Integrated rapid mapping of onchocercasis and loiasis in the Democratic Republic of Congo: Impact on control strategies

Afework Hailemariam Tekle*1, Honorat Zoure1, Samuel Wanji1,2, Stephen Leak3, Mounkaila Noma1, Jan H.F. Remme4, Uche Amazigo1

1 African Program for Onchocercasis Control (APOC), Epidemiology and Vector Elimination, Rue Naba Zombre 1538, Sector 9 Door Number 1473, Ouagadougou, Burkina Faso
2 Research Foundation in Tropical Diseases and Environment, P.O. Box 474, Buea, Cameroon

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ABSTRACT

Background: Onchocercasis can be effectively controlled by annual mass treatment with ivermectin in endemic communities. However, in communities that are endemic for loiasis there may be significant risk of severe adverse reactions after ivermectin treatment. Planning of control requires therefore mapping of these two infections using rapid assessment tools developed for each disease. These tools were initially implemented independently till the feasibility of combining them was demonstrated. This paper reports the results of integrated mapping in four epidemiological zones in the Democratic Republic of Congo and its implications on operational decision-making on ivermectin treatment.

Methods: Rapid assessment surveys were conducted between 2004 and 2005 using both rapid epidemiological mapping of onchocercasis (REMO) and rapid assessment procedure for loiasis (RAPLOA). The survey results were subjected to a spatial analysis in order to generate for each of the two diseases maps of the estimated prevalence of infection throughout the four zones.

Results: Surveys were undertaken in 788 villages where 25,754 males were examined for palpable onchocercal nodules and 62,407 people were interviewed for history of eye worm. The results showed major differences in the geographic distribution of the two diseases. Loiasis was highly endemic in some areas, where special precautions were required, but not in others where routine ivermectin treatment could proceed.

Conclusion: Integrated rapid mapping of onchocercasis and loiasis reduces both time and cost of surveys and greatly facilitates operational decision-making on ivermectin treatment in areas where loiasis might be co-endemic.

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River blindness (Onchocercasis) is a parasitic disease caused by the filarial worm Onchocerca volvulus. It is transmitted through the bites of infected Simulium blackflies, which breed in fast-flowing streams and rivers. Onchocercasis is endemic in many sub-Saharan African countries, with minor foci in Central and South America and the Yemen (World Health Organization, 1995). It is estimated to affect over 37 million people worldwide (Remme et al., 2006). It is a major cause of blindness affecting about half a million people in sub-Saharan Africa. Onchocercasis also causes skin disease with acute and chronic dermatitis, lichenification, atrophy, depigmentation and severe itching.

There have been successful and longstanding efforts by WHO programmes to reduce the onchocercasis burden using vector control and mass chemotherapy. The Onchocercasis Control Programme (OCP) in West Africa started in the 1970s and targeted transmission by controlling the blackfly vectors. Control operations were based on weekly aerial spraying of insecticides to kill the larvae of the blackfly vectors, which breed in fast-flowing rivers and streams. By this means, OCP succeeded in eliminating onchocercasis as a public health problem in 10 of the 11 countries in which it operated (Boatin, 2008). This successful programme could not be extended to forested areas in the central and West Africa where onchocercasis is also endemic due to inaccessibility of the vector breeding sites. The registration of ivermectin as a safe and effective drug for mass treatment of onchocercasis in 1987 raised great hopes for onchocercasis control in Africa. This led to the launching of the African Programme for Onchocercasis Control (APOC) in 1995 to pilot the chemotherapeutic control of onchocercasis in Africa. A new strategy involving a large-scale distribution of ivermectin to endemic communities (TDR, 1996) was rapidly put in place by APOC with the objective of controlling onchocercasis as a public health problem and a barrier to socio-economic development, through community-directed treatment (Amazigo, 2008). When ivermectin became available for the treatment of onchocercasis, and its potential for mass treatment became apparent, identifying the affected onchocercasis endemic communities
became a challenge in order to implement ivermectin treatment. A tool was urgently needed to determine the geographical distribution of the disease and identify which communities to treat and the populations at risk.

A study conducted by the UNICEF/UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) led to the development of a tool to rapidly assess the geographical distribution of the onchocerciasis prevalence. This tool, called rapid epidemiological mapping of onchocerciasis (REMO), was based on nodule palpation (Ngoumou et al., 1994). A relationship was established between the prevalence of nodules and the prevalence of onchocerciasis infection in the community. Nodule palpation was then recommended for identifying communities at risk and selecting them for mass drug administration. REMO uses geographical information, from a spatial sample of communities where nodule surveys are done to identify high risk areas. Areas with a nodule prevalence of ≥20% in adults are considered eligible for mass treatment (World Health Organization, 1991). APOC uses this tool to produce nationwide maps of onchocerciasis and identify priority areas for community-directed treatment with ivermectin. The threshold of 20% (corresponding to 40% microfilaria prevalence in the total population) for onchocerciasis as a public health problem was based on extensive evidence from West Africa showing that onchocercal blindness was extremely rare below this threshold (Dadzie et al., 1991). APOC uses REMO to produce nationwide maps of onchocerciasis and identify priority areas for community-directed treatment with ivermectin. In addition the programme also recommends clinic-based treatment in health facilities in areas where the nodule prevalence is below 20%.

The large-scale distribution of ivermectin was successfully introduced into forested areas of Africa until neurologic serious adverse events (SAEs) were reported in individuals with high *Loa loa* microfilaraemia after ivermectin treatment (Ducorps et al., 1995; Gardon et al., 1997; Boussinesq et al., 2001). *Loa*osis, or African eye worm, is another vector-borne filarial disease occurring in Africa and sometimes co-endemic with onchocerciasis. The SAEs are caused by reactions from the large numbers of microfilaria in the blood, which are killed by ivermectin treatment, and are characterized by progressive neurological decline and encephalopathy within a few days of taking ivermectin. In some cases, this can result in death or chronic disability and their possible occurrence is an impediment for APOC activities. The only method that has been used to assess microfilaraemia prevalence in the community was the collection, processing and examination of thick blood smears. This technique is costly, time consuming, cumbersome and unsustainable. There was therefore an urgent need for another rapid method to identify communities in which individuals are at risk of developing SAEs, before the implementation of mass treatment with ivermectin. A study carried out in Cameroon and Nigeria in 2001, supported by TDR and APOC, led to the development of a rapid assessment procedure for loiasis (RAPLOA) (Wanjii, 2001; Takougang et al., 2002). This study enabled a relationship between the prevalence of eye worm and *L. loa* microfilaraemia and the level of risk to be established. It was found that in communities where more than 40% of individuals experienced subconjunctival migration of the adult *L. loa*, confirmed by a photograph of the worm in the eye, with the most recent episode lasting <7 days, at least 5% of individuals harboured more than 8000 mf/ml. They are consequently exposed to a significant increase risk of occurrence of functional impairment after ivermectin treatment. In such communities at least 2% of individuals carry more than 30,000 microfilariae (mf) per millilitre (ml) and have a high risk of serious neurological reactions following ivermectin treatment. After the development of RAPLOA, the Mectizan® Expert Committee and the Technical Consultative Committee of APOC recommended that RAPLOA should be undertaken to assess the prevalence of *L. loa* before commencing ivermectin distribution in areas suspected, or known to be endemic for loiasis. Guidelines were also developed to be used in areas where *L. loa* coexists with *O. volvulus* when ivermectin treatment is envisaged (Mectizan Expert Committee, 2004).

APOC was now equipped with two tools: REMO for the rapid mapping of onchocerciasis and RAPLOA for the rapid assessment of loiasis. Using the two protocols, maps of the distribution of the two diseases could easily be generated and superimposed to make a decision on the endemicity of the two diseases and on treatment strategies. These two protocols were initially carried out independently in the field until the feasibility of combining the two protocols was demonstrated in a study carried out in an area co-endemic for the two filarial infections in the rain forest of Cameroon (Wanjii et al., 2005). It became advantageous both in time and cost for the National Onchocerciasis Control Programmes in Africa to combine the two protocols for assessing the level of endemicity of the two infections during surveys in order to facilitate rapid decision-making on treatment, identification of communities at risk and management of side effects. APOC adopted this combination in many surveys carried out in countries where its programme is implemented. This paper reports the results of integrated mapping surveys undertaken in four distinct epidemiological zones in the Democratic Republic of Congo (DRC) and highlights the implications of integrated mapping on the operational functioning of onchocerciasis control programmes in terms of identification of communities to treat and identification of communities at risk of SAEs and their management.

1. Materials and methods

1.1. Study sites

The surveys were conducted between 2004 and 2005 in four onchocerciasis endemic areas in four regions of DRC: Orientale, Katanga, Bas-Congo and Equateur (Fig. 1).

1.2. Orientale

The Orientale province is dense equatorial rain forest with precipitation throughout the year. The River Congo and its affluents (*Tshopo, Lomomi, Lindi and Aruwimi*) constitute the main hydrological network in this region. The population lives on small-scale farming, hunting and fishing.

1.3. Bas-Congo

The topography of the region of Bas-Congo features hills and deep valleys. The climate is tropical and is made up of two seasons: a dry season lasting from June to September and a rainy season from October to May, with a short dry season at the end of December and early January. Population density is concentrated along the main roads and rivers where fertile land is found. Farming is the main activity with maize, cassava, groundnuts, beans and bananas as the main crops.

1.4. Katanga

The climate of Katanga region is equatorial with two seasons: a rainy season (November to April) and a dry season (May to October). The main rivers are the Lualaba, Lufira, Luvua, Lukuga and Lomami. Lake Tanganyika also extends into this region. Other lakes include: lakes Upemba and Kisale. Farming is the main activity in this region and the main crop include maize, cassava, vegetable and potatoes. Small scale cattle rearing and fishing is also carried out in the region.
1.5. Equateur

Three bio-ecological zones characterise this region: a forest area, a savannah and a transitional zone made up of forest savannah. The climate is equatorial with a rainy season lasting for about 9 months (February to November) and a dry season of 3 months (December to February). Temperatures are very high. This region is characterised by its extensive hydrological network. The main rivers are the Ubangi, Uélés, Lokame, Loko, Ligbala, Mongala and Tshuapa. Several swampy areas are also found in this region. The population lives on subsistence farming.

1.6. Survey procedures

1.6.1. REMO

Mass distribution of ivermectin is always preceded by mapping of the target area, using REMO. REMO takes into consideration specific spatio-epidemiological characteristics of onchocerciasis (spatial distribution of vectors around breeding sites in fast-flowing rivers) in the selection of sample villages to be surveyed and in the extrapolation of the findings to the rest of the area. In the selected sample villages, a Rapid Epidemiological Assessment for onchocerciasis (REA) is conducted, which involves the estimation of the prevalence of onchocercal nodules in adult males aged 20 years and above using simple palpation. The REMO procedure and REA surveys follow a protocol described in detail previously (Ngoumou et al., 1994). Briefly, the process follows three successive steps:

The first step is the division of the country of interest into bioclimatic/biogeographical zones, each of which is reasonably uniform with regard to the potential for onchocerciasis;

The second step consists of selecting communities to be surveyed within each survey zone. The main criterion used is the distance between the communities and the rivers, and the location of the communities in first, second, or third line from the river (Prost et al., 1979).

The third step consists of carrying out the surveys. The coordinates of the villages surveyed are recorded using global positioning system (GPS) instruments. In each selected community REA is based on examination for the presence of nodules in a sample of 30 adult males, aged 20 years and above, who have been resident in the community for at least 10 years (Taylor et al., 1992). The sample is selected randomly from those residents whose activities are principally rural. Where the prevalence of nodules is ≥20%, onchocerciasis is considered a public health problem and community treatment with ivermectin is indicated (World Health Organization, 1991).

Once the data have been collected for the target area, they are then integrated in a geographical information system and used to estimate through interpolation the distribution of onchocerciasis endemicity throughout the target area. A three colour scheme is used on REMO maps to indicate different treatment strategies. Red zones indicate that onchocerciasis is highly endemic (nodule prevalence ≥20%) and constitutes a public health problem. These zones are priority areas for community-directed treatment with ivermectin (CDTI). Green zones indicate where mass treatment is not needed. In these zones, the prevalence of sub-cutaneous nodules is <20% and only clinically based treatment with ivermectin is applied. Yellow zones indicate areas where onchocerciasis endemicity data are lacking or insufficient for defining the treatment strategy; there, additional epidemiological assessments may be needed. The onchocerciasis map is then overlaid with a population map, allow-
ing control programmes to plan which communities are eligible for treatment and to estimate the number of treatments required. The details and comprehensive description of REMO was described in REMO Guideline (WHO/TDR, 1995) and recently released REMO BOOK entitled: Charting the Lion’s Stare: the story of river blindness mapping in Africa (WHO/APOC, 2009).

1.6.2. RAPLOA

The RAPLOA procedure is based on the following steps: selection of communities, administration of a community questionnaire, selection of households and individuals to be interviewed, and administration of individual questionnaires.

1.6.2.1. Selection of communities. RAPLOA is intended for use in those communities which are earmarked for inclusion in ivermectin treatment campaigns for onchocerciasis and which are located in areas that are potentially endemic for loiasis.

1.6.2.2. Community questionnaire. A questionnaire is administered to community leaders or key informants (village heads, headmasters, schoolteachers, health workers, patent medicine dealers, traditional healers and leaders of women’s groups) to determine the local names for eye worm, the population size and the number of households in the community.

1.6.2.3. Selection of households. RAPLOA requires that a minimum of 80 subjects of both sexes, aged 15 years and above recruited from randomly selected households in the community be interviewed. The individual questionnaire is conducted at household level and all eligible individuals are interviewed.

1.6.2.4. Individual questionnaire. Individual questionnaires are designed to elicit responses on experience of eye worm. Three key questions are asked chronologically to collect data on the experience of eye worm, the recognition of eye worm from a photograph and the duration of the last episode of eye worm.

The first question asked in each interview is “Have you ever experienced or noticed worms moving along the white of the lower part of your eye?” After recording the response, the interviewer then shows a photograph of the eye worm to each respondent, guiding him/her to recognise the worm. This follows by the second question: “Have you ever had the condition in this picture?” After recording the response, the interviewer proceeds to ask the third question: “The last time you had this condition, how many days did the worm last before disappearing?”

1.7. Processing of results

A respondent is classified as having a history of eye worm when the answers to questions 1 and 2 are both positive and the duration in question 3 is ≤7 days. For each community the results are summarised and the percentage of respondents with a history of eye worm in the community is calculated. If more than 40% of subjects have a history of eye worm, then there is a significant risk of serious adverse reaction to ivermectin treatment.

Once the RAPLOA data have been collected for a given area, they are submitted to a spatial analysis in order to interpolate the prevalence of eye worm throughout the area and prepare a contour map of the estimated prevalence. This analysis is done using kriging (Isaaks and Srivastava, 1989), a geostatistical method for spatial interpolation, which in the present study involved two steps. First, a semi-variogram analysis was done using SURFER 9 software (Golden Software Inc., Golden, USA) to fit a spatial correlation model to the full set of RAPLOA data for all study areas combined. This analysis showed a very high spatial correlation among the RAPLOA data. The best fit was obtained with a spherical model with a nugget of 74, partial sill of 137.5 and range of 1.137. This fitted model was subsequently applied in ARCGIS version 9.2 (ESRI Inc., Redlands, USA) for spatial interpolation and to prepare contour maps of the prevalence of eye worm for each surveyed area.

1.8. Combined rapid mapping of onchocerciasis and loiasis

The integrated mapping work was performed by national teams of the Ministries of Health of endemic countries with a financial and technical support from APOC. To carry out the REMO and RAPLOA Projects, the Management of APOC engage experts who visit the country to be surveyed, train local staff, and oversee the mapping activities. When these technical experts arrive in a country, they plan the exercise with the national teams, who are selected and briefed prior to the arrival of the consultant. Technical advisors then help construct the budget, plan the itinerary, ensure there are sufficient materials for recording results, and train national team members in integrated mapping methods and techniques.

Since 2004, RAPLOA and REMO have been used with a combined protocol for the two procedures in order to accelerate decision-making for onchocerciasis treatment in areas of co-endemicity. In this combination, a team is constituted that carries out both exercises simultaneously. A team made up of 1 REMO surveyor and 2 RAPLOA surveyors and 1 supervisor visit a community only once to evaluate the endemicity of the two diseases. RAPLOA interviews are carried out in households; usually the nodule palpation is done in a fixed post in a given village. The normal practice was that, the RAPLOA surveyors sent eligible individuals for nodule palpation at the REA post. Therefore, all individuals palpated for nodules have been interviewed for RAPLOA.

The results of the RAPLOA and REA are then superimposed to generate a combined map to identify areas where CDTI is recommended and also areas where treatment precautions are needed to monitor the SAEs. Four main scenarios are possible after combining the RAPLOA and REMO maps (Table 1).

2. Results

Integrated REMO/RAPLOA surveys were conducted in 788 villages in four epidemiologically distinct areas of DRC for onchocerciasis and loiasis endemicity. A total number of 25,754 males were examined for the presence or absence palpable nodules (REA) while 62,407 people were interviewed for their history

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Table 1

Possible scenarios and decisions reached after overlapping RAPLOA and REMO maps.

<table>
<thead>
<tr>
<th>Possible scenario</th>
<th>Onchocerciasis prevalence</th>
<th>Loiasis prevalence</th>
<th>Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≥20%</td>
<td>≥40%</td>
<td>Administration of ivermectin through CDTI necessary, high risk of SAEs following treatment, the strict use of the MEC/TCC guidelines required</td>
</tr>
<tr>
<td>B</td>
<td>≥20%</td>
<td>&lt;40%</td>
<td>Administration of ivermectin through CDTI necessary, minimal risk of SAEs following treatment. The use of the MEC/TCC guidelines is optional</td>
</tr>
<tr>
<td>C</td>
<td>&lt;20%</td>
<td>≥40%</td>
<td>No CDTI recommended. Clinically based administration of ivermectin. The use of the MEC/TCC guidelines is recommended</td>
</tr>
<tr>
<td>D</td>
<td>&lt;20%</td>
<td>&lt;40%</td>
<td>No CDTI recommended. Treatment is clinic-based, less risk of having SAEs</td>
</tr>
</tbody>
</table>
of eye worm. Table 2 gives per area the number of communities surveyed, the number of individuals examined and the percentage of communities that exceeded the thresholds of 20% and 40% for REMO/REA and RAPLOA, respectively.

2.1. Study area 1: high level of endemicity of both onchocerciasis and loiasis

In study area 1, in the Orientale region, both onchocerciasis and loiasis were highly endemic. Of the 90 villages surveyed, 69% had an onchocerciasis nodule prevalence $\geq$20% while nearly all villages exceeded the threshold of a 40% prevalence of eye worm (Table 2). The geographic distribution of the results is shown in Fig. 2. Loiasis was clearly highly endemic throughout the area and the level of endemicity even exceeded 60% in most of the surveyed villages (Fig. 2b). The geographical distribution of onchocerciasis endemicity was less uniform, with villages showing the highest endemicity levels located at the outer ring of the surveyed area while most villages with a nodule prevalence <20% were located in the centre of the area. However, even in the centre there were several villages with a nodule prevalence $\geq$20% and the whole area was therefore classified as requiring community-directed treatment with ivermectin (CDTi). Hence, area 1 provides an example of scenario A (Table 1) in which ivermectin treatment is indicated for onchocerciasis control but where there is also a high risk of SAEs because of loiasis.

2.2. Study area 2: high level of onchocerciasis endemicity and low prevalence of loiasis

Study area 2, in the region of Katanga provides a clear example of scenario B (onchocerciasis high, loiasis low). Onchocerciasis was highly endemic with 76% of surveyed villages having a nodule prevalence $\geq$20% (Table 2) while the geographical distribution of onchocerciasis endemicity was fairly even throughout the study area (Fig. 3). In contrast, loiasis was virtually absent from the area with only 7 out of 4400 persons interviewed reporting a history of eye worm. Hence, CDTi is indicated throughout the area and ivermectin treatment could be given without any concern over SAEs due to loiasis.

2.3. Study area 3: of non-overlapping high risk areas for onchocerciasis and loiasis

Study area 3 in the region of Bas-Congo showed a very different epidemiological pattern for the two diseases. In the eastern half of the area, onchocerciasis was highly endemic while the level of endemicity of loiasis was very low and there were no villages with a prevalence of eye worm $> 40\%$. In the western half the epidemiological pattern was the reverse: onchocerciasis was absent or only hypoendemic while the level of endemicity of loiasis was extremely high, indicating a severe risk of SAEs from ivermectin treatment. The high risk zones for onchocerciasis and loiasis do not overlap, and the study area showed a combination of scenario B (onchocerciasis high, loiasis low) in the east where ivermectin treatment is indicated and scenario C (onchocerciasis low, loiasis high) in the west where ivermectin treatment is neither needed nor recommended under the current MEC/TCC guidelines (Fig. 4).

2.4. Study area 4: high endemicity of onchocerciasis and mostly low prevalence of loiasis

Study area 4, in the Equateur region, is much larger than the other study areas with a surface area of around 300,000 km²;
ranking in size between Great Britain and Germany. The mapping of onchocerciasis and loiasis in this area therefore provides an example of truly large-scale application of the integrated mapping method. A total of 499 villages were surveyed for both diseases, and the results are given in Table 2 and Fig. 5. Onchocerciasis was highly endemic throughout this vast area (Fig. 5A), and although there was variation in endemicity levels with the highest levels found near river basins in the centre of the area, there were villages with a nodule prevalence >20% along virtually all rivers, and the whole area was classified as high risk for onchocerciasis and requiring CDTi. The only exceptions where endemicity of onchocerciasis is low were the south western and north western border areas where previous surveys (not described here) had indicated that onchocerciasis was absent or of low endemicity. With respect to loiasis, integrated mapping showed that the level of endemicity was generally low. There were only two pockets in which a few villages had a prevalence of eye worm >40%, but otherwise loiasis appeared absent or of such low endemicity that there would be little risk of SAEs with ivermectin treatment. Hence, most of this vast zone falls under scenario B (onchocerciasis high, loiasis low).

3. Discussion

This paper discusses the combined utilization of RAPLOA/REA procedures on the rapid mapping of onchocerciasis and loiasis and its implications for the implementation of onchocerciasis control programmes. Before the development of RAPLOA, CDTi projects were chosen based on REMO (Ngoumou et al., 1993; Noma et al. 2002) surveys only. With the advent of SAEs following ivermectin treatment (Gardon et al., 1997; Boussinesq et al., 2001) the Mectizan Expert Committee recommended that before introducing mass distribution of ivermectin in an area suspected or known to be endemic for loiasis, RAPLOA should be carried out to assess the prevalence of loiasis (Mectizan Expert Committee, 2004). Since 2004, APOC has adopted the combined use of RAPLOA and REA surveys to establish and map the distribution of these infections and to identify areas in which the two infections co-exist. The ability to simultaneously carry out RAPLOA and REA has had a great impact on the planning and implementation of control programmes in APOC countries (Wanji et al., 2005). The combined use of the two protocols enables APOC to define areas in which the two diseases
co-exist, to generate maps of the two diseases and to superimpose the two maps for decision-making regarding implementation of mass treatment or not and to identify areas where individuals are at risk of SAEs because of loiasis.

The experience in DRC, in which integrated mapping of onchocerciasis and loiasis was undertaken in different epidemiological zones, has demonstrated the practicability of the procedures and the implications for operational decision-making.

In study area 1, both diseases were highly endemic. CDTi was clearly indicated for onchocerciasis control but because of the high level of loiasis endemicity there would be a significant risk of SAEs. Two independent expert committees (the Mectizan Expert Committee and the Technical Consultative Committee of APOC) have carefully reviewed such scenarios and concluded that CDTi is still indicated in such situations because the health benefits of ivermectin treatment of the large number of patients suffering from onchocerciasis outweighs the relatively rare risk of SAEs due to loiasis. Nevertheless, the two committees have issued joint guidelines for reinforced monitoring and improved management of possible adverse reactions in such high risk areas (Mectizan Expert Committee, 2004). The procedures in these guidelines are mandatory for all CDTi projects and APOC is working with national control programmes to provide the necessary capacity and support to ensure that the guidelines are strictly adhered to.

These extra efforts, consuming time and human resources are relatively costly, and are unnecessary in most of the other areas according to the results REMO and RAPLOA. Study area 2 was virtually free of loiasis, and the endemicity levels were low or zero in the eastern half of study area 3 and most of study area 4. This is a very important result that greatly facilitated the accelerated implementation of onchocerciasis control in these areas.

The results for study area 3 provide a very special example of the operational importance of integrated mapping of onchocerciasis and loiasis. Historical data (Fain et al., 1974; Maertens et al., 1971; World Health Organization, 1998) had suggested that the two diseases were both endemic in this area, and the first REMO surveys undertaken in 2001 by national teams indicated that onchocerciasis was hyper endemic throughout Bas-Congo. The whole area was therefore targeted for ivermectin treatment. However, during the first round of treatment in 2003/2004, a large number of SAEs

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**Fig. 3.** Prevalence of onchocerciasis and loiasis in study area 2: Katanga, DRC 2004–2005.
occurred in the western part of the area. It was therefore decided to suspend the treatment programme and to undertake integrated mapping to determine the distribution of loiasis and onchocerciasis in detail. The results showed that both diseases were indeed present throughout the area, but that high levels of endemicity were only found for onchocerciasis in the east and for loiasis in the west, and the high risk areas for these two diseases did not overlap. Hence, CDTi is now only indicated in the eastern part where there is no significant risk of SAEs, and the treatment strategy has been adjusted accordingly. Some important lessons were learned from this experience in Bas-Congo. The integrated mapping results were not consistent with the 2001 REMO data for the western part of the area, and after careful review of all data, it was concluded that the 2001 data had not been accurate. APOC has therefore instituted the use of external experts in all REMO and RAPLOA surveys in order to ensure standardization and quality control. Lessons learned from Bas-Congo also contributed towards the revision in June 2004 of the guidelines for ivermectin treatment in areas co-endemic for onchocerciasis and loiasis (Mectizan Expert Committee, 2004).

These examples show how integrated mapping of onchocerciasis and loiasis has significant operational implications by providing the evidence base for reinforced control operations where needed, and less costly, simple control operations elsewhere. They indicate that co-implementation of REMO and RAPLOA is a cost-effective strategy, but that the data collected should be accurate and validated to enable appropriate decision-making. However, given that each of the two rapid assessment tools have their own specificities (time factor, mode of assessment, selection of participants and sample size requirements), the workability of combining the two methods, has some limitations and challenges (Wanji et al., 2005).

Onchocerciasis mapping has almost been completed in Africa using REMO (Noma et al., 2002), and in 2009, high risk areas requiring CDTi had been identified in over 95% of all potentially onchocerciasis endemic areas. RAPLOA surveys, however, have mainly targeted areas potentially endemic for loiasis for which operational decisions were required concerning the launching of CDTi. Hence, the RAPLOA data, including those from integrated mapping surveys, do not cover all onchocerciasis endemic areas and there are still large gaps for which no data on loiasis endemicity are available. Further integrated mapping surveys are planned for the near future to fill important gaps for operational decision-making on CDTi. In addition, a comprehensive spatial analysis of all
available RAPLOA and parasitological data and remote sensing data on environmental risk factors for loiasis in Africa, will be undertaken in 2010 using a spatial model developed for this purpose (Crainiceanu et al., 2008; Diggle et al., 2007). This will permit the production of a comprehensive map of loiasis in Africa to update and improve on existing loiasis maps based on remote sensing data alone (Thomson et al., 2000). Although this older map has been useful for predicting in which areas loiasis might be endemic, a comparison with the results of the current study showed important discrepancies, e.g. for Bas-Congo, suggesting that the older map is not sufficiently reliable for local operational decision-making on ivermectin treatment.

The combined mapping of loiasis and onchocerciasis significantly reduces the time taken and cost of surveys, and increases the rapidity in decision-making, as a single survey in a given area will be sufficient to assess the level of endemicity of the two filarial species. Hence, combined mapping of onchocerciasis and loiasis is an effective and essential element of sound operational planning of onchocerciasis control in the many areas in Africa where the two infections may be co-endemic.

Fig. 5. Prevalence of onchocerciasis and loiasis in study area 4: Equateur, DRC 2004–2005.

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