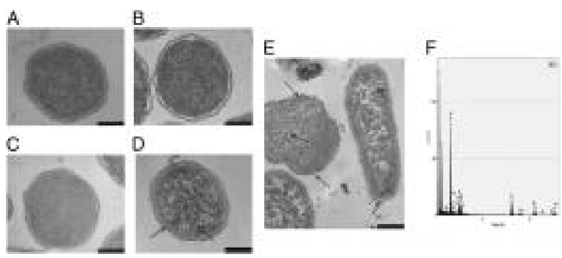
Noxious nanotech: Water-borne nanomaterials promote multidrug-resistance gene transfer

March 30 2012, by Stuart Mason Dambrot



TEM detection of E. coli in ultrafine slices and elemental analysis. (A) In the control group, the cell membranes are distinct and the cytoplasm is compact. There were no highly dense particles in these cells. (B and C) The cell membranes of bacteria that were treated with different concentrations of bulk alumina (B, 5 mmol/L; C, 50 mmol/L) are distinguishable, and the cytoplasm is compact. There are no highly dense particles in these cells. (D and E) The cell membranes of bacteria that were treated with different concentrations of nanoalumina (D, 5 mmol/L; E, 50 mmol/L) were damaged, and the extent of damage increased with increasing concentration of nanoalumina. There were also many highly dense particles in the cells (indicated by arrows), and the number of highly dense particles increased with increasing concentration of nanoalumina. (Scale bars, 100 nm.) (F) The composition of chemical elements in the bacteria from D. Elemental aluminum (from nanoalumina) gave the highest counts; elemental copper originated from the copper net, whereas lead, arsenic, and other elements came from dye liquid or bacteria. Image Copyright © PNAS, doi: 10.1073/pnas.1107254109

(PhysOrg.com) -- The arms race between effective antibiotic prophylaxis and closely related strains or species of bacteria is continually escalating. Bacteria can quickly develop genetic resistance to a range of antibiotic treatments – genes that can spread though *horizontal conjugative transfer* due to antibiotics used in medicine and animal feed, as well as increasing presence in the environment (for example, water supplies and wastewater seepage). Moreover, this pattern can reach global levels in the emergence of so-called superbugs that can be extremely difficult to treat. Recently, scientists at the Key Laboratory of Risk Assessment and Control for Environment and Food Safety, at the Institute of Health and Environmental Medicine in Tianjin, China investigated the role of nanomaterials in conjugative gene transfer between bacteria. In addition, they studied the mechanisms associated with related morphological, biochemical, and molecular biological changes. They found that nanoalumina (a form of aluminum) in water promotes such transfer of multidrug-resistant genes. They concluded that their findings are important in assessing the environment risk of nanomaterials in the manufacture and deployment.

Jun-Wen Li, Zhigang Qiu, and other researchers told *PhysOrg* that the main challenges in determining the role of nanoalumina in promoting the transfer of multidrug-resistance genes had to do with the construction of their multidrug-resistance genes transfer model – specifically, determining how to exclude the effects of all variables except for the nanostructure of the materials and how to evaluate the main aspects of conjugative transfer. “We designed an orthogonal experimental design to evaluate the main factors on the conjugative transfer, and this protocol reduced the number of experiments we needed to perform.” says Qiu. Orthogonal design allows the reliable evaluation of multiple variables in a single experiment.

“We constructed the resistance genes transfer model using resistance plasmid with conjugative transfer functions,” he continues, “and acquired many receptors which contained specific antibiotic resistance by mutation induction." In order to exclude the effects of other factors except the nanostructure of the materials, they set a number of control experiments.

Further innovations are possible, Li adds. "It's possible to quantitatively analyze the transconjugant occurrence in regards to time using kinetics, including mass-action forms. This would provide simultaneous treatment of these processes in a more rigorous data interpretation. Moreover, notes Qiu, there are two aspects in our team's next research step. "Firstly, we'll investigate the effect of more nanomaterials, including different kinds, crystal types and sizes, on the conjugative transfer of resistance gene to improve the data on the impact of nanomaterials on gene transfer. Secondly," he continues, "we'll carry out the experiments to evaluate the effects of nanomaterials on the naked plasmid transfer into living cells by transmission and transduction." (Transmission and transduction are the other two pathways for plasmid-mediated gene transfer.) Finally, they agree that it's possible to transition to *in silico* modeling.

As to how their findings might impact the development of medical, healthcare and environmental technology and practices, Li and Qiu point out that "Despite the fact that nanotechnology is often described as a future technology, few realize that nanomaterials are actually already being used in a wide variety of consumer products – and many new nanotechnologies and nanomaterials are being investigated to be applied to medicine, healthcare and the environment. Many people have concerned about the exposure of nanomaterials, and our work is only a small part in all the work to evaluate the effect of nanoparticles." However, they emphasize that their findings are directly related to medical, healthcare and environmental factors.

"For example," they illustrate, "many new materials were investigated to be used as drug carriers. We must evaluate the effects of these nanomaterials on the antibiotic-resistant bacteria in our body *before* the practical application of these nanomaterials. Also," they continue, "the nanomaterials used as antiseptic or antibacterial agents in healthcare, and as adsorbents and oxidants in environmental technology and practices, must be evaluated completely. We believe that our findings dramatically improve the development of medical, healthcare and environmental technology and practices, and make nanomaterial applications more secure."

Further afield, Qiu and Li conclude that important technologies and applications to transfer exogenous genes into cells, which have been widely used in the field of molecular biology – such as conjugative transfer, transmission, transduction and transfection – might benefit from their findings. "Nanomaterials might promote those processes and enhance transfer efficiency of exogenous genes."

More information: *Nanoalumina promotes the horizontal transfer of multiresistance genes mediated by plasmids across genera*, *PNAS* Published online before print March 12, 2012, doi: 10.1073/pnas.1107254109