

# New Delhi Metallo-beta-lactamase around the world: An eReview using Google Maps

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Gram-negative carbapenem-resistant bacteria, in particular those producing New Delhi Metallo-beta-lactamase-1 (NDM-1), are a major global health problem. To inform the scientific and medical community in real time about worldwide dissemination of isolates of NDM-1-producing bacteria, we used the PubMed database to review all available publications from the first description in 2009 up to 31 December 2012, and created a regularly updated worldwide dissemination map using a web-based mapping application. We retrieved 33 reviews, and 136 case reports describing 950 isolates of NDM-1-producing bacteria. *Klebsiella pneumoniae* (n= 359) and *Escherichia coli* (n=268) were the most commonly reported bacteria producing NDM-1 enzyme. Several case reports of infections due to imported NDM-1 producing bacteria have been reported in a number of countries, including the United Kingdom, Italy, and Oman. In most cases (132/153, 86.3%), patients had connections with the Indian subcontinent or Balkan countries. Those infected were originally from these areas, had either spent time and/or been hospitalised there, or were potentially linked to other patients who had been hospitalised in these regions. By using Google Maps, we were able to trace spread of NDM-1-producing bacteria. We strongly encourage epidemiologists to use these types of interactive tools for surveillance purposes and use the information to prevent the spread and outbreaks of such bacteria.

## Introduction

New Delhi Metallo-beta-lactamase-1 (NDM-1) is the most recently discovered transferable molecular class B beta-lactamase. Unlike class A, C and D beta-lactamases, NDM-1 has zinc ions at its active site, and it can hydrolyse all beta-lactam antimicrobials except for monobactam [1-3]. Moreover, most NDM-1-positive bacteria are resistant to a wide variety of other antimicrobial classes and carry several additional resistance mechanisms for example to aminoglycosides, fluoroquinolones, macrolides and sulfonamides, leaving few

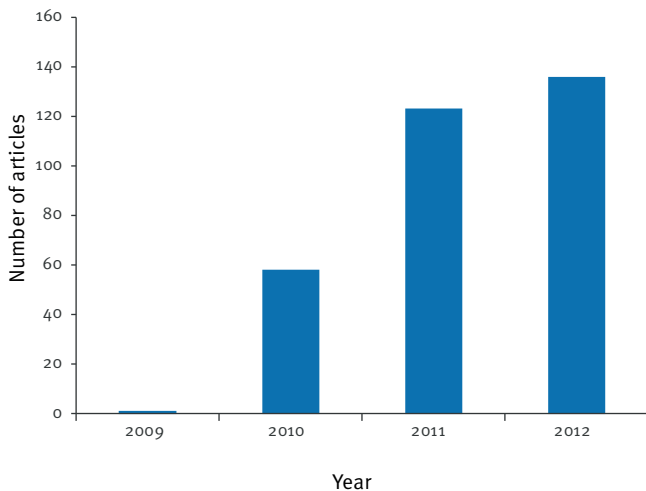
or no therapeutic options [4-8]. The putative original source of the *bla*<sub>NDM-1</sub> gene could be from a chromosome of plant pathogens, such as *Pseudoxanthomonas* and related bacteria that are widespread in the environment [9].

The first published reports of infections involved individuals who had received medical care in India. The precise geographic origin and the time of the first appearance of the *bla*<sub>NDM-1</sub> genes are unknown, however. The first NDM-1-producing bacteria were isolated from a Swedish resident of Indian origin who contracted a urinary tract infection caused by carbapenem-resistant *Klebsiella pneumoniae* while he was in New Delhi in late 2007, hence the name [10]. At present, most bacteria isolated worldwide have originated from people colonised/infected (with or without showing infection symptoms) on the Indian subcontinent who have then traveled elsewhere [3,11]. However, it is presumed that there are other reservoirs of colonised/infected patients in the Balkan countries [12]. There is also an unknown burden in the Middle East, where people often travel to and from the Indian subcontinent [13].

NDM-1-producing bacteria have been recovered from many infection sites; they have been found in patients with urinary tract infections, pneumonia, septicaemia, wound infections and device-associated infections [7,14,15]. Both hospital- and community-acquired infections have been reported [7,14,16]. The following factors have influenced the geographically widespread emergence of these NDM-1-producing bacteria: the increase in long-distance travel [17], the increase in international travel to access medical care [18] and widespread access to broad spectrum antibiotics. The latter is due to the fact that in many countries, antibiotics can be obtained without a prescription because of the strong economic incentives to sell and use them [19].

**FIGURE 1**

Number of articles retrieved from PubMed database using keywords 'NDM-1' or 'New Delhi Metallo-beta-lactamase-1' per year, 1 December 2009–31 December 2012 (n=235)



Given the volume of international travel, the quality of hygienic standards in many countries, and the number of humans carrying NDM-1-producing bacteria, it is likely that these bacteria will continue to spread worldwide [15]. There has been an increase in the number of articles about the 'New Delhi Metallo-beta-lactamase-1' enzyme added to the PubMed database since 2010 (Figure 1), but the current spread of NDM-1-producing bacteria is likely broader than the published reports suggest.

To conduct an eReview of all published isolates worldwide as of end 2012, we used in this article the Google Maps application to simplify and accelerate access to documentation, organise information about published isolates of NDM-1-producing bacteria and provide real-time information to the scientific and medical community about published isolates of NDM-1-producing bacteria around the world. Few studies have used this type of automated system to investigate, in real time, web-based electronic reports for the purpose of monitoring the spread of infectious diseases caused by influenza A (H1N1) and Dengue viruses [20,21]. Google Maps is a widely available, free of charge, and extremely powerful tool for visualisation with a simple, intuitive interface that requires little training or experience to use it. It can be run on any conventional desktop computer or laptop, and there is also a Google Maps application available for mobile phones [22].

Because a visual representation of scientific data is more informative than a written description, this article describes the development of an internet-based mapping and geo-referencing application for tracking the worldwide dissemination of NDM-1-producing bacteria as an example of this application. We analysed in this article the medical literature from the first case report in December 2009 until 31 December 2012.

## Methods

### Literature search in the PubMed database

We started by retrieving all published articles from the PubMed database using 'NDM-1' and 'New Delhi Metallo-beta-lactamase-1' as keywords, from the first case report in 2009 until 31 December 2012. We included in our analysis only the first publications that reported on isolates of NDM-1-producing bacteria. We excluded all consecutive publications about the same isolates with descriptions of genomic or protein analysis or others types of analysis. After reading and analysing the full article, we specifically extracted the year of detection of the isolates, their geographic location (city and country), the NDM-1-producing bacterial species, the number of published isolates, the type of case reports, the title and the full reference for the published article, the link to the isolates description in PubMed database.

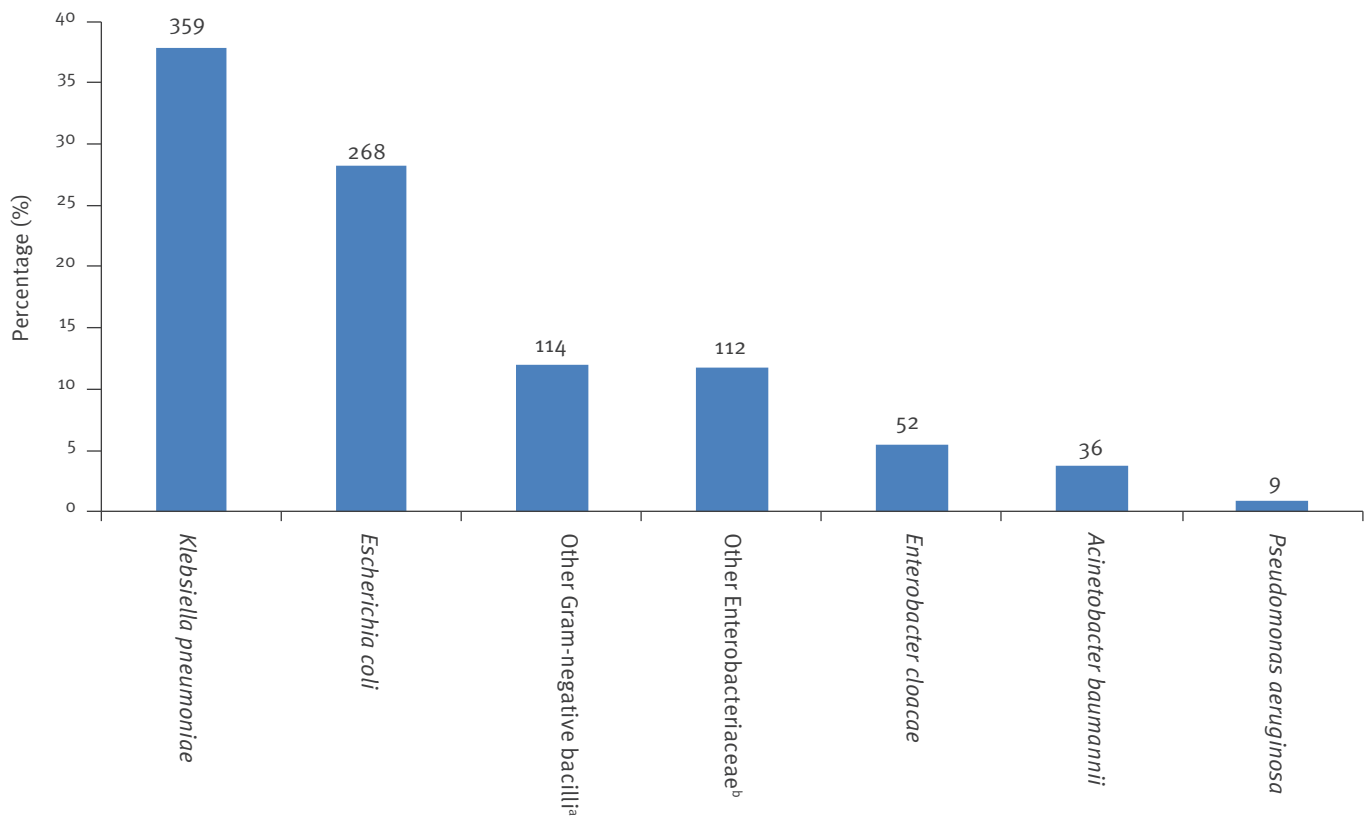
A case report of NDM-1-producing bacteria was defined as a patient from whom one or more Gram-negative bacteria had been isolated that produce NDM-1 or when an isolate from the environment contains NDM-1-producing bacteria, with the test result confirmed by an expert laboratory. We categorised case reports into five different types: (i) imported human infection case reports (NDM-1-producing bacteria isolated from patients with a history of recent travel or contact with healthcare facilities abroad before the detection of *bla*<sub>NDM-1</sub> gene), (ii) autochthonous human infection case reports (reports of patients with an infection caused by NDM-1-producing bacteria who did not have contact with a travel-associated case), (iii) autochthonous human carriage case reports (carriage of NDM-1-producing bacteria in patients who did not have contact with a travel-associated case), (iv) autochthonous environmental case reports (a description of NDM-1-producing bacteria in the hospital or the external environment) and (v) autochthonous human carriage and environmental case reports (a description of the two types of cases in the same article).

### Construction of Google Maps

We used Google Maps to create an electronic map depicting the geographic locations of case reports of NDM-1-producing bacteria listed in our database. Google provides full documentation for Google Maps, tutorials and other materials to help users take full advantage of the application (<https://maps.google.com>). The locations on the map were tagged using different symbols for each type of report of NDM-1-producing bacteria. Clicking the tags will provide a display of the important information about the selected article (the same information stored in the columns in the database). If there are several tags within close proximity to one another, the tags expand outward to facilitate selection of a single tag. Google Maps navigation tabs in the upper left of the screen can be used to zoom in on an area of interest. Alternatively, one can double-click on one of the locations in the table of

**FIGURE 2**

Distribution of New Delhi Metallo beta-lactamase-producing bacteria species, 1 December 2009–31 December 2012 (n=950)



<sup>a</sup> *Acinetobacter pittii* (n=27), *Acinetobacter lwoffii* (n=20), *Acinetobacter* sp. (n=20), *Pseudomonas aeruginosa* (n=9), *Moraxella* ssp. (n=8), *Comamonas testosteroni* (n=7), *Pseudomonas* sp. (n=7), *Stenotrophomonas maltophilia* (n=5), *Vibrio cholerae* (n=3), *Achromobacter* spp. (n=2), *Acinetobacter johnsonii* (n=2), *Alcaligenes faecalis* (n=2), *Pseudomonas pseudoalcaligenes* (n=2), *Pseudomonas putida* (n=2), *Acinetobacter junii* (n=1), *Acinetobacter ursingii* (n=1), *Aeromonas caviae* (n=1), *Kingella denitrificans* (n=1), *Methylobacterium* spp. (n=1), *Pseudomonas oryzae* (n=1), *Suttonella indologenes* (n=1)

<sup>b</sup> *Citrobacter* spp. (n=44), non-determined Enterobacteriaceae (n=15), *Klebsiella* spp. (n=10), *Morganella morganii* (n=8), *Enterobacter* spp. (n=7), *Providencia rettgeri* (n=6), *Klebsiella oxytoca* (n=5), *Proteus mirabilis* (n=4), *Providencia stuartii* (n=3), *Enterobacter aerogenes* (n=2), *Proteus* spp. (n=2), *Citrobacter braakii* (n=1), *Proteus vulgaris* (n=1), *Providencia* spp. (n=1), *Salmonella enterica* (n=1), *Salmonella* spp. (n=1), *Shigella boydii* (n=1)

contents on the left-hand side of the screen to access information about the selected article.

Data retrieved were stored and analysed in Excel (Microsoft, Redmond, WA, USA).

## Results

### The eReview display

To visualise the case reports of NDM-1-producing bacteria detected that have appeared around the world since the first description, we developed a Google Maps application as described in the methods section that is regularly updated and freely available on line at the following website: <http://www.mediterranean-infection.com/article.php?laref=318&titre=new-delhi-metallo-lactamase-around-the-world>. As soon as an article with the keyword 'NDM-1' or 'New Delhi Metallo-beta-lactamase-1' is added to the PubMed database, we automatically receive an alert by email. In less than

10 minutes, we are able to analyse the article, extract the relevant information about the published isolates, add it to our own database and update the map so that the information is freely accessible. Other NDM enzymes are not included in the manuscript but have been added in the Google map website.

### Distribution of case reports of New Delhi Metallo-beta-lactamase-1-producing bacteria

From its first description in 2009 through 31 December 2012, there have been 33 reviews describing the *bla*NDM-1 gene [3,11,14,15,19,23-50], and 136 case reports in the PubMed database, reporting on 950 isolates of NDM-1-producing bacteria from around the world. There have been 66 articles describing imported human infection isolates with 153 (16.1%) isolates of NDM-1-producing bacteria; 57 articles describing autochthonous human infection isolates with 571 (60.1%) isolates of NDM-1-producing bacteria; and 13 articles describing autochthonous human carriage

**TABLE 1**

Bacteria producing New Delhi Metallo-beta-lactamase-1 enzyme reported worldwide by frequency, 1 December 2009 - 31 December 2012 (n=950)

Species	Number of isolates	Percentage of total
<i>Klebsiella pneumoniae</i>	359	37.8
<i>Escherichia coli</i>	268	28.2
<i>Enterobacter cloacae</i>	52	5.5
<i>Citrobacter</i> spp.	44	4.7
<i>Acinetobacter baumannii</i>	36	3.8
<i>Acinetobacter pittii</i>	27	2.8
<i>Acinetobacter lwoffii</i>	20	2.1
<i>Acinetobacter</i> sp.	20	2.1
Non-determined Enterobacteriaceae	15	1.6
<i>Klebsiella</i> spp.	10	1.0
<i>Pseudomonas aeruginosa</i>	9	0.9
<i>Moraxella</i> spp.	8	0.8
<i>Morganella morganii</i>	8	0.8
<i>Comamonas testosteroni</i>	7	0.7
<i>Enterobacter</i> spp.	7	0.7
<i>Pseudomonas</i> sp.	7	0.7
<i>Providencia rettgeri</i>	6	0.6
<i>Klebsiella oxytoca</i>	5	0.5
<i>Stenotrophomonas maltophilia</i>	5	0.5
<i>Proteus mirabilis</i>	4	0.4
<i>Providencia stuartii</i>	3	0.3
<i>Vibrio cholerae</i>	3	0.3
<i>Achromobacter</i> spp.	2	0.2
<i>Acinetobacter johnsonii</i>	2	0.2
<i>Alcaligenes faecalis</i>	2	0.2
<i>Enterobacter aerogenes</i>	2	0.2
<i>Proteus</i> spp.	2	0.2
<i>Pseudomonas pseudoalcaligenes</i>	2	0.2
<i>Pseudomonas putida</i>	2	0.2
<i>Acinetobacter junii</i>	1	0.1
<i>Acinetobacter ursingii</i>	1	0.1
<i>Aeromonas caviae</i>	1	0.1
<i>Citrobacter braakii</i>	1	0.1
<i>Kingella denitrificans</i>	1	0.1
<i>Methylobacterium</i> spp.	1	0.1
<i>Proteus vulgaris</i>	1	0.1
<i>Providencia</i> spp.	1	0.1
<i>Pseudomonas oryzihabitans</i>	1	0.1
<i>Salmonella enterica</i>	1	0.1
<i>Salmonella</i> spp.	1	0.1
<i>Shigella boydii</i>	1	0.1
<i>Suttonella indologenes</i>	1	0.1
<b>Total</b>	<b>950</b>	<b>100.0</b>

and environmental case reports, reporting 172 (18.1%) and 54 (5.7%) isolates of NDM-1-producing bacteria, respectively.

*Klebsiella pneumoniae* (n= 359) and *Escherichia coli* (n=268) were the most commonly described NDM-1-producing bacteria (Figure 2). The *bla*<sub>NDM-1</sub> gene has also been recorded in Enterobacteriaceae other than *K. pneumoniae* and *E. coli* (Table 1); NDM-1-production has been found in clinical *Acinetobacter baumannii* (n=36), *Pseudomonas aeruginosa* (n=9) isolates and in a wide variety of non-fermenting Gram-negative species (Table 1).

### Distribution of autochthonous case reports of New Delhi Metallo-beta-lactamase -producing bacteria by country

In India, NDM-1-producing bacteria were retrieved from patients in many different cities, including Chennai, Guwahati, Varanasi, Mumbai, Haryana, Kolkata, New Delhi, Pune, Bangalore, and Assam. There have been 374 isolates of NDM-1-producing bacteria responsible for autochthonous human infection [6,7,51-66]; 21 isolates of NDM-1-producing bacteria were responsible for autochthonous human carriage [54,67,68], and 22 isolates of NDM-1-producing bacteria were identified in the environment [54,69]. In Pakistan, 32 isolates of NDM-1-producing bacteria were responsible for autochthonous human infection described in nine cities [66, 70], and 101 isolates of NDM-1-producing bacteria were responsible for autochthonous human carriage [70,71]. In China, 16 isolates of NDM-1-producing bacteria were responsible for autochthonous human infection described in eight cities [72-81], 49 isolates of NDM-1-producing bacteria were responsible for autochthonous human carriage [72,82,83], and 30 isolates of NDM-1-producing bacteria were identified in the environment [84-86]. For the remainder countries, 149 isolates of NDM-1-producing bacteria responsible for autochthonous human infection have been identified in the United Kingdom (n=23) [59,66], Canada (n=18) [87-90], Bangladesh (n=17) [91,92], Singapore (n=15) [93-95], Israel (n=10) [96,97], Serbia (n=8) [98,99], Kenya (n=7) [100], Kosovo (n=7) [101], Thailand (n=6) [102], France (n=4) [103-105], Japan (n=4) [106-108], Morocco (n=4) [109,110], South Korea (n=4) [111], Sweden (n=4) [59], Switzerland (n=3) [112], Afghanistan (n=2) [113], Guatemala (n=2) [114], South Africa (n=2) [115], Vietnam (n=2) [116], United Arab Emirates (n=2) [117], Iran (n=1) [118], Mauritius (n=1) [119], Netherlands (n=1) [120], Spain (n=1) [121], and Taiwan (n=1) [122]. Details are included in Figure 3A. Table 2 summarises the distribution of NDM-1-producing bacteria, grouped according to the type of autochthonous case reports in 29 countries. The year of the first description is indicated for each country. The first NDM-1 producing bacteria causing a human infection was isolated in India in 2006 [6], followed by Kenya in 2007 [100] and the Netherlands in 2008, the latter a putative secondary transmission [120].

**TABLE 2**

Distribution of New Delhi Metallo-beta-lactamase-1-producing bacteria reported in autochthonous case reports by country, 1 December 2009–31 December 2012 (n=797)

Type of case reports	Country	Cities	Number of isolates	First description	References
Human infection	Afghanistan	Kabul	2	2011	[113]
	Bangladesh	Dhaka	17	2008	[91, 92]
	Canada	Brampton, Toronto, Winnipeg	18	2009-2010	[87-90]
	China	Beijing, Changsha, Chongqing, Fujian, Guangzhou, Hangzhou, Hebei, Hong Kong	16	2009-2012	[72-81]
	France	Bordeaux, Lyon, Toulon	4	2011	[103-105]
	Guatemala	Not available	2	2011	[114]
	India	Assam, Bangalore, Chennai, Guwahati, Haryana, Kolkata, Mumbai, New Delhi, Pune, Varanasi	374	2006-2007	[6, 7, 51, 51-66]
	Iran	Tehran	1	2011	[118]
	Israel	Jerusalem, Tel Aviv	10	2010	[96, 97]
	Japan	Saitama, Tokyo	4	2010	[106-108]
	Kenya	Nairobi	7	2007-2009	[100]
	Kosovo*	Pristina	7	2010	[101]
	Mauritius	Quatre Bornes	1	2009	[119]
	Morocco	Rabat, Taza	4	2011	[109, 110]
	The Netherlands	Enschede	1	2008	[120]
	Pakistan	Charsadda, Faisalabad, Gujrat, Hafizabad, Karachi, Khan, Lahore, Rahim Yar, Sheikhpura	32	2009	[66, 70]
	Serbia	Belgrade	8	2010	[98, 99]
	Singapore	Singapore	15	2011	[93-95]
	South Africa	Johannesburg	2	2011	[115]
	South Korea	Seoul	4	2010	[111]
	Spain	Madrid	1	2012	[121]
	Sweden	Stockholm	4	2011	[59]
	Switzerland	Geneva	3	2009-2010	[112]
	Taiwan	Taipei	1	2011	[122]
	Thailand	Khon Kaen	6	2010	[102]
	Vietnam	Hanoi	2	2010	[116]
United Arab Emirates	Abu Dhabi	2	2011	[117]	
United Kingdom	10 cities (not available)	23	2011	[59, 66]	
Human carriage	Cameroon	Douala	1	2012	[195]
	China	Beijing, Changsha	49	2011	[72,82, 83]
	India	Chennai, Guwahati, Kolkata	21	2009	[54, 67, 68]
	Pakistan	Rawalpindi	101	2010	[70, 71]
Hospital or the external environment	China	Beijing, Chengdu	30	2012	[84-86]
	India	Kolkata, New Delhi	22	2010	[54, 69]
	Vietnam	Hanoi	2	2011	[116]

\* This designation is without prejudice to positions on status, and is in line with UNSCR 1244/99 and the ICJ Opinion on the Kosovo declaration of independence.

Distribution of imported case reports of New Delhi Metallo beta-lactamase-producing bacteria by country. Several imported isolates of NDM-1-producing bacteria have been reported in a number of countries in different geographical locations, but most of them have been reported in the United Kingdom (n=44) [7,123-125] (Table 3). The first imported NDM-1-producing bacteria was isolated in 2007 in Germany [126], followed by two isolates in 2008 in the United Kingdom [7] and the Netherlands, respectively [127]. In most of the cases, patients had connections to other countries or regions such as the Indian subcontinent (n=121) [7,57, 104,106,109,123-125,128-162], the Balkan (n=11) [8,112,131,163-168], Africa (n=10)[117,123,160,165,169-174], the Middle East (n=6) [175-178], and East Asia (n=5)[179,180]. The patients originated from these areas, had spent time or been hospitalised there, or they might have been secondarily linked to other hospitalised patients who had recently returned from these areas. Figure 3B shows the putative countries of origin for the imported isolates of NDM-1-producing bacteria. The majority of these patients (61.2%) had been previously admitted to hospitals in another country because of an accident or an illness that occurred during their travel, although a minority of patients was traveling for medical reasons.

## Discussion

The data presented indicate a worldwide increase in the spread of NDM-1-producing bacteria and other carbapenemase-producing bacteria [2,7,181]. In this study, we describe 950 isolates of NDM-1-producing bacteria from different types of case reports in 55 countries between 2006 and 31 December 2012, with the majority of isolates of NDM-1-producing bacteria from India, Pakistan and China. It is probable that the number of published NDM-1-producing bacteria underestimates the true number of cases infected/colonised with NDM-1-producing bacteria because most countries do not perform systematic surveillance for such infections with highly resistant bacteria and many bacteria are not tested for the production of NDM-1 enzyme. In some cases, the patient is asymptomatic, so only colonised. In addition, microbiological guidance on the detection and the identification of carbapenemase-producing bacteria is only available in a minority of countries, including the European Union [15,41]. The highest concentration of NDM-1-producing bacteria per million square kilometers of land was found between 30° and 60° northern latitude, with the main hotspots on the Indian subcontinent and in the Balkan countries. Moreover, the majority of the imported isolates described in our survey using published information to display the geographical occurrence of NDM-1, involved patients with a history of recent travel or hospital admission on the Indian subcontinent or in Balkan countries [4,7,15]. In 2008, India and Pakistan received an estimated five million visitors, and an estimated 10 million residents migrated from these countries which amount to a movement and dispersion of 15 million people to third countries [14]. It should be also

noted that for some cases travel alone was sufficient to acquire NDM-1-producing bacteria [182].

In view of this situation, we believe that an immediate response to the emergence of NDM-1-producing bacteria and other carbapenemases should be an urgent priority worldwide. At a local level, patients with a history of travel to or originating from high-risk countries or areas should be screened for NDM-1-producing bacteria [126,127,183,184]. This screening should prevent the development of onward transmission and potential outbreaks and help to optimise the antibiotic therapy. At the international level, the response to growing multidrug resistance of Gram-negative bacteria should be the implementation of a worldwide surveillance network to discover and report emerging resistance traits [29]. To the best of our knowledge, this study is the first that used Google Maps as an interactive and free tool to document all isolates of NDM-1-producing bacteria worldwide. This tool could be also used to document occurrence and spread of other antibiotic resistance genes. It offers a new way to monitor genes responsible for antibiotic resistance, unlike other works that report on the bacteria responsible for infectious disease. Such a development is important because we are now witnessing outbreaks of resistance genes, not bacteria.

Google Maps can be advantageous to the scientific and medical community for a number of reasons. It facilitates (i) counting the isolates producing antibiotic resistance enzymes, (ii) estimating the prevalence of each bacterial species, (iii) differentiating between different types of case reports, (iv) visualising the relationship between the circulation of antibiotic resistance genes and the worldwide human traffic patterns, (v) identifying the origin and reservoir of the antibiotic resistance gene, and finally (vi) communicating information about the local and worldwide dissemination of antibiotic resistance genes in real time. The advantages of Google Maps also include the immediate access to the PubMed publications from the link in the case report description and the real-time update of the map as soon as an article is added on the PubMed database. Google Maps represents a new generation of interactive review capability; it is easy to use, and it is accessible everywhere by everyone, facilitating the diffusion and the circulation of knowledge.

Simple mapping in public health is not new. The cholera map by John Snow marked a critical turn in the use of maps to understand geographic patterns of disease [185]. Moreover, the geographic distribution of scientific data is a growing area of interest in many fields, including infectious diseases [20,186], paleontology [187], natural products research [22], microbial marine biology [188], ecology [189], and archaeology [190]. It allows the presentation of data (even old data) in new ways. For example, a paper examined the geographic origins of emerging infectious diseases from 1940 to 2004, showing non-random global patterns

**TABLE 3**

Distribution of New Delhi Metallo-beta-lactamase-1-producing bacteria reported in imported case reports by country, 1 December 2009–31 December 2012 (n=153)

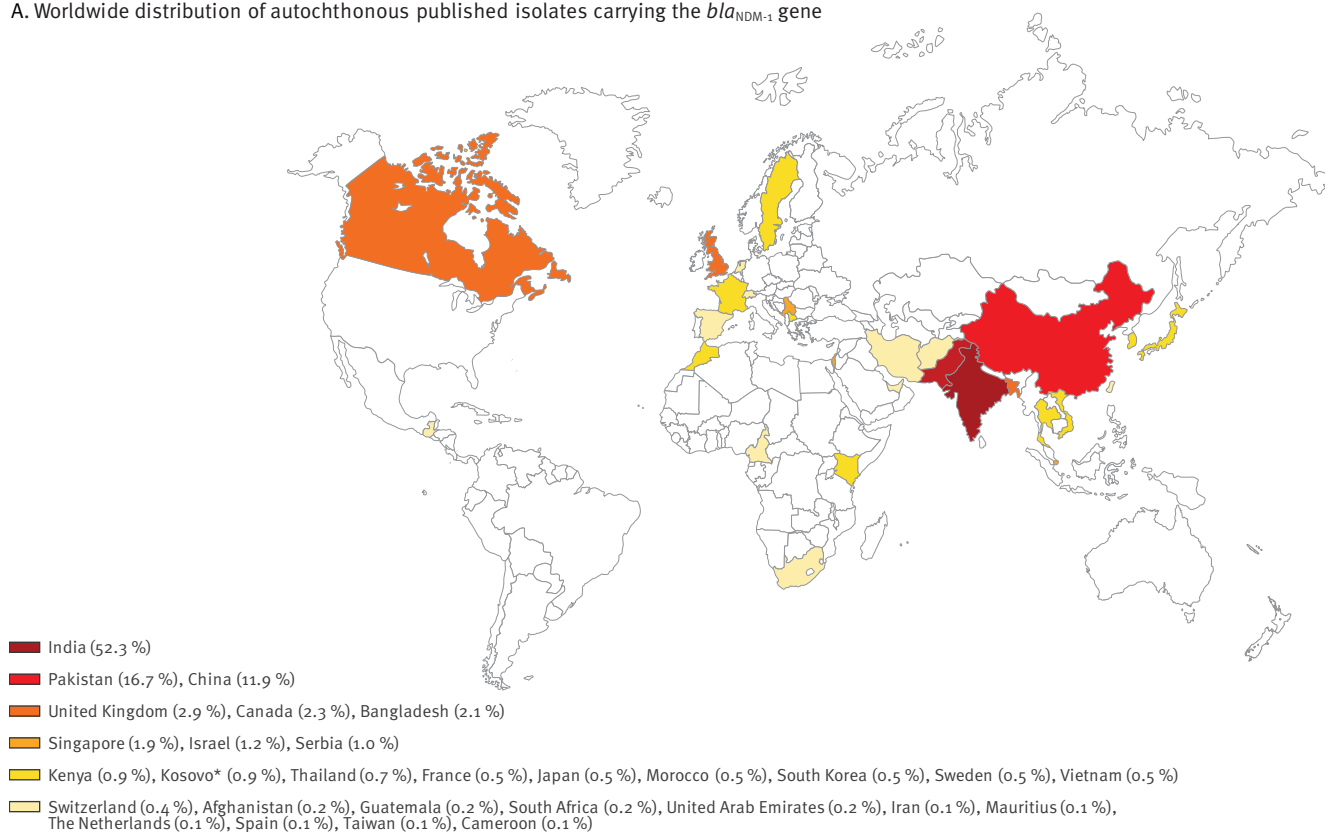
Type of case reports	Country	Cities	Imported from	Number of isolates	First description	References
Human infection	Australia	Sydney (n=3)	Bangladesh (n=1), India (n=2)	3	2010	[128-130]
	Austria	Graz (n=2)	India (n=1), Kosovo* (n=1)	2	2009-2011	[131]
	Belgium	Yvoir (n=1)	Algeria (n=1)	6	2010	[165, 196]
		Antwerp (n=2)	Montenegro (n=2)			
		Brussels (n=1)	Pakistan (n=1)			
		Namur (n=2)	Serbia and Kosovo*(n=2)			
	Canada	Brampton (n=1), Calgary (n=3), Toronto (n=1), Winnipeg (n=2)	India (n=7)	7	2010	[132-134, 162, 197]
	China	Hong Kong (n=1)	India (n=1)	1	2010	[161]
	Croatia	Zagreb (n=1)	Bosnia and Herzegovina (n=1)	1	2009	[166]
	Czech Republic	Plzeň (n=2), Prague (n=1)	Egypt (n=3)	3	2011	[170, 171]
	Denmark	Copenhagen (n=1)	Libya (n=1)	2	2011	[135, 174]
		Hvidovre (n=1)	Pakistan (n=1)			
	France	Lyon (n=3)	India (n=3)	11	2010	[57, 104, 136-138, 160, 167, 168, 172, 175]
		Marseille (n=1)	India (n=1)			
		Paris (n=5)	Algeria (n=1), India (n=1), Iraq (n=1), Serbia (n=2)			
		Saint Pierre (n=2)	India (n=1), Mauritius(n=1)			
	Germany	Not documented (n=1)	Egypt (n=1),	3	2007	[139, 164, 169]
		Bonn (n=1)	India (n=1),			
		Frankfurt (n=1)	Serbia (n=1)			
	Ireland	Dublin (n=1)	India (n=1)	1	2011	[140]
	Italy	Bologna (n=6), Siena (n=8)	India (n=14)	14	2009-2010	[141, 142]
	Japan	Niigata (n=1), Tochigi (n=1), Tokyo (n=1), Soka (n=1)	India (n=4)	4	2009	[106, 143, 144, 159]
	Kuwait	Jabriya (n=2)	India (n=2)	2	2010-2011	[145]
	Lebanon	Beirut (n=4)	Iraq (n=4)	4	2008-2011	[177, 178]
	Netherlands	Utrecht (n=2)	India (n=2)	3	2008	[120, 146]
		Enschede (n=1)	Serbia (n=1)			
	New Zealand	Porirua (n=4)	India (n=4)	4	2009-2010	[147]
	Norway	Tromsø (n=2)	India (n=2)	2	2010	[148]
	Oman	Muscat (n=14)	India (n=14)	14	2010	[149, 150]
	Singapore	Singapore (n=1)	India (n=1)	1	2010	[151]
	South Africa	Johannesburg (n=1)	Mozambique and Zambia (n=1)	1	2010	[173]
	Spain	Barcelona (n=1), Madrid (n=1)	India (n=2)	2	2011	[152, 153]
Sweden	Örebro (n=1)	India (n=1)	1	2009	[10]	
Switzerland	Geneva (n=2)	India (n=1), Serbia (n=1)	2	2009-2010	[112, 154]	
Taiwan	Taipei (n=5)	China (n=4), India (n=1)	5	2010	[155, 179]	
Turkey	Istanbul (n=1)	Iraq (n=1)	1	2011	[176]	
United Kingdom	Bristol (n=5)	India (n=5)	44	2008	[7, 123-125]	
	London(n=39)	India (n=38), Kenya (n=1)				
United States	Atlanta (n=3)	India (n=3),	9	2010	[8, 156-158, 180]	
	Chicago (n=1)	India (n=1)				
	Los Angeles (n=3)	Pakistan (n=3)				
	Providence (n=2)	Vietnam (n=1), India (n=1)				

\* This designation is without prejudice to positions on status, and is in line with UNSCR 1244/99 and the ICJ Opinion on the Kosovo declaration of independence.

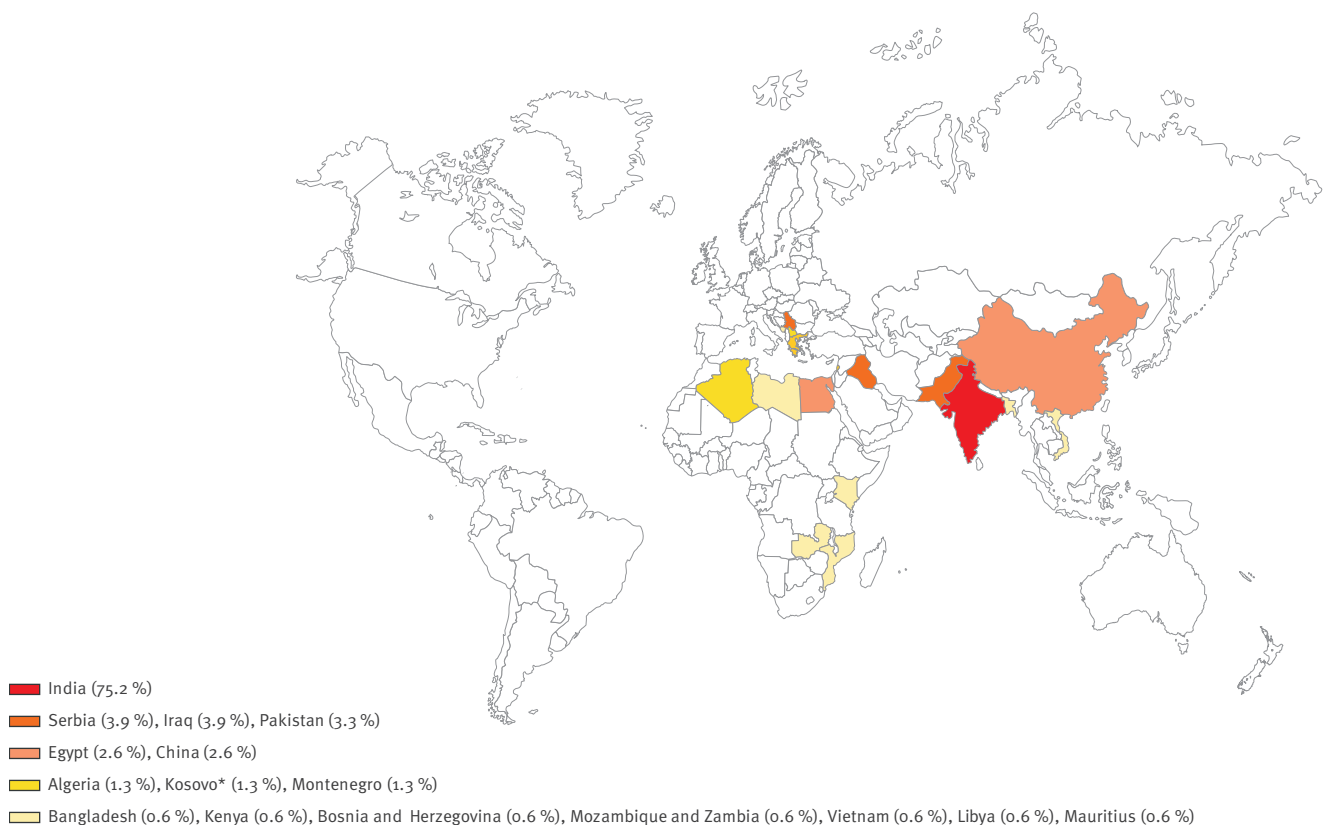
**FIGURE 3**

The worldwide distribution of New Delhi Metallo-beta-lactamase-1-producing bacteria 1 December 2009–31 December 2012 (n=950)

A. Worldwide distribution of autochthonous published isolates carrying the *bla*<sub>NDM-1</sub> gene



B. Putative countries of origin for imported published isolates carrying the *bla*<sub>NDM-1</sub> gene



\* This designation is without prejudice to positions on status, and is in line with UNSCR 1244/99 and the ICJ Opinion on the Kosovo declaration of independence.

NDM-1: New Delhi Metallo-beta-lactamase-1



[191]. Another online, real-time disease outbreak monitoring system, 'HealthMap', developed by the John Brownstein and his team in 2008, has demonstrated the effectiveness of collecting new media sources for improved situational awareness of infectious disease worldwide [192].

Given the popularity of Google Maps, it can be expected that Google will continue to add new features, such as higher resolution, more options for the maps, three-dimensional views, and a Smartphone application. Smartphone applications are a growing field that offers novel approaches, with software that allows data entry and retrieval of data from the maps using a mobile phone [193,194]. The possibilities are vast and for all those interested to better convey information we propose to keep an open mind and test different visual representations. We strongly encourage epidemiologists to embrace new types data collection by using interactive tools for surveillance purposes and perhaps more importantly to communicate these data to other members of the research community and the general public in real time. Using detailed maps to convey such data visually helps to break down communication barriers and bring diverse research ideas together [22].

### Conflict of interest

None declared.

### Authors' contributions

MB, SMD, LM, PP, MD, DR, and JMR analysed the data, and wrote the manuscript. MB and SMD collect the data and build the map.

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