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This is a "Post-Print" accepted manuscript, which has been published in "Foodborne Pathogens and Disease"

Please cite this publication as follows:

Vriesekoop, F., Russel, C., Alvarez-Mayorga, B., Aidoo, K., Yuan, Q., Scannell, A., ... Menz, G. (2010). Dirty money: an investigation into the hygiene status of some of the world's currencies as obtained from food outlets. Foodborne Pathogens and Disease, 7(12), 1497-1502. https://doi.org/10.1089/fpd.2010.0606

Dirty Money.
An investigation into the hygiene status of some of the world's currencies as obtained from food outlets.

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Keywords:
Currency, banknotes, bacteria, pathogens, antibiotic resistance, money

Running Title: Dirty Money

Abstract

A total of 1280 banknotes were obtained from food outlets in ten different countries (Australia, Burkina Faso, China, Ireland, the Netherlands, New Zealand, Nigeria, Mexico, the United Kingdom, and the USA), and their bacterial content was enumerated. The presence of bacteria on banknotes was found to be influenced by the material that the notes were made of, and there was a strong correlation between the number of bacteria per square cm and a series of indicators of economic prosperity of the various countries. The strongest correlation was found with the "index of economic freedom", indicating that the lower the index value, the higher the typical bacterial loading on the banknotes in circulation. The banknotes were also screened for the presence of a range of pathogens. It was found that pathogens could only be isolated following enrichment and their mere presence does not appear to be alarming. The potentially pathogenic isolates from three countries were screened for their susceptibility against the most commonly prescribed antibiotics. The overall incidence of antibiotic resistance of most pathogenic bacteria was typically above 50 %. In light of our international findings it is recommended that current guidelines as they apply in most developed countries with regards to the concurrent hygienic handling of foods and money should be universally adopted. This includes that in some instances the handling of food and money have to be physically separated by employing separate individuals to carry out one task each; while in other instances it could be advantageous to handle food only with a gloved hand and money with the other hand. If neither of these precautions can be effectively implemented, it is highly recommended that food service personnel practice proper hand washing procedures after the handling of money and before handling food.

Introduction

Money is probably the most sought after exchange matter that people seek to obtain in order to barter for good and services, or to accumulate as a safe gathering of wealth. There are not too many people who will abscond from money. Even in economically turbulent times, money is the accepted means of exchange for goods and services with a fixed and often assured face value. Notwithstanding a hastily moving society where credit cards are rapidly replacing the use of hard currencies, cash exchanges still make up a significant means of exchange for small value purchases, while cash is still commonly used in developing countries for high value purchases.

Even though money is highly sought after, it is often seen as a potential source of contamination by bacteria through handling, because its history is at best doubtful: "You never know where the money you receive has been!" The hygienic status of currency has been a scourge to some for over a century. During the late 1800's and early 1900's several authors raised the issue that banknotes could be vectors in the transmission of disease causing microorganisms (Boyer, 1921; Hilditch, 1908; Morrison, 1910; Schaarschmidt, 1884). It was easy then to find heterogenous mixtures of bacteria on currency, as it has been more recently (Abrams and Waterman, 1972; Barro et al., 2006; El-Din El-Dars et al., 2005; Emikpe and Oyero, 2007; Ferenc, 2000; Goktas and Oktay, 1992; Hosen et al., 2006; Oo et al., 1989; Oyero and Emikpe, 2007; Singh et al., 2002; Uneke and Ogby, 2007). However, each of these studies were carried out in complete isolation with no means of comparison or control of sampling and processing.

Many food outlets rely heavily on the exchange of cash for their goods. The possibility that the handling of money by the same person (who also serves and even

prepares the food) might cause contamination has resulted in several changes with regards to *how* foods are handled and traded, especially with regards to ready-to-eat foods. In some instances the handling of food and money have been physically separated, by employing separate individuals to carry out one task each; while in other instances there have been a move to handle food only with a gloved hand. However, employees in the food service industry are still sometimes observed handling both food and money, even with the same gloved hands (Michaels, 2002).

This study aims to provide a cross-sectional overview of the number of bacteria associated with banknotes obtained from food outlets, through a standardised method, and their relative occurrence on commonly handled currency notes from various countries.

1. Materials and Methods

1.1. Sampling and extraction

All banknotes used in this study were sampled from food outlets, with an emphasis on the two most commonly used denominations in the particular country involved. Only banknotes that were not obviously damaged or worn out were used in this study. A basic standardised protocol between collaborating laboratories was used in this investigation. Banknotes were collected from food vending sites and kept in individual sterile stomacher bags. Forty ml of extraction buffer [(g/L) NaCl (10); K_2HPO_4 (2)] was added to each stomacher bag, which was then stomachered twice for 5 minutes with a 30 minute soak-interval.

1.2.Microbial analysis

Bacteria were enumerated on Columbia base agar (Oxoid), while specific pathogens were screened for following enrichment for 24 hours in liquid medium containing [final concentration: (g/L) peptone (9); K_2HPO_4 (6.5); NaCl (2); glucose (1)]. Bacterial cultures presumed to be *Escherichia coli* were screened on Eosin Methylene Blue Agar (Oxoid), and Baird Parker Agar (Oxoid) for *Staphylococcus aureus*, Bacillus cereus Agar (Oxoid) for *Bacillus cereus*, while *Salmonella* was screened for according to the dual enrichment method described elsewhere (Jay et al., 1997). Further identification of these pathogens was carried out as described elsewhere (Vriesekoop and Shaw, 2010). Subcultures of all isolated potential pathogens were screened in duplicate for their ability to grow on Columbia base agar (Oxoid) within 48 hrs while incubated at 37 °C in the presence of 10 mg/L of commonly prescribed, pharmacy supplied antibiotics as described elsewhere (Vriesekoop and Shaw, 2010). Growth was scored as "+" or "─". Good to strong growth

was scored as "+", while the absence of obvious growth (as compared to the control plate) was scored as "—". Each antibiotic was screened individually.

1.3.Scanning Electron Microscopy (SEM) of banknote surfaces

Small sections of banknotes were removed and coated with gold using a sputter coater (Agar Aids, Essex, UK). Banknote surfaces were visualised using a JSM-6300 scanning electron microscope (JEOL, Frenchs Forest, Australia).

2. Results and Discussion

2.1.Enumeration of bacteria on the surface of banknotes

The number of bacteria on banknotes obtained from food outlets varied widely within a single country and to an even greater degree between individual countries (Fig. 1). While there is an obvious difference between the various countries, the numbers of bacteria on different individual banknotes within one single country varied enormously. For instance, the lowest number of bacteria detected on a banknote from the USA was about 20 CFU per note (0.1 CFU per cm^2), while the highest number found in the USA was about 2.5×10^4 CFU per note (128 CFU per cm^2). However the median 50% of notes from the USA contained bacteria in the range from 2.5 to 14 CFU per cm^2. The difference between the ranges of bacteria detected on the banknotes appears to relate to a number of different factors. Firstly, the material used to produce banknotes plays a role in the number of bacteria that can be isolated from banknotes; while the social and/or economical statuses of a given country appears to have a large influence on the disparity in the number of bacteria found on the various banknotes of the various countries.

145 Most banknotes are produced from a cotton-based material, which provides more
146 strength and durability than paper. A recently developed polymer-based substrate
147 presents an alternative banknote material with an even greater durability and strength.
148 The data shown in Figure 1 reveals that banknotes produced on polymer-based substrate
149 have a relatively low bacterial count compared to the cotton-based banknotes. During this
150 study we sampled banknotes in Mexico where the denominations sampled were available
151 concurrently in both polymer and cotton-based notes. The average number of bacteria
152 encountered on the polymer notes was approximately 25% of that found on the cotton-
153 based notes. Hence it is clear that the substrate material plays a significant role in the
154 number of bacteria found on banknotes. The polymer notes are a bi-axial polypropylene
155 based substrate that provides a relatively smooth surface (Fig. 2) that appears to hinder
156 the adherence of bacteria. On the other hand, the cotton-based banknotes provide a
157 fibrous surface, which provides ample opportunity for bacterial attachment.
158 The social and/or economic status of a given country can be expressed in terms of the
159 "index of economic freedom". The index scores most of the world's nations according to
160 ten factors deemed to be of significant influence to the economic freedom of individuals
161 living in a given country. These factors include: business freedom; trade freedom;
162 monetary freedom; freedom from government; fiscal freedom; property rights; freedom
163 to invest; financial freedom; freedom from corruption; and labour freedom (Gwartney
164 and Lawson, 2006). Figure 3 shows the average number of bacteria detected on a range of
165 banknotes from different countries plotted against the index of economic freedom for
166 each country. The correlation between the average number of bacteria on banknotes and
167 the index of economic freedom for banknotes is quite strong (Pearson's correlation

coefficient: *r*-cotton based = 0.92; *r*-polymer based = 0.98). Other indicators of social and/or economic prosperity also show strong correlations, such as: gross domestic product per capita (*r*-cotton based = 0.74; *r*-polymer based = 0.99); Human development index (www.hdr.org) (*r*-cotton based = 0.51; *r*-polymer based = 0.99); while only very weak correlations could be ascertained between the average number of bacteria per cm^2 and the exchange rates of the various currencies. It appears that the coincidence of low economic prosperity and elevated levels of bacteria found on banknotes is linked to generally limited social and municipal sanitary infrastructure. While there are parallels linking socioeconomic development to improved public health programs (Taylor and Hall, 1967); improvements in basic sanitation have in the past been to be linked to enhanced economic progress (Netto, 1968).

It is typically difficult to determine the age of banknotes, since most printworks do not specifically indicate a production date/year. However, the British system is different to most and an approximation of age can be made. Upon examination of the British banknotes we were able to determine that there was a linear correlation between the age of the notes and the signs of wear (taken as folds or creases on the notes). It was observed that on average the number of folds increased by one per year in circulation ($p < 0.05$). This correlation held true for notes up to five years of age. Furthermore, we found that the number of folds on the British banknotes were linked to a logarithmic increase in average bacterial cells found per cm^2 ($p < 0.05$).

2.2.The presence of foodborne pathogens on the surface of banknotes

Further to the quantitative investigation into the occurrence of bacteria on banknotes, we extended our investigation to screen for the occurrence of typical food borne pathogens. Enumeration of pathogens was found to be extremely difficult, presumably because their numerical presence was below that of a typical detection threshold. Furthermore, in the instance of food handling the mere presence of certain pathogens is considered to be potentially detrimental. Hence, we carried out a qualitative analysis to screen for a series of potential pathogens *E. coli*, *S. aureus*, *B. cereus*, and *Salmonella* spp. The presence of *E. coli* (typically associated with feacal contamination) was taken as an indicator of poor hygiene and sanitation standards; while the presence of *Salmonella* spp. was taken as an indicator of severely compromised hygiene and sanitation standards. The presence of *S. aureus* was taken as a "background" microorganism, since it is a common resident bacterium on human skin and all the banknotes analysed in this study were recently handled by hand; while the presence of *B. cereus* was taken as an indicator of the ability of spore forming bacteria to sustain a presence of banknotes. While there was a significant correlation between the overall number of total bacteria and either the index of economic freedom and the material banknotes are made of (Fig 3); there was no discernable correlation between the presence of specific pathogens and any external influence such as banknote substrate or prosperity level of a given country.

Bacterial cultures presumed to be *E. coli* were found at a relatively low incidence (≤ 25 %) in all countries (Fig 4), except for banknotes sampled in the USA and China where the incidence of *E. coli* was 55 % and 50 % respectively. The more severe pathogenic Gram negative bacterium *Salmonella* could not be isolated from the banknotes in most

213 countries, however, *Salmonella* spp. were found to be present on banknotes sampled in
214 the USA, Ireland and China at 4 %, 6 %, and 25 % respectively. It is not clear whether
215 the presence of feacal bacteria on banknotes could cause an infection in those humans
216 that handle and receive the currency, however, the presence of these bacteria is indicative
217 of compromised or poor personal hygiene of those who recently handled the banknotes.
218 *Staphylococcus aureus* is a common skin-associated bacterium, whose presence on
219 recently handled banknotes should not be taken as alarming. The bacterial cultures
220 presumed to be *S. aureus* were found at varying incidences in all countries (Fig 3). The
221 lowest incidence (< 25 %) of *S. aureus* occurred in Australia, Mexico and Ireland; while a
222 relatively high incidence (> 50 %) of *S. aureus* occurred in New Zealand, the Netherlands
223 and China. The spore forming, Gram positive bacterium *Bacillus cereus* was found to be
224 present in relatively low to moderate levels in most countries, while a high incidence (>
225 75 %) of this bacterium was detected on banknotes from New Zealand and China.
226
227 ***2.3.Incidence of antibiotic resistance***
228 Since banknotes are common and continuously in circulation, there is the possibility
229 that banknotes could be an effective vector in the transmission of pathogens. However,
230 while we were able to report on the incidence of a number of potential pathogens on the
231 notes examined, their actual numbers were below the threshold for enumeration. They
232 could only be detected following an enrichment procedure. In a number of instances (in
233 Australia, New Zealand and the USA) we carried out a further investigation into the
234 occurrence of antibiotic resistance against commonly prescribed antibiotics. In Australia
235 and New Zealand we screened for antibiotic resistance against ampicillin, roxythromycin

236 and cefaclor, while in the USA we screened for resistance against ampicillin and
237 tetracycline (Table 1). In all instances did we note a high level of antibiotic resistance
238 against ampicillin among the isolates. The commonly prescribed roxythromycin showed
239 some effectiveness against the Australian and New Zealand isolates of *S. aureus* and *B.*
240 *cereus*, while cefaclor only showed limited or no effectiveness against *B. cereus*. While
241 tetracycline showed a strong antibacterial activity against the USA isolates of *E. coli* and
242 *S. aureus* it only showed limited effectiveness against the *B. cereus* and *Salmonella*
243 isolates.
244
245 In summary, the numbers of bacteria found on banknotes obtained from food outlets
246 vary enormously within individual countries. The variation of bacterial numbers was
247 even greater between separate countries; the dominating influence for the disparity in
248 bacterial numbers appeared to be related to economic factors such as the index of
249 economic freedom. The potential pathogens isolated in this study were present at very
250 low numbers only, however the high incidence of antibiotic resistance among the isolates
251 is a potential cause of concern and severely immuno-compromised individuals should
252 take great care in handling banknotes. Furthermore, commonsense with regards to the
253 hygienic handling of foods and money have to prevail and current guidelines as they
254 apply in most developed countries should be universally adopted. This would mean that
255 in some instances the handling of food and money have to be physically separated by
256 employing separate individuals to carry out one task each; while in other instances it
257 could be advantageous to handle food only with a gloved hand and money with the other
258 hand. If neither of these precautions can be effectively implemented, we suggest that food

service personnel implement proper hand washing procedures after the handling of money and before handling food.

3. Acknowledgements

The authors are grateful for the support they received from Stafford McKnight with the SEM analysis and Julie Worrall for her unrelenting help during the initial stages of the project.

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314 potential vector in the transmission of foodborne pathogens at outdoor eateries.
315 Foodborne Pathogens and Disease. Accepted for publication
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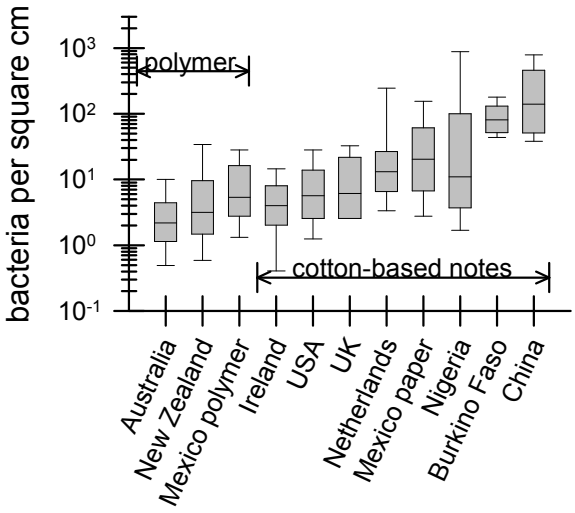
317
318
319
320
321 Table 1. Percentage antibiotic resistance among the potential pathogens isolated from
322 banknotes in Australia, New Zealand, and the USA.

Isolates	*E. coli*				*Staph. aureus*				*B. cereus*				*Salmonella*			
Country/ Antibiotics	Am[#]	Te*	Ro[##]	Ce**	Am	Te	Ro	Ce	Am	Te	Ro	Ce	Am	Te	Ro	Ce
AUS	88	—‡	100	100	43	—	32	71	100	—	40	100	×[†]	×	×	×
NZ	70	—	67	67	30	—	16	32	74	—	11	68	×	×	×	×
USA	91	2	—	—	93	4	—	—	92	58	—	—	94	16	—	—

323 Am[#], resistance to ampicillin at 10 mg L^{-1}
324 Te[*], resistance to tertracycline at 10 mg L^{-1}
325 Ro[##], resistance to roxythromycin at 10 mg L^{-1}
326 Ce[**], resistance to cefaclor at 10 mg L^{-1}
327 ×[†], organisms not found
328 —‡, not tested

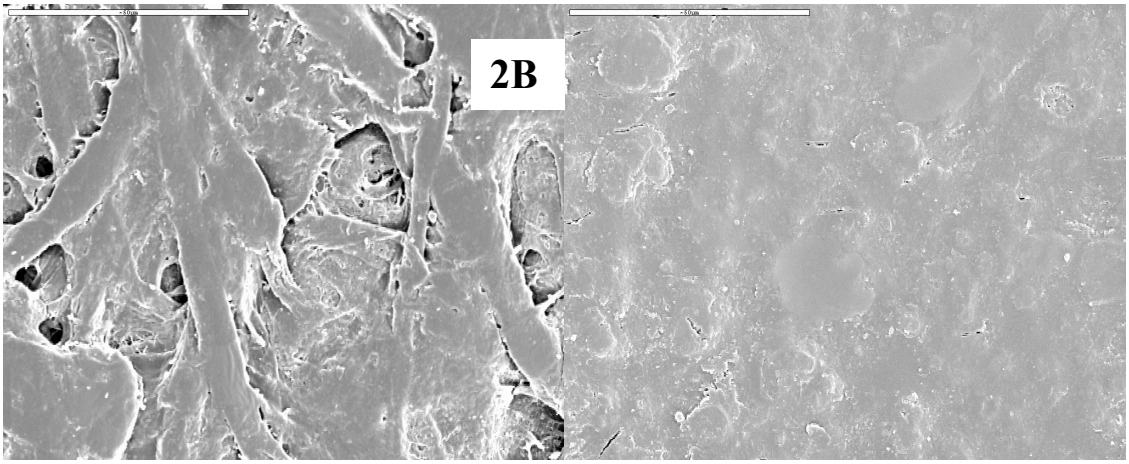


329

330 Figure 1. Number of bacteria per square cm on banknotes. The grey box represents the
331 median data (central 50 %) regarding the number of bacteria on banknotes analysed,
332 while the whiskers represent either the upper or lower 25 % of banknotes analysed.
333 Number of banknotes sampled per country: Australia (134); New Zealand (120); Mexico
334 – polymer notes (129); Mexico – paper notes (81); Ireland (195) USA (118); UK (40);
335 Netherlands (113); Nigeria (60); Burkina Faso (20); China (99).

336

337

338 

339 Figure 2. Electron micrographs of the surface of banknotes. **2A** micrograph of a typical
340 cotton-based banknote (British Pound); **2B** micrograph of a typical polymer-based
341 banknote (Australian Dollar). Bar represents 50 μm.

342

343

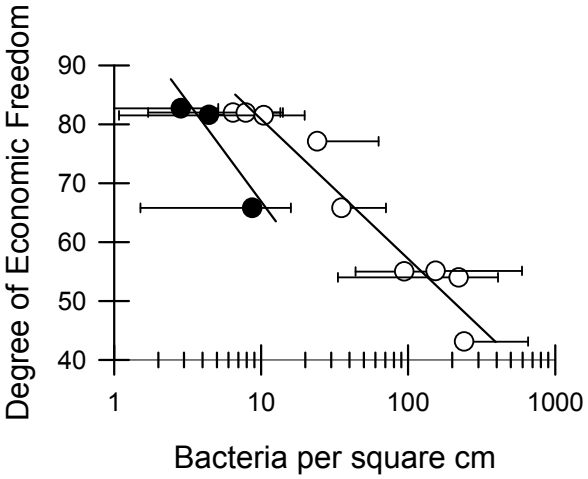
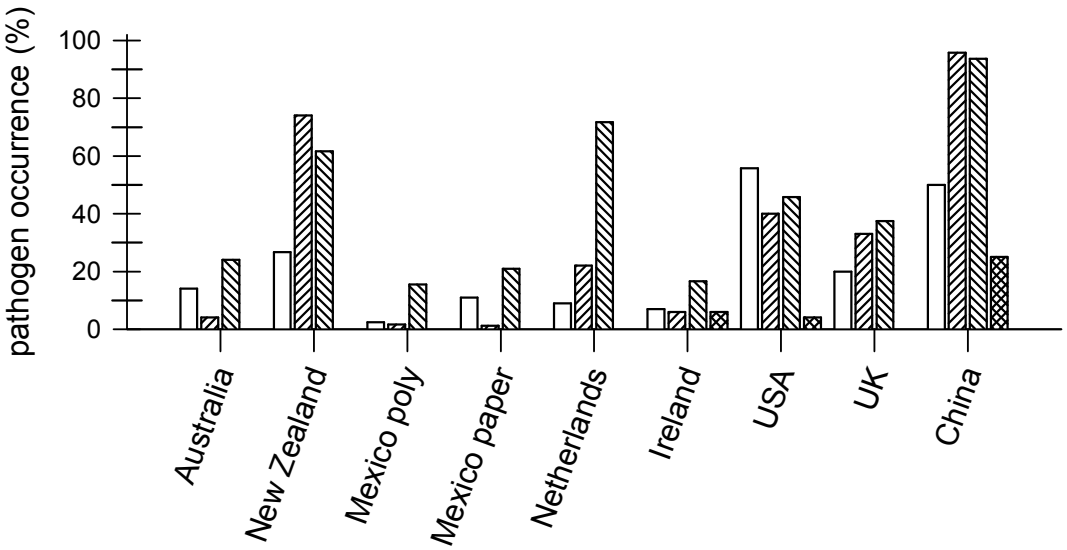


Figure 3. Correlation of average bacterial number (error bars = SD) on banknotes and the Degree of Economic Freedom. ● Average bacterial number of polymer-based banknotes; O Average bacterial number on paper (cotton-based) banknotes.



350

351 Figure 4. The occurrence of presumed pathogens on banknotes. In order of display: blank
352 bars, presumed *E. coli*; diagonal stripes (upwards), presumed *B. cereus*; diagonal stripes
353 (downwards), presumed *S. aureus*; cross-hatched, presumed *Salmonella*. Number of
354 banknotes sampled per country: Australia (134); New Zealand (120); Mexico – polymer
355 notes (129); Mexico – paper notes (81); Ireland (195) USA (118); UK (40); Netherlands
356 (113); China (99).

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