<th>Number of households sampled (% of total households)</th>
<th>Number of individuals aged ≥6–59 months (male:female)</th>
<th>Number of households sampled (% of total households)</th>
<th>Number of children aged 9–14 years (male:female)</th>
<th>Number of households sampled (% of total households)</th>
<th>Number of adults aged ≥15 years (male:female)</th>
<th>Number of households sampled (% of total households)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nionsomoridou</td>
<td>3,132</td>
<td>2,458</td>
<td>113 (40.4)</td>
<td>137 (120:17)</td>
<td>46 (3:50)</td>
<td>145 (54.2)</td>
<td>80 (23:57)</td>
<td>105 (36.0)</td>
</tr>
<tr>
<td>Foma</td>
<td>630</td>
<td>606</td>
<td>26 (42.8)</td>
<td>27 (15:12)</td>
<td>13 (11:12)</td>
<td>14 (23.7)</td>
<td>8 (11:6)</td>
<td>9 (15.0)</td>
</tr>
<tr>
<td>Banko</td>
<td>661</td>
<td>636</td>
<td>33 (50.7)</td>
<td>34 (18:16)</td>
<td>11 (8:13)</td>
<td>12 (18.6)</td>
<td>7 (10:6)</td>
<td>8 (12.5)</td>
</tr>
<tr>
<td>Dandano</td>
<td>598</td>
<td>578</td>
<td>30 (51.3)</td>
<td>31 (16:15)</td>
<td>9 (5:3)</td>
<td>9 (15.4)</td>
<td>6 (9:3)</td>
<td>7 (12.0)</td>
</tr>
<tr>
<td>Banankoro</td>
<td>195</td>
<td>195</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Boola I</td>
<td>636</td>
<td>606</td>
<td>28 (46.7)</td>
<td>29 (15:14)</td>
<td>9 (7:12)</td>
<td>10 (16.6)</td>
<td>6 (9:3)</td>
<td>8 (13.0)</td>
</tr>
<tr>
<td>Boola II</td>
<td>4,713</td>
<td>524</td>
<td>80 (15.3)</td>
<td>81 (43:38)</td>
<td>21 (12:9)</td>
<td>22 (36.0)</td>
<td>13 (20:13)</td>
<td>15 (24.6)</td>
</tr>
<tr>
<td>Traoréla</td>
<td>952</td>
<td>106</td>
<td>30 (28.3)</td>
<td>32 (15:17)</td>
<td>10 (5:5)</td>
<td>11 (19.4)</td>
<td>7 (11:6)</td>
<td>9 (16.0)</td>
</tr>
<tr>
<td>Moribadou 1</td>
<td>636</td>
<td>606</td>
<td>30 (51.3)</td>
<td>31 (16:15)</td>
<td>11 (8:13)</td>
<td>12 (18.6)</td>
<td>7 (10:6)</td>
<td>8 (12.5)</td>
</tr>
<tr>
<td>Moribadou 2</td>
<td>40 (20:20)</td>
<td>51 (28:23)</td>
<td>38 (8:30)</td>
<td>39 (18:21)</td>
<td>10 (4:6)</td>
<td>11 (22.4)</td>
<td>7 (11:6)</td>
<td>8 (12.5)</td>
</tr>
</tbody>
</table>

The survey on helminth infections in schoolchildren (aged 9–14 years) revealed that *S. mansoni* is the predominant species (overall prevalence: 66.2%; range: 13.3–90.0%). *S. haematobium* was found in 21.0% of the children surveyed (range: 0–76.7%). The prevalence of hookworm, *A. lumbricoides* and *T. trichiura* was 51.2% (range: 6.7–93.3%), 8.1% (range: 0–33.3%) and 2.4% (range 0–6.7%), respectively (Hodges et al., 2011).

Compared to the regional average of 21.1% (DNS, 2008), 78.5% of the investigated households (n = 441) had open pit latrines, ranging from 41.7% (Nionsomoridou) to 100% (Foma and Banko) (Fig. 3). Approximately half of the interviewed adolescents/adults reported regularly washing their hands with soap; the lowest percentage was found in Banko (29.6%) and the highest in Nionsomoridou (78.5%).

Tube wells are the preferred source of drinking water in the project region. At eight of the 13 sentinel sites, over 80% of the households use well water for drinking purpose. From the 206 drinking water samples that were collected at every second surveyed household, 157 (76.2%) were found positive for *E. coli*. This high level of contamination can partially be explained by poor well water quality (six of 37 wells (16.2%) showed contamination with *E. coli* (Fig. 4).

4.3. Access to health care

On average, 68.1% of the parents (n = 745) sought care at a health facility the last time their youngest child was sick. In those communities without a health centre, the utilisation rate was, as expected, poorer. As seen in Fig. 6, this was particularly evident in Foma (28.8%). Among parents who did not take their children to a health facility, non-affordability was the primary reason (40.3%).

Of the 180 interviewed mothers, 64.1% reported that their last child was delivered in a health facility, which is similar to the regional average of 68.7% (DNS and ORC Macro, 2006). Of note, for Traoréla and Foma, the two most remote sentinel sites, none or only 11.1% of the mothers interviewed reported that they had delivered their last child in a health facility, respectively. In contrast, at the sentinel sites where a health post or a health centre is available, generally more than 80% of the women delivered at these facilities.

5. Discussion

Quantitative assessments of health impacts and the need for adequate tools and methods have been identified as important features for realising the full potential of a HIA (Bhatia and Seto, 2011; Mindell et al., 2001; Veerman et al., 2005). In areas where demographic, ecological, environmental, epidemiological, health and socioeconomic data are sparse, these factors are anticipated to be highly heterogeneous. This quantitative documentation gap hampers long-term M&E activities (Eisenberg et al., 2007). Although, the most relevant international guidelines on HIA consider baseline data collection as integral part of a comprehensive assessment, it is interesting to note that none provides clear guidance on how to perform a representative...
baseline health survey (ICMM, 2010; IFC, 2009; IPIECA, 2005; WHO, 2009). With the modular baseline health survey methodology presented here, we have addressed this shortcoming by providing a ‘hands-on’ tool that is designed for the context of complex industrial development projects implemented in remote rural areas of a developing country. The modular framework does not only provide the flexibility to exclude or incorporate further modules according to identified data gaps, but also provides overall guidance for the planning of a baseline health survey, including required study instruments, and thus equipment, logistics and personnel. The broad set of KPIs is guiding our baseline health survey approach for obtaining quantitative and defendable baseline health data.

Our case study pertaining to the baseline health survey of the Rio Tinto Simandou project region in the Republic of Guinea primarily used quantitative methods. However, KAP surveys supplemented qualitative data, which further strengthened the local-level baseline evidence. Essential data gaps had previously been identified (e.g. extent and magnitude of malaria, schistosomiasis and soil-transmitted helminth infections), during the scoping analysis (Winkler et al., 2011). There were marked differences when comparing our findings to the available regional level data (DNS, 2008; DNS and ORC Macro, 2006). This finding illustrates the importance of developing appropriate, local-level baseline data. In turn, the obtained data can serve as benchmark for subsequent M&E activities.

Against the background of considerable heterogeneity and dynamics within a small geographical area and over a small temporal scale, the data collection strategy becomes of central importance. The definition of a suitable measurement strategy is a challenging task, particularly when there is a large number of indicators of different qualities (Bennett et al., 1991; Bilukha, 2008; Deitchler et al., 2008; Katz, 1995). Sentinel surveillance, focused on PACs, is a primary basis for answering epidemiological questions and monitoring trends in selected population groups impacted by industrial projects (Bachmann et al., 2003; Randrianasolo et al., 2010; WHO, 1999). In our view, the combination of a sentinel site approach with modular surveys tied to specific KPIs is an efficient and cost-effective approach for objectively documenting the baseline health situation of affected communities. The case study presented here, and our experience and lessons learnt while conducting baseline health surveys for large industrial development projects elsewhere in the tropics (Erlanger et al., 2008b), has demonstrated the feasibility and promise of this methodology.

In conclusion, a modular cross-sectional baseline health survey methodology should be considered as a key strategic option for conducting HIA in complex settings where considerable heterogeneities are anticipated in terms of small-scale eco-epidemiological characteristics and potential health impacts. HIA can reinforce the importance of health within the overall suite of impact assessments by documenting baseline conditions in a practical manner that will allow for objective, longitudinal monitoring. The dictum “if you can’t measure it, you can’t manage it” should continue to be embraced by the HIA community as a core practice component. Our experiences made thus far is that the modular survey methodology techniques presented in this paper further facilitate this process.

Fig. 4. Selected findings related to malaria; (A) children aged 6–59 months (%) tested positive for Plasmodium infection; (B) children under the age of 5 years (%) who slept under an insecticide-treated net; and (C) adolescents/adults (aged ≥15 years) (%) who reported mosquito bites as malaria transmission mode.

Fig. 5. Selected findings related to sanitation and drinking water quality; (A) households (%) using a tube well as main drinking water source; (B) households (%) having an open pit latrine; and (C) households (%) that had E. coli contaminated drinking water.
Fig. 6. Selected findings related to health care; (A) mothers (%) who went to a health facility when their child was sick for the last time (cross: health facility available); (B) mothers (%) who reported affordability as primary reason for not going to the health facility; and (C) mothers (%) who delivered their last child at a health facility.

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