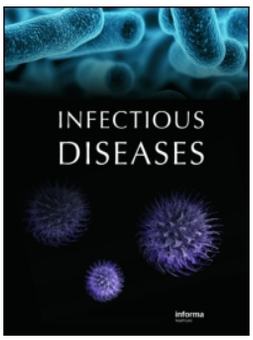

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LETTER TO THE EDITOR

Microbiological contamination of the euro currency in Estonia

Sir,

In the present journal, the potential risk for spread of pathogens by mobile phones was recently highlighted.[1] Ten percent of sampled phones were contaminated with viral pathogens. In daily life, coins and banknotes may be even more important transmission routes of infections. We focused on this route, our aim being to study the bacterial contamination of euro money in Estonia. The 5 cent coins ($n = 22$), 20 cent coins ($n = 20$), 1 euro coins ($n = 15$) and 5 euro banknotes ($n = 24$) were investigated. Aerobic cultures were performed and bacteria were identified by use of mass spectrometry.

The study was conducted in November 2015 and included 29 gymnasium students (17 to 18 years old) who were asked to provide the study with 5 cent coins, 20 cent cons, 1 euro coins and 5 euro banknotes. The coins and banknotes were placed onto the blood agar medium for 5 s and then removed with sterile forceps. The cultures were incubated aerobically at 37 °C for 48 h and thereafter the bacterial colonies were counted. Three predominant morphologically different bacteria of each culture were identified using mass spectrometry (MALDI Biotyper, Bruker Daltonics, Billerica, MA). To identify methicillin-resistant *Staphylococcus aureus* (MRSA), all bacteria of the species *S. aureus* were tested for methicillin resistance using a 30-μg cefotaxim paper disks. Statistical analysis was performed using SigmaStat (Jandel Scientific, San Rafael, CA, USA) and Excel (Microsoft Corp., Redmond, OR, USA). Differences between the groups were calculated using Fisher's test, *t*-test (in case of parametric distribution of data) and Mann–Whitney *U* test (in case of nonparametric distribution of data). Correlations between the different coins were calculated using Spearman' correlation. Differences were considered statistically significant if the p values <0.05.

The mean colony count in 5 euro banknotes was 42.3 (range 10–122), the mean colony count in 1 euro coins 17.5 (2–45), in 20 cent coins 17.4 (1–40) and in 5 cent coins 15.7 (1–45). When we calculated the density of bacteria per square centimeter, the coins turned out to be more contaminated than paper money (Table 1). A very strong association was discovered between the coins of one person – the strongest correlation was revealed between the contamination of 5 cent and 20 cent coin ($R = 0.82$, $p < 0.01$) while positive correlation was present also between 5 cent and 1 euro ($R = 0.53$, $p = 0.049$) and 20 cent and 1 euro ($R = 0.61$, $p = 0.02$). No correlations between coins and banknotes were revealed. All banknotes originated from the year 2013 but the year of coins differed: 5 cent coins from period 1999 to 2011, 20 cent coins also from the period 1999 to 2011 and 1 euro coins from period 1999 to 2014. We did not reveal association between bacterial contamination and release year.

In total, 49 different bacteria belonging to 4 phyla were found from the coins and banknotes, the most numerous being different species of staphylococci (Table 2). The highest number of different species were found from 5 euro banknotes (39 species). The 1 euro coins displayed 11 species, 20 cent coins, 21 species and 5 cent coins, 17 different species. Six isolates were identified as *S. aureus*, none of which MRSA (growth free zones were 23–42 mm).

Hence, our study revealed on the average nearly 4 culturable aerobic bacteria per square centimeter of the euro coins and nearly one bacterial cell per square centimeter of 5 euro banknote. Altogether 49 species of 4 phyla were found. Contamination levels of different coins were in strong correlation.

Previous studies have indicated that contamination of currency may vary in wide ranges depending on material, country, climate and age.[2] Bacterial counts on the surface of the polymer-based banknotes are much lower than on cotton-based notes that are used in most of countries.[3] The euro banknotes are made of 75% cotton and of 25% of linen, too. Very high colony counts have been found on currency from Rangoon, Myanmar (up to $2.9 \times 10^7/cm^2$) [4] and Nigeria (up to 4×10^5 CFU).[5] At the same time, new banknotes have been found to be bacteria-free.[6] Many different species have been detected from banknotes but gram positive bacteria prevail in Westerns countries in general. In some studies also the causative agents of intestinal infections, tuberculosis and other infections have been found on the surface of banknotes.[2] The banknotes of our study contained on the average 1.16 (range 0.28–3.39) culturable aerobic bacteria per square centimeter on their surface that is quite a moderate microbial load. Since Estonia belongs to the Nordic countries it can be associated with good hygiene habits on one side and quite cold climate on the other.

Coins are made of different materials but they contain different proportions of copper that is considered to be limiting factor of microbial contamination. However, both gram positive and gram negative opportunistic bacteria have been found on the surface of coins. Multiple genes that are potentially involved in copper resistance have been identified in these bacteria.[2,7] We assumed that different coins (5 cent, 20 cent, 1 euro) may display different contamination level due to different material but all the investigated coins displayed quite similar results (Table 1). All of these coins contain copper. At the same time the coins were more contaminated than paper money in our study, a finding which may apparently be due to the size of the surface in contact with the skin of hands.

It has been supposed that antibiotic resistance genes may be transmitted via currency.[8] Experimental studies have indicated that MRSA could not survive in an environment in

which no organic protection was offered, but these organisms did survive relatively well in an environment in which pus or blood was present and can offer the organisms protection from desiccation, therefore, contaminated coins may serve as a potential source for MRSA.[9] In our study, six isolates of *S. aureus* were found, none of which MRSA. This result is in accordance with antimicrobial resistance surveillance data indicating that less than 5% of infections with *S. aureus* in Estonia are associated with MRSA.

Although the source of each microorganism cannot be verified, our results generally coincided with the results of other studies [2] that most of bacteria on currency are common cutaneous (*Staphylococcus*, *Micrococcus*, *Kocuria*, *Corynebacterium*) or environmental bacteria (*Acinetobacter*, *Aerococcus*, *Bacillus*, *Brevibacterium*, *Cellulosimicrobium*, *Chryseobacterium*, *Lysinibacillus*, *Microbacterium*, *Paenibacillus*, *Pseudomonas*, *Roseomonas*) that do not constitute a significant threat to health. It has been shown that cutaneous bacteria survive well on dry copper surfaces.[7] It is interesting to note that a species of the latter genus, *Roseomonas pecuniae* was first time found from euro coin.[10] *Kocuria*, *Leuconostoc*

Table 1. Density of aerobic culturable bacteria on the surface of euro currency.

	Colony count per cm^2		
Coins and banknotes	Mean	Range	Difference from 5 euro
5 Euro	1.16	0.28–3.39	
1 Euro	4.22	0.48–10.83	$p < 0.001$
20 Cent	4.59	0.26–10.52	$p < 0.001$
5 Cent	4.53	0.29–12.99	$p < 0.001$

Table 2. Bacteria isolated from euro currency.

			No of contaminated coins or banknotes with particular microorganism[a]			
Species	Family	Phylum	5 Cent	20 Cent	1 Euro	5 Euro
Acinetobacter junii	*Moraxellaceae*	*Proteobacteria*				1
Acinetobacter lwoffii	*Moraxellaceae*	*Proteobacteria*	1	1		1
Acinetobacter schindleri	*Moraxellaceae*	*Proteobacteria*		1		1
Actinomyces naeslundii	*Actinomycetaceae*	*Actinobacteria*				1
Aerococcus viridans	*Aerococcaceae*	*Firmicutes*				1
Bacillus cereus	*Bacillaceae*	*Firmicutes*	1	1		1
Bacillus licheniformis	*Bacillaceae*	*Firmicutes*		1		1
Bacillus megaterium	*Bacillaceae*	*Firmicutes*			1	2
Bacillus mycoides	*Bacillaceae*	*Firmicutes*			1	1
Bacillus pumilus	*Bacillaceae*	*Firmicutes*				4
Bacillus simplex	*Bacillaceae*	*Firmicutes*				1
Bacillus subtilis	*Bacillaceae*	*Firmicutes*				2
Bacillus thuringiensis	*Bacillaceae*	*Firmicutes*				2
Brevibacterium casei	*Brevibacteriaceae*	*Actinobacteria*				1
Cellulosimicrobium cellulans	*Promicromonosporaceae*	*Actinobacteria*	1			
Chryseobacterium gleum	*Flavobacteriaceae*	*Bacteroidetes*				2
Corynebacterium afermentans	*Corynebacteriaceae*	*Actinobacteria*		1		
Corynebacterium mucifaciens	*Corynebacteriaceae*	*Actinobacteria*	1			1
Corynebacterium xerosis	*Corynebacteriaceae*	*Actinobacteria*	1		1	
Kocuria carniphila	*Micrococcaceae*	*Actinobacteria*				1
Kocuria kristinae	*Micrococcaceae*	*Actinobacteria*	1	1		
Leuconostoc mesenteroides	*Leuconostocaceae*	*Firmicutes*		1		
Lysinibacillus sphaericus	*Bacillaceae*	*Firmicutes*				1
Macrococcus caseolyticus	*Staphylococcaceae*	*Firmicutes*				1
Microbacterium aurum	*Mycobacteriaceae*	*Actinobacteria*				1
Micrococcus luteus	*Micrococcaceae*	*Actinobacteria*	8	8	7	23
Moraxella sp.	*Moraxellaceae*	*Proteobacteria*			1	1
Neisseria flavescens	*Neisseriaceae*	*Proteobacteria*		1		1
Neisseria sp.	*Neisseriaceae*	*Proteobacteria*				1
Paenibacillus sp	*Paenibacillaceae*	*Firmicutes*		1		
Paenibacillus urinalis	*Paenibacillaceae*	*Firmicutes*		1		
Pantoea agglomerans	*Enterobacteriaceae*	*Proteobacteria*				1
Pantoea calida	*Enterobacteriaceae*	*Proteobacteria*				1
Pseudomonas stutzeri	*Pseudomonadaceae*	*Proteobacteria*		1		1
Roseomonas mucosa	*Acetobacteraceae*	*Proteobacteria*	1			
Rothia aeria	*Micrococcaceae*	*Actinobacteria*				1
Rothia amarae	*Micrococcaceae*	*Actinobacteria*		1		1
Staphylococcus aureus	*Staphylococcaceae*	*Firmicutes*	1	1	2	2
Staphylococcus auricularis	*Staphylococcaceae*	*Firmicutes*	1			1
Staphylococcus capitis	*Staphylococcaceae*	*Firmicutes*	4	5		3
Staphylococcus cohnii	*Staphylococcaceae*	*Firmicutes*		1		
Staphylococcus epidermidis	*Staphylococcaceae*	*Firmicutes*	11	10	8	11
Staphylococcus haemolyticus	*Staphylococcaceae*	*Firmicutes*			1	3
Staphylococcus hominis	*Staphylococcaceae*	*Firmicutes*	3	1	1	6
Staphylococcus pasteuri	*Staphylococcaceae*	*Firmicutes*	1	2		2
Staphylococcus saprophyticus	*Staphylococcaceae*	*Firmicutes*	1	1	4	
Staphylococcus sp.	*Staphylococcaceae*	*Firmicutes*				1
Staphylococcus warneri	*Staphylococcaceae*	*Firmicutes*	6	2	3	5
Streptococcus sp. viridans-gupp	*Streptococcaceae*	*Firmicutes*	1			6

[a]Altogether twenty-four 5 euros, fifteen 1 euro, twenty 20 cents and twenty-two 5 cents were available.

and *Macrococcus caseolyticus* are used in food industry therefore these bacteria could emanate from foodstuffs but also from animals.

Our study revealed an interesting tendency – a very strong association was discovered between the coins of one person that can be related to the general hygiene habits as well as the place where the coins are held. This issue needs to be clarified in future studies.

In conclusion, many different bacteria can be found from current money originating from both human body and environment. Therefore, the money can be a potential carrier of infectious agents. The information about microbiological contamination of money should be disseminated that hopefully helps to improve the people's hygiene habits.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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