

***Stegomyia* indices of *Aedes* aquatic stages in El Geneina town, Western Sudan**

Hamid Hamid,^{1,2} Hiba Musa,¹ Adla Ahmed,² Tayseer Abdul Azeez,² Asma Adam,² Mwahib Abdel Malik,² Azeeza El Tahir,² Hmooda Kafy³ and Rasha Azrag⁴

¹Health & Nutrition Program, Catholic Relief Services Organization, West Darfur State, Sudan. ²Integrated Vector Management Unit, Ministry of Health, West Darfur State, Sudan. ³Directorate General of Primary Health Care, Federal Ministry of Health, Sudan. ⁴Vector Genetics and Control Laboratory, Department of Zoology, Faculty of Science, University of Khartoum, Sudan (Correspondence to: Rasha Azrag: razrag@hotmail.com).

Abstract

Background: Darfur in Western Sudan has the most volatile camps of internally displaced persons (IDPs) and has experienced several outbreaks of dengue, chikungunya and yellow fever.

Aims: To determine the prevalence and *Stegomyia* indices of *Aedes* aquatic stages in El Geneina town, Western Darfur.

Methods: Cross-sectional entomological surveys of immature stages of *Aedes* were carried out during August–November 2019 in 4 sites with IDP camps and a residential area with no camp.

Results: We searched 17 730 houses, IDP camps and buildings of governmental corporations for *Aedes* larvae, and 6809 (38.4%) were positive for *Aedes* aquatic stages. Both *Aedes aegypti* and *Aedes vittatus* larvae were found. However, *Ae. aegypti* constituted > 90% of the larvae. Six positive water containers were recorded: tyres, clay pots, barrels, plastic water tanks, flower vases and old cars: 26% of 92 tyres contained *Aedes* larvae compared to 23.8% of 21 old cars and 17.1% of 44 198 clay pots. This suggested that clay pots were the main source of *Aedes*. The results showed high infestation of El Geneina town with *Aedes* immature stages in all study sites including public buildings and residential areas with no IDP camps. *Stegomyia* indices varied among study sites, and were more elevated in sites with IDP camps. For all sites, House index = 38.40, Container Index = 11.40, Breteau index = 13.60 and Pupa Index = 27.

Conclusion: Multisectoral response coupled with community participation are urgently needed to reduce the burden of *Aedes*-borne diseases in the unstable El Geneina town.

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Introduction

Greater Darfur, Western Sudan, has a history of yellow fever (YF) epidemics and has experienced several outbreaks of dengue fever (DF), dengue haemorrhagic fever (DHF), and West Nile virus (WNV) and chikungunya virus diseases (1–5). Out of the 5 Darfur states, West Darfur was the most affected with high morbidity and mortality rates of DF, WNV and chikungunya virus (3). In August 2019–March 2020 West Darfur State Ministry of Health reported 135 positive cases of DF and 247 positive cases of chikungunya from 5 localities including the capital, El Geneina town (State Ministry of Health, unpublished data, 2020).

West Darfur suffered from civil war unrest due to intercommunal violence. Since 2003, internally displaced persons (IDPs) began flooding into El Geneina town from surrounding areas, which, like much of West Darfur, were greatly affected by militia activity. El Geneina town includes the most vulnerable IDP camps in Sudan as a result of intercommunal violence, which has doubled in the second half of 2020. One of the important results of intercommunal violence that characterize IDPs in El Geneina town is that when attacks happen, IDPs fled and found temporary refuge in public buildings located

within the town or escaped to Chad. There is continuous movement of inhabitants between El Geneina and Adria in Chad for purposes of marketing, seeking healthcare services and escaping intercommunal violence in IDP camps. This movement raises special concern about the transmission of *Aedes*-borne diseases across the countries' borders.

Despite the fact that *Aedes*-borne diseases are reported in El Geneina town, there is a lack of published data concerning *Stegomyia* indices of *Aedes* mosquitoes. The present study aimed to determine the prevalence and *Stegomyia* indices of *Aedes* aquatic stages in El Geneina town during an outbreak of DF and chikungunya.

Methods

Study area

West Darfur State is in the western part of Sudan between 11–15° N and 22–25° E. West Darfur is the least populated state in Darfur, with about 41% of the population residing in IDP camps and hard-to-reach areas. It is located across 2 different climatic zones, savannah with relatively high rainfall in the south and the semi-desert in the north. The state is mainly flat but interrupted in

some areas with small hills and seasonal valleys. The prevailing climate is tropical continental, with temperatures ranging between 10 and 40°C, with a mean monthly temperature of around 35°C. El Geneina town is located in the savannah zone with relatively high rainfall. It lies at an open border with Adri town, Chad (distance < 30 km).

Study sites

Entomological surveys were conducted in 4 residential areas with IDP camps: Omdoin, Ardamate, Elgabal and Almadaris (including both Madinat Elhujaj and Riad IDP camps), in addition to a residential area with no IDPs, El shati in El Geneina town (Figure 1). Each site was divided into 2 groups: households, and IDP camps and public buildings. For surveying purposes, households and IDP camps were grouped together as significant numbers of IDPs live near residences. Public buildings included buildings of governmental corporations, organizations, health facilities, guest houses, tea shops, restaurants, grain mills and garages. Public buildings have different infrastructure which could further affect types, number, volume and usage of water containers; therefore, they were treated as a separate group.

Entomological surveys

Entomological surveys were carried out during August–November 2019. Entomological surveillance data were collected on a daily basis during the study period from all target premises and corporations in the 5 study sites. Data were recorded in a standard modified World Health Organization form. Each team comprised 2 health workers and a supervisor; 1 health worker conducted the

inspection and the other led discussion with household members and distributed information, education and communication materials. Each team visited 20 houses per day. Larvae and pupae from water containers were counted and recorded. All positive water containers were emptied and internal surfaces of water containers were cleaned (source reduction) in the presence of the household head and members, supervisors in public buildings and the sheikh (local leader) in IDP camps.

Morphological identification of *Aedes* larvae

A random sample of *Aedes* larvae from each site was preserved in 80% ethanol for further morphological identification. No morphological identification was carried out on pupal stages. Samples of *Aedes* larvae were morphologically identified using the identification key in Sudan (6).

Calculation of *Stegomyia* indices

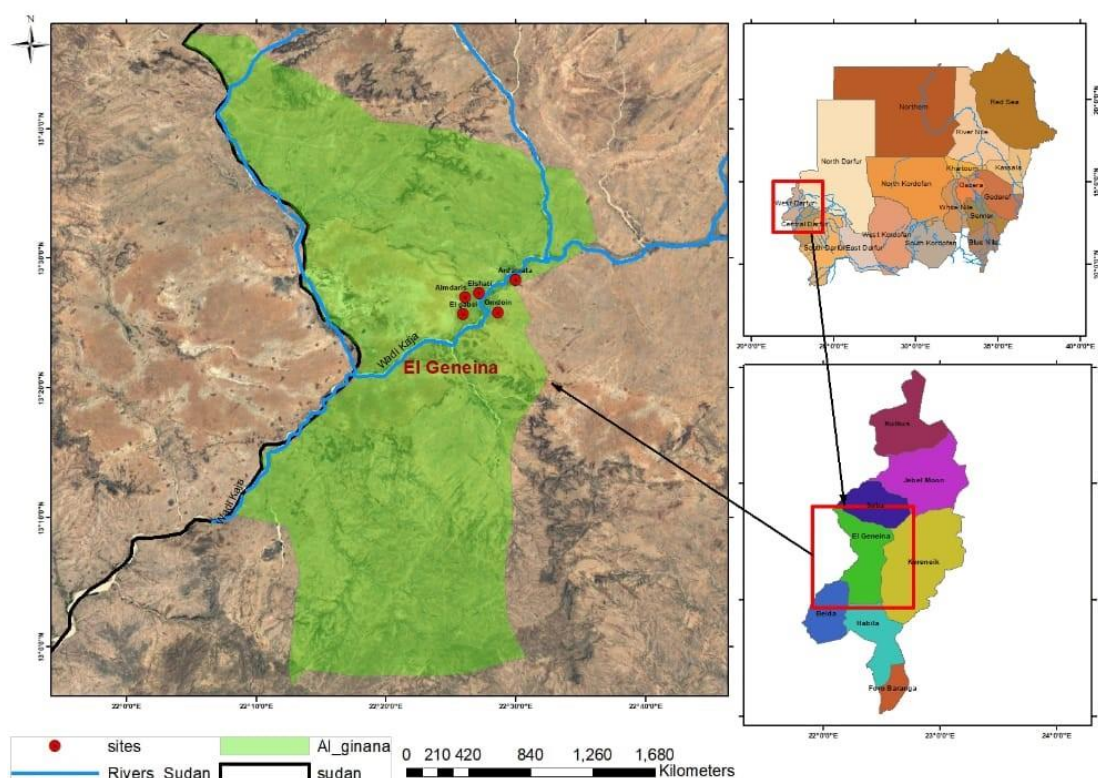
Stegomyia indices were calculated using Microsoft Excel. *Aedes* indices were calculated using the following formulae (7,8):

House Index (HI) = Number of positive houses for *Aedes* larvae and pupae/Number of inspected houses × 100

Container Index (CI) = Number of positive containers with *Aedes* larvae and pupae/Number of containers inspected × 100

Breteau Index (BI) = Number of positive containers with larvae and pupae/Total number of houses inspected per 100 houses.

Figure 1 Location of El Geneina



Pupa Index (PI): Total number of collected pupae of *Aedes* mosquitoes/Total number of inhabitants in the inspected houses per 100 houses.

Productivity of pupae/larvae = Total number of pupae/larvae in specific container or cluster/Total number of pupae/larvae in all containers or clusters.

Results

Identification and prevalence of *Aedes* mosquitoes

Morphological identification of *Aedes* samples showed the presence of 2 species, *Ae. aegypti* and *Ae. vittatus*. *Ae. aegypti* represented > 90.0% of collected larvae and was recorded in all surveyed clusters, whereas *Ae. vittatus* was recorded in Omdoin households and IDP camps in both zeers and water tanks.

Six types of water containers were recorded, which included tyres, clay pots (locally known as zeers and used to preserve drinking water), barrels, plastic water tanks, flower vases and old cars (Table 1). *Aedes* immature stages were more abundant in tyres (26%) and old cars (23.8%) compared to zeers (17.1%). However, tyres and old cars might not represent the main source of *Aedes* mosquitoes due to their low numbers (92 and 21, respectively) compared to zeers (44 198). Flower vases recorded low positivity rates in comparison to water tanks used for preserving water for different household activities such as cooking and washing clothes.

A total of 17 730 households, IDP camps and public buildings were searched for *Aedes* immature stages, and 6809 (38.4%) were positive. The results showed the high infestation of El Geneina town with *Aedes* immature stages in all study sites including public buildings and residential areas with no IDP camps.

Stegomyia indices

Stegomyia indices varied among study sites, and were more elevated in sites with IDP camps compared to those without IDP camps (Table 2). HI and CI were higher in households and IDP camps in Omdoin and Ardamata in comparison with other sites with IDP camps and El shati residential area with no IDP camp. However, public buildings in Elgabal site had the highest HI, CI and BI in comparison with other public buildings in the area. BI was high in both sites with IDP camps and the residential site with no IDP camp. For all sites HI = 38.40, CI = 11.40 and BI = 13.60.

Contribution to production of *Aedes* immature stages

Contribution to productivity of *Aedes* larvae and pupae in all 4 sites with IDP camps (Omdoin, Ardamata, Elgabal and Almadaris) was higher in comparison with El shati residential area with no IDP camps. Despite this, public buildings in Ardamata and Elgabal sites reported higher PI values in comparison with public buildings in other

study sites. Within the sites with IDPs camps both Omdoin and Ardamata reported higher PI (Table 2).

Discussion

The present study documents the presence of *Ae. aegypti* and *Ae. vittatus* mosquitoes during an outbreak of DF and chikungunya in El Geneina town. These species have been previously reported during the 1940s and 1950s (9–11) and recently from different parts of Sudan including Port Sudan, Kassala and Elgadarief (12,13). *Ae. aegypti* is a vector of several globally important arboviruses such as dengue virus, YF virus and chikungunya virus (14–17). In Sudan, *Ae. aegypti* has been involved with outbreaks of YF in the Nuba Mountains and Darfur States, as well as DF and chikungunya in the Red Sea, Kassala and Elgadarief States (12,13,18). *Ae. vittatus* plays an important role in transmitting several arboviral diseases such as YF, DF, chikungunya and zika virus disease (19–21). Therefore, further studies on the possible role of *Ae. vittatus* in transmitting arboviral diseases in El Geneina town are needed.

Six types of water containers were positive for *Aedes* immature stages in El Geneina town; tyres, zeers, barrels, plastic water tanks, flower vases and old cars. However, zeers might have been the main source of *Aedes* immature stages due to high numbers in comparison with other types of water containers. This can be explained by the habit of storing drinking water in zeers. Previous studies conducted in different regions in Sudan have revealed that storing drinking water in zeers and other types of water containers provides suitable breeding sites for *Ae. aegypti* (12,13,22–24).

Many studies have highlighted the impact of climatic conditions on the abundance of *Aedes* mosquitoes (25–27). High abundance of *Aedes* mosquitoes during this study might also be linked to suitable temperature, humidity and rainfall during the rainy season, in addition to storing water for domestic usage. Other studies from neighbouring countries such as Saudi Arabia and other Asian countries have shown that the development of *Ae. aegypti* larvae and pupae in domestic containers occurs due to poor rain fall and water-storage practices (28–33).

In the present study high *Stegomyia* indices (HI, CI and BI) were reported from all sites including residential and public buildings. The high *Stegomyia* indices in public buildings could be attributed to presence of different types of water containers such as old cars and tyres in garages and large-volume barrels and plastic water containers in governmental organizations and guest houses, which hold water for a long time to fulfil the need of employees, vehicles and machines, as well as other general uses. Due to ignorance of proper covering and regular thorough cleaning of these water containers, they could be major source for *Aedes* immature stages. This could explain the high HI, CI and BI in Elgabal.

The high *Stegomyia* indices in Elshati residential area in El Geneina town could be attributed to the high prevalence of tyres, which are a known source of *Aedes* mosquitoes, in addition to its close proximity to Wady

Table 1 Types and positivity rates of water containers with *Aedes* aquatic stages in El Geneina town during August–November 2019

Area	Type of container										All containers	
	Clay pots (zeers)		Barrels		Plastic tanks		Flower vases		Tyres		No. inspected	No. positive (%)
	No. inspected	No. positive (%)	No. inspected	No. positive (%)	No. inspected	No. positive (%)	No. inspected	No. positive (%)	No. inspected	No. positive (%)		
Omdoin												
Households and IDPs	7560	1915 (25.3)	2818	504 (17.9)	3504	235 (6.7)	0	0 (0.0)	0	0 (0.0)	13882	2654 (19.1)
Public buildings	84	38 (45.2)	09	0 (0.0)	57	3 (5.2)	178	2 (2.5)	0	0 (0.0)	328	43 (13.1)
Ardamata												
Households and IDPs	10292	1819 (17.6)	2974	354 (12.0)	4184	243 (5.8)	0	0 (0.0)	0	0 (0.0)	17450	2416 (13.8)
Public buildings	48	3 (6.2)	08	1 (12.5)	02	0 (0.0)	0	0 (0.0)	0	0 (0.0)	58	4 (6.8)
Almadaris												
Households and IDPs	13210	1822 (13.7)	5762	421 (7.3)	4171	91 (2.1)	0	0 (0.0)	0	0 (0.0)	23143	2334 (10.0)
Public buildings	363	9 (2.4)	11	0 (0.0)	57	3 (5.2)	205	2 (0.9)	0	0 (0.0)	636	14 (2.2)
Elgabai												
Households and IDPs	3904	451 (11.5)	1141	50 (4.3)	8563	3 (0.4)	0	0 (0.0)	0	0 (0.0)	13608	504 (3.7)
Public buildings	22	13 (59.0)	03	0 (0.0)	30	11 (36.7)	29	0 (0.0)	04	0 (0.0)	106	29 (27.3)
Elshati												
Households	8690	1501 (17.2)	6854	362 (5.2)	2433	121 (4.9)	0	0 (0.0)	0	0 (0.0)	17977	1981 (11.0)
Public buildings	109	14 (12.8)	47	11 (23.4)	09	0 (0.0)	0	0 (0.0)	88	24 (27.2)	253	49 (19.3)
Grand Total	44198	7585 (17.1)	19627	1703 (8.7)	23010	710 (3.0)	412	4 (0.9)	92	24 (26.0)	87441	10 028 (11.4)

IDPs = internally displaced persons.

Table 2 *Stegomyia* indices of *Aedes* immature stages in El Geneina town during August–November 2019

Area	No. inspected	No. positive	HI	No. container inspected	No. positive	CI	BI	No. larvae	Productivity of larvae	No. pupae	Productivity of pupae	No. Residents	PI
Omdoin													
Households and IDP camp	4000	1999	49.90	13 882	2654	19.00	66.350	33950	0.30	8885	0.290	22886	38.82
Public buildings	48	19	39.60	328	43	13.00	89.580	1502	0.0120	315	0.010	528	59.65
Ardamata													
Households and IDP camp	4500	1823	40.50	17 450	2416	13.80	53.70	31 770	0.270	7896	0.250	29663	26.60
Public buildings	46	4	08.70	58	4	06.80	08.60	150	0.0012	90	0.003	32	281.30
Almadaris													
Households and IDP camps	4480	1450	32.40	23 143	2334	10.0	52.0	26087	0.2280	5871	0.20	28 078	20.90
Public buildings	96	41	42.70	636	14	02.20	14.50	3241	0.0270	956	0.031	4110	23.30
El gabal													
Households and IDP camp	1500	447	29.80	13 608	504	03.90	35.70	7296	0.0620	1716	0.056	9358	18.30
Public buildings	10	6	60.0	106	29	27.30	260.0	566	0.0040	265	0.009	180	147.30
El Shati													
Households	3000	1009	33.70	17 977	1981	11.0	66.10	12 251	0.1050	4459	0.145	18292	24.40
Public buildings	50	11	22.0	253	49	19.30	98.0	237	0.0020	290	0.009	400	07.20
Grand total	17 730	6809	38.40	87 441	10 028	11.40	13.60	117 050	1.0	30 743	1.0	113 527	27.0

BI = Breteau Index; CI = Container Index; HI = House Index; IDP = internally displaced person; PI = Pupa Index.

Kaja in the opposite direction to Omdoin. Wady Kaja banks contain numerous mango and guwafa trees, which are known habitats for *Aedes* aquatic stages.

Pupal index is the best indicator to estimate dengue virus transmission thresholds (34). The pupal index reported in this study during the rainy season was higher than that reported in Eastern Sudan (13), Kenya (35), Ethiopia (36) and Democratic Republic of Congo (37).

The intercommunal violence and instability of the area could complicate the epidemiological situation. Therefore, we consider these indices as alarming as the reported *Stegomyia* indices exceeded the previously mentioned parameter in other cities with DF, YF transmission inside and outside Sudan. In addition, the

location of El Geneina town at the open border with Chad highlight the possibility of cross-border spread of DF, YF and chikungunya diseases.

Conclusion

A multisectoral response coupled with community participation are urgently needed to reduce the burden of *Aedes*-borne diseases in the unstable El Geneina town and to minimize the importation/exportation of communicable diseases through frequent cross-border population movement with Chad. Further studies should be carried out to study the possible role of *Ae. vittatus* in transmission of arboviruses in El Geneina town.

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Competing interests: None declared.

Indices *Stegomyia* parmi les moustiques *Aedes* aux stades aquatiques dans la ville d'El-Genena dans l'ouest du Soudan

Résumé

Contexte : Le Darfour, dans l'ouest du Soudan, compte les camps de personnes déplacées internes les plus instables et a connu plusieurs épidémies de dengue, de chikungunya et de fièvre jaune.

Objectifs : Déterminer la prévalence des moustiques *Aedes* aux stades aquatiques et les indices *Stegomyia* parmi ces derniers dans la ville d'El-Genena, au Darfour occidental.

Méthodes : Des enquêtes entomologiques transversales sur les stades immatures des moustiques *Aedes* ont été réalisées entre août et novembre 2019 dans quatre sites abritant des camps de personnes déplacées internes et dans une zone résidentielle sans camp.

Résultats : Nous avons recherché des larves d'*Aedes* dans 17 730 maisons, camps de personnes déplacées internes et bâtiments de sociétés gouvernementales, et 6809 (38,4 %) étaient positifs pour les stades aquatiques du moustique *Aedes*. Des larves d'*Aedes aegypti* et d'*Aedes vittatus* ont été trouvées. Cependant, *Ae. aegypti* représentait plus de 90 % des larves. Six récipients d'eau positive ont été recensés : pneus, pots en argile, barils, réservoirs d'eau en plastique, vases à fleurs et anciennes voitures : 26 % des 92 pneus contenaient des larves d'*Aedes* contre 23,8 % des 21 anciennes voitures et 17,1 % des 44 198 pots en argile. Cela laisse penser que les pots en argile étaient la principale source d'*Aedes*. Les résultats ont révélé une infestation élevée de la ville d'El-Genena par des moustiques *Aedes* aux stades immatures dans tous les sites examinés, notamment les bâtiments publics et les zones résidentielles sans camps de personnes déplacées internes. Les indices *Stegomyia* variaient selon les sites d'étude ; ils étaient plus élevés dans les sites abritant des camps de personnes déplacées internes. Pour tous les sites, l'indice habitation était de 38,40, l'indice récipient de 11,40, l'indice de Breteau de 13,60 et l'indice pupaire de 27.

Conclusion : Une réponse multisectorielle et la participation de la communauté sont nécessaires de toute urgence pour réduire le fardeau des maladies transmises par les moustiques *Aedes* dans la ville d'El-Genena marquée par l'instabilité.

مؤشرات السَّقَافَات لمرحلة الزاعجة المائية في بلدة الجنية، غرب السودان

حامد حامد، هبة موسى، عادلة أحمد، تيسير عبد العزيز، أسماء آدم، موهب عبد عبدالمالك، عزيزة الطاهر، حمودة كافي، رشا أزرق

الخلاصة

الخلفية: يضم إقليم دارفور غرب السودان أحد أكثر مخيمات النازحين داخلًا تأثرًا، وقد شهدت هذه المخيمات العديد من فاشيات حمى الضنك والشيكونجونيا والحمى الصفراء.

الأهداف: هدفت هذه الدراسة إلى تحديد معدل انتشار مؤشرات "السَّقَافَات" لمرحلة "الزاعجة" المائية في بلدة الجنية، غرب دارفور.

طرق البحث: أُجريت مسوحات حشرية مقطعية للمراحل غير الناضجة من "الزاعجة" خلال شهري أغسطس/ آب ونوفمبر/ تشرين الثاني 2019 في 4 مواقع بها مخيمات للنازحين داخلًا ومنطقة سكنية ليس فيها مخيم.

النتائج: لقد قمنا بتفتيش 17730 موقعًا من المنازل ومخيمات النازحين داخلًا وأبنية المؤسسات الحكومية بحثًا عن يرقات "الزاعجة"، فوجدنا أن 6809 عينات (38.4%) كانت إيجابية للمراحل المائية "للزاعجة". وعُثر على يرقات كل من "الزاعجة المصرية" و"الزاعجة فيتاتوس". إلا أن "الزاعجة المصرية" شكلت أكثر من 90% من اليرقات. وسُجِّلَت ست حاويات مياه إيجابية، وهي إطارات السيارات، والأوعية الطينية، والبراميل، وخزانات المياه البلاستيكية، ومزهريات الزهور، والسيارات القديمة: واحتوى 26% من 92 إطارًا على يرقات "الزاعجة" مقارنة بنسبة 23.8% من 21 سيارة قديمة، و17.1% من 44198 وعاء طينيًا. ويشير ذلك إلى أن الأوعية الطينية كانت المصدر الرئيسي "للزاعجة". وأظهرت النتائج انتشارًا مرتفعًا للمراحل غير الناضجة من "الزاعجة" في بلدة الجنية في جميع مواقع الدراسة، ومنها المباني العامة والمناطق السكنية التي ليس فيها مخيمات للنازحين داخلًا. واختلفت مؤشرات "السَّقَافَات" بين مواقع الدراسة، وكانت أعلى في المواقع التي فيها مخيمات للنازحين داخلًا. وفي جميع المواقع، كان مؤشر المنازل = 38.40، ومؤشر الحاويات = 11.40، ومؤشر بريتو = 13.60، ومؤشر الخادرة = 27.

الاستنتاجات: توجد حاجة ماسة إلى استجابة متعددة القطاعات مقترنة بمشاركة مجتمعية من أجل تخفيف عبء الأمراض المنقولة عن طريق الزاعجة في بلدة الجنية غير المستقرة.

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