New Catalytic DNA Biosensors for Radionuclides and Metal Ions

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We are developing new DNA biosensors for simultaneous detection and quantification of bioavailable radionuclides, such as strontium, uranium, technetium, and plutonium, and metal contaminants, such as lead, chromium, and mercury [1,2] They will be applied to the on-site, real-time assessment of concentration, speciation, and stability of the radionuclides and metal contaminants during and after bioremediation. To achieve this goal, we have employed a combinatorial method called "in vitro selection" to search for catalytic DNA molecules that are highly specific for radionuclides or other metal ions [3]. The DNA has been labeled with fluorescent donor/acceptor pairs to investigate and to signal the structural changes upon metal ion binding. Once a collection of individual DNA sensors is identified, each one specifically for a particular metal ion at a certain concentration range, they will be assembled into a DNA microarray for the simultaneous detection and quantification of radionuclides and metal contaminants.

We have successfully used the methodology mentioned above to develop a highly sensitive and selective DNA biosensor for Pb^{2+}, with a quantifiable detection range from 10 nM to 4 μM [4]. Even in the presence of other metal ions, this biosensor displays a remarkable sensitivity and selectivity. Recently we have carried out several studies to further improve the sensor's sensitivity and selectivity. For example, by combining both inter- and intramolecular quenchers, we have improved the signal to noise ratio significantly [5]. To further improve the metal ion selectivity, we have developed a "negative" selection strategy that can significantly improve the metal-binding selectivity in the selection process [6]. To improve the metal-binding affinity, we have developed a new synthetic strategy for making phosphoroselenote DNA/RNA that are capable of binding different metal ions [7]. To provide insight into the metal-binding sites in DNA and to allow the design of metal ion sensors and chelators from the first principle, we have also carried out a detailed biochemical [8] and biophysical [9] study of the DNA lead sensors obtained in the lab. This year we have made a breakthrough by converting the catalytic DNA into colorimetric metal sensors, making on-site, real-time detection even more affordable and achievable because no equipment is needed in the operation [10]. We accomplished this by taking advantage of recent advance in both biotechnology and nanotechnology. Finally, we are making progress in applying the strategy developed in the lab toward making sensors for radionuclides such as uranium and chromium(VI) ions. Now we are poised to make sensors for NABIR applications. The latest results from the lab will be presented.

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