Recycling and Reusing Tennis Balls: 
Is There a Sustainable Game Plan?

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References
I. Abstract:
Tennis balls are made mostly of rubber, with zinc as the main metal element. We found no serious health hazard associated with zinc in tennis balls, but more research would be valuable. While there is an industry for re-pressurizing the balls to prolong their lifespan, there is no option for ultimately recycling the material of the balls in the U.S. The approach to assess the possibility for recycling tennis balls was through elemental analysis and exploring recycling opportunities for similar materials. Since 2009, France has developed a system for collecting and recycling balls and so far 13 athletic fields have been constructed from recycled tennis balls. The only known initiative to recycle the balls in the U.S has been Project Green Ball in Massachusetts. They are currently in the process of collecting tennis balls to make the first equestrian turf. This report demonstrates that it is possible to recycle the rubber in the balls for use as other surfaces in addition to equestrian turf such as athletic surfaces and playgrounds.

II. Introduction:
Tennis is a worldwide popular sport. An estimated 300 million balls are manufactured each year, of which 125 million are used in the U.S. Tennis balls don’t last very long, and players frequently discard old balls for new ones. Even though some balls are re-used as toys for dogs or on bottoms of chairs, millions of balls eventually end up in landfills every year. This report demonstrates the research in finding out if the life of tennis balls can be prolonged and if there is an environmentally friendly way to recycle the material in tennis balls.

III. Method:
A. Contacting people and companies
i. The USTA
I first contacted the U.S Tennis Association (USTA) and 15 different nationwide tennis centers to find out what they do with old tennis balls.

ii. reBounce
After online research on how to reuse tennis balls I found the company reBounce that has developed a machine that re-pressurizes tennis balls. According to them and many users, the machines can double the life of a tennis ball. I emailed and spoke on the phone with Bill Durst, the founder of the company, to ask about the machine and if I could try some of the re-pressurized balls.

iii. The Bay Club SF Tennis
The Bay Club SF Tennis uses a reBounce re-pressurizing machine for their program and Bill Durst connected me with Weston Reese, the director, to set up a date when I could try balls from the machine.

iv. Technical Experts: Martin Mulvihill, David Killilea, Kin Man Yu, Professor Sunseri, Timothy Teague

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1 http://digitaljournal.com/article/322596
2 http://projectgreenball.com/
The process of doing an elemental analysis to detect any harmful metals and chemicals was challenging. My first contact person was Dr. Mulvihill who is a chemist at the Berkeley Center for Green Chemistry. He directed me to Dr. Killilea who is the director of the elemental analysis facility at the Children’s Hospital Oakland Research Institute (CHORI). He explained that tennis balls are very difficult to dissolve and it is possible that his equipment would not be useful for gathering precise readings from the elements of the balls given the extensive amount of serious solvent added to dissolve the balls. Consequently the results could easily be skewed. Therefore, he connected me with Dr. Yu and the Lawrence Berkeley National Laboratory (LBNL). At this time I was also told about the possibility of doing an X-ray Fluorescence (XRF) for elemental analysis, which I discussed with Dr. Yu. He directed me to the anthropology department on campus since they have an XRF machine. After asking anthropology professor Jun Sunsuri I got in contact with Timothy Teague, who runs the machine. I finally set up a date to do the elemental analysis of the tennis ball.

v. Project Green Ball: Scott Soloway
Scott Soloway and his son Ben started a sustainability initiative in 2012 to recycle tennis balls called Project Green Ball. They have developed a method for recycling balls into equestrian turf by crushing the balls. In August 2012 they had collected 7000 tennis balls and installed the first tennis ball-based equestrian turf. I contacted Mr. Soloway to learn more about their process of exploring ways to recycle tennis balls. I also learned about Operation Balle Jaune, a program in France that collects and recycles tennis balls for sport surfaces.

vi. Landfill
I contacted a landfill company in the Bay Area to ask how many balls they receive per month and if there is a concern of the environmental impact of balls in landfills.

B. Fieldwork
i. Observing the material of the ball
Before doing the elemental analysis of the ball I decided to observe the material of the ball myself. I took a sharp knife and a magnifying glass to do the observation. I looked for texture, color and smell.

ii. Elemental analysis XRF machine
I went to the Earth and Planetary Science department and met with Timothy Teague. I observed him testing the inside of the ball with the XRF machine. He explained to me what X-Ray Fluorescence is and how it works. When the object is placed in the
machine it gets bombarded with high-energy X-rays or gamma rays. When the atoms absorb these high-energy photons, inner shell electrons are ejected from the atoms. The atom is now in an “excited” state, with a vacancy in the inner shell. Outer shell electrons want to go to this vacancy place and when they do they emit photons with energy that is equal to the energy difference between the two states. All elements have a specific and unique set of energy levels, and an element emits the X-rays that are distinctive for that element. Therefore, we only had to look at the pattern of X-rays to know what elements the ball contained.

iii. Bay Club SF Tennis
I went to the tennis club in San Francisco to see how the re-pressurizing machine works. The balls are placed in the machine, the machine is closed and charged, and after three days the balls are ready. I observed Weston Reese taking out the “cooked” balls and I got some balls to take home to play with.

iv. Hellman Tennis Courts
To see how effective the re-pressurizing machine was I did an experiment comparing the re-pressurized balls with new ones. I spray painted the balls in blue so that the players, four women on the Cal women’s team including me, would not feel or see which ball was new or re-pressurized. We played for 20 minutes with these balls.
Using the re-pressured balls, spray-painted.

C. Online research
The online research involved looking at the International Tennis Federation (ITF) website to find out about the formulations of tennis balls. I looked into similar projects such as Project Green Ball and Operation Balle Jaune. I explored recycling of similar rubber materials, such as automobile tires, and tennis shoes. I looked at the West Coast rubber recycling website, the Nike program called Re-Use a Shoe, and YouTube videos on rubber recycling. I researched how much rubber a tennis ball contains and how much is needed to make other things, like sport surfaces or playgrounds. I also did calculations based on the amount of rubber from tires needed for a playground to find out how many balls are required to make a tennis-ball based tennis court.

III. Results:
A. What do tennis clubs and general players do with old tennis balls?
Currently, there is no industrial solution to recycle tennis balls in the U.S. When I asked players what they do with the balls many seemed concerned since they don’t know what they are supposed to do with them. They usually keep them at home until they are discarded in the trash and end up in landfills. Most tennis clubs either discard the balls directly or donate them to city programs, schools or hospitals where they put the balls under chairs, dog parks, and sometimes they are distributed to foreign countries. Ultimately, there is no end solution to what to do with old tennis balls, as they eventually all wind up in landfills.

B. How many balls do landfills get? Is there an environmental concern?
I contacted one landfill organization called Zanker Road Resource Management. Michael Gross, their representative, explained that they do not have any environmental concerns except that the balls take up space. They get in between 500-1000 balls a month.

B. Can the life of tennis balls be prolonged by re-pressurizing them?
The four players on the Cal tennis team, including me, were asked to try different balls and see if they could feel a difference between them. It was relatively easy to distinguish between the balls that were new and those that had been re-pressurized. The re-pressurized balls bounced a bit higher and had inconsistent bounces.

C. Observation and Elemental Analysis
By cutting the ball open, I could clearly see and feel the rubber and the melton cloth. They are strongly glued together and do not seem to be easily separated. The XRF showed that the Zinc had the highest concentration of all the elements both when we measured the outside and the inside of the ball. The outside of the ball had 4497 ppm of Zinc, followed by Iron of 2873 ppm. The inside of the ball contained more Zinc, 11666 ppm and 4654 ppm of Iron.

D. Online Research
i. International Tennis Federation
On the ITF website they had a section on what tennis balls are made of. The main material is natural rubber that contains fine-particle fillers. The formulation (parts by weight) is the following:
Natural rubber 100
General purpose furnace (GPF) black - a reinforcing filler - 30
Clay 32
Zinc oxide 9
Sulphur 3.5
Diphenylguanidine (DPG) - an accelerator for the curative system - 2
Cyclohexyl benthiazyl sulphenamide (HBS) - also an accelerator - 1

ii. Project Green Ball
Project green ball worked with IGK Equestrian to develop a method for crushing tennis balls and adding them to the manufacturing of horse arena turf. They provided 7000 balls to make the first tennis ball-based equestrian turf. The process is simple: first the IGK Equestrian grinds the balls, then they pre-mix the grinded balls with equestrian soil, and finally the balls and soil are fully mixed and can be ready for use in a riding center. Project Green Ball is currently collecting tennis balls to make the first equestrian turf that is completely made of tennis balls. They have so far collected 63,000 balls.

iii. Operation Balle Jaune
LABOSPORT made a study on the recycling of tennis balls and ball cans to evaluate possible recycling systems, the elements of the waste products, as well as their value. It is a comprehensive report that was translated by Kerri O’Keeffe and given to me by Scott Soloway from Project Green Ball. It presents a chemical analysis of the rubber, which indicates that it contains less than 18% of mineral fillers, and therefore up to 82% of organic rubber. They also researched the rubber material for sports fields, such as synthetic fields with rubber of the type SBR, which is of inferior quality with 40% mineral fillers. However, in athletic fields the rubber is of better quality as they

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3 See table
4 http://www.itftennis.com/technical/equipment/balls/manufacture/index.asp
use type EPDM and has very close characteristics to that of tennis balls. In terms of toxicity, they found that the Zinc content is 0.42ml/l, which is two times the standard in building sport fields in France. The recycling process involved separating the felt and rubber through grinding. They used a line of specific semi-automated grinding where they loaded and removed the materials manually. The granules that came out from the grinder were separated from the felt in very small parts, and the sifting was the more time consuming step. They were able to recover 80% of the initial mass inserted into the grinder. The report demonstrates how they did manufacture test samples of athletic fields and playgrounds. They concluded that the rubber of the granules correspond to the needs in athletic fields. For security reasons in terms of toxicity from Zinc, they eliminated playgrounds. The optimal surfaces to use the tennis balls in were synthetic turf, sub-layer of synthetic turf, and tennis courts. Operation Balle Jaune started in 2009 and the number of collected balls has steadily increased each year. 14 million balls are used in France each year and they expect to collect 1.1 million for recycling by the end of 2012. So far 13 athletic fields have been constructed from recycled tennis balls.

iv. Zinc oxide, Diphenylguanidine, and Cyclohexyl benthiazyl sulphenamide
I could not find U.S. standards for zinc in sport fields. However, I found many articles, including a report from the National Institute of Health, on the health risks from deficiency of zinc rather than the risks of excessive intake of zinc in one’s diet. For the two chemicals DPG and HBS I asked Dr. Mulvihill if they were of a concern. He was not worried about HBS but explained that there have been cases where workers exposed to dust containing DPG suffered health consequences. He directed me to read a report from the Hazardous Substances Data Bank. After reading the report it is evident that there are health risks with DPG. However, the dangerous exposure to DPG is through inhalation of dusts and dermal contact at workplaces where NPG is produced or used. It is possible that the DPG is not a concern in tennis balls after they have been grinded and manufactured into new materials. However, I did not explore this in depth.

iv. Recycling of tennis shoes and automobile tires.
The main material of tennis balls is rubber, which also tennis shoes and automobile tires consist of. The Nike program Reuse a Shoe started in 1990 and 28 000 000 shoes have been collected globally since then. They use a slice-and-grind technique where each shoe is cut into three slices- rubber outsole, foam mid sole and fiber upper. These are then placed in grinders and are purified. The rubber outsole is used in track surfaces, gym floors, playground surfaces, and new Nike products. The foam is used for outdoor basketball and tennis courts, and the fiber is used in indoor synthetic and wood courts. West Coast Ground Rubber Recycling is a company located in Hollister in San Benito County, CA. They grind and recycle all car tires for various markets including playground covering, horse arena footing, and high traffic areas golf courses injection.

iv. How much rubber is in a ball? How many balls are needed to make a tennis

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5 French lab raport to FFT
6 http://digitaljournal.com/article/322596
7 http://www.nikereuseashoe.com/using-nike-grind
8 http://www.groundrubber.com/
court?
A ball contains 55.6g of rubber. For a playground of 92.9sqm the amount of rubber needed is 3175kg. Consequently, 1sqm playground needs 92.9/3175 = 0.029kg. The surface of a tennis court is 650sqm, thus 22 226kg of rubber is needed, which corresponds to 392 000 tennis balls.

IV. Discussion
Clearly, the current end destination for old tennis balls in the U.S is landfills. One exception is the Project Green Ball that demonstrates that tennis balls can be recycled for equestrian turf. Operation Balle Jaune in France further shows that they can also be used for other sport surfaces such as synthetic turf, and tennis courts. My research supports the conclusion from these organizations that tennis balls are recyclable. By comparing the rubber in tennis balls to synthetic and athletic fields it is evident that they are of similar rubber material. Furthermore, other rubber products such as automobile tires and tennis shoes are being recycled into these surfaces. The toxicity does not seem to be of a greater issue when looking at the other programs. Although more research is needed, it is hard to imagine that people using an athletic field would inhale more than 4mg of zinc a day. It would also be important to know what happens to DPG in the recycling process. In terms of reusing the tennis balls through repressurizing, I think it would have been useful to do a broader experiment. The players in my experiment were all from a small group of high-level tennis players. They get new balls frequently and play matches with new balls every weekend. It is thus natural that they are more skeptical of the quality of their balls. It would have been beneficial to try the balls for a longer time and with club players of all ages. The machine was effective in the way that the balls got the pressure back, yet some may have got too much pressure hence the inconsistent bounces.

V. Conclusion
To reduce the environmental impact of tennis two things can be done: (1) Tennis balls can be reused through a re-pressurizing machine, and (2) the material of the balls can be recycled and used for athletic surfaces. Tennis is a popular sport with many tennis clubs purchasing thousands of new balls each year. A re-pressurizing machine for the club members would increase the life of the ball, thus reducing the overall need for new balls. When the balls can no longer be re-pressurized the best solution is to recycle them. While it is evident that these two approaches are possible to deploy, this report does not address if it is economically feasible. The main concern would be transport of the balls to a recycling industry. Almost 400 000 balls are needed to build a tennis court. Nevertheless, over 125 million balls are used in the U.S every year. Project Green Ball is looking for players and clubs to send them balls, and is working on funding for shipping. Recycling of tennis balls in France is a success case with 1.1 out of 14 million balls collected in a year. It is evidently possible to recycle tennis balls, which means that there is a sustainable game plan for tennis.
VI. Appendix

a. XRF Spectrum of the Outside of a Tennis Ball
b. XRF Spectrum of the Inside of a Tennis Ball
c. Analysis Report of the Outside of a Tennis Ball

EDXRF Analysis Report
Thermo Fisher Scientific Inc., Madison, Wisconsin, USA

Sample List: 2012/10/24 11:24
Analyzed: 10/24/12

Conditions

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</tr>
</thead>
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<tr>
<td>Voltage</td>
<td>30 kV</td>
<td>Voltage</td>
<td>50 kV</td>
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<tr>
<td>Livetime</td>
<td>200 seconds</td>
<td>200 seconds</td>
<td>200 seconds</td>
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<tr>
<td>Filter</td>
<td>Pd Medium</td>
<td>Filter</td>
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<tr>
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<td>Maximum Energy</td>
<td>40 keV</td>
</tr>
<tr>
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<td>Warmup time</td>
<td>5 seconds</td>
</tr>
<tr>
<td>Current</td>
<td>Auto</td>
<td>Current</td>
<td>0.28 mA</td>
</tr>
<tr>
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<td>Counts Limit</td>
<td>0</td>
</tr>
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<td>Atmosphere</td>
<td>Air</td>
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<td>Count Rate</td>
<td>High</td>
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Results
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<th>Element</th>
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<tr>
<td>tennis ball</td>
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<td></td>
</tr>
<tr>
<td>Ti</td>
<td>406 ppm</td>
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</tr>
<tr>
<td>Mn</td>
<td>41.5 ppm</td>
<td>7.5</td>
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<tr>
<td>Fe</td>
<td>2873 ppm</td>
<td>13</td>
</tr>
<tr>
<td>Co</td>
<td>13 ppm</td>
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</tr>
<tr>
<td>Ni</td>
<td>[2.8] ppm</td>
<td>2.2</td>
</tr>
<tr>
<td>Cu</td>
<td>8.6 ppm</td>
<td>2.2</td>
</tr>
<tr>
<td>Zn</td>
<td>4497 ppm</td>
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<tr>
<td>Ga</td>
<td>6.9 ppm</td>
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<td>Rb</td>
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<tr>
<td>Sr</td>
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<tr>
<td>Zr</td>
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<tr>
<td>Nb</td>
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<tr>
<td>Ba</td>
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<tr>
<td>Pb</td>
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<tr>
<td>Th</td>
<td>3 ppm</td>
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</table>

d. Analysis Report of the inside of a Tennis Ball

EDXRF Analysis Report
Thermo Fisher Scientific Inc., Madison, Wisconsin, USA

Sample List: 2012/10/31 10:20
Analyzed: 10/31/12
10:30:29
Analysis Technique: Linear
Last Calibrated: 04/24/12
15:25:46
Method File: C:\...\Thermo\Desktop\Tim\Ti-Nb, Pb, Th, Ba.MTH
Software version: 7.0 (Build 54)

Conditions

Mid Zb
- Voltage: 30 kV
- Livetime: 200 seconds
- Filter: Pd Medium
- Maximum Energy: 40 keV
- Warmup time: 5 seconds
- Current: Auto
- Counts Limit: 0
- Atmosphere: Air
- Count Rate: Low

High Zb
- Voltage: 50 kV
- Livetime: 200 seconds
- Filter: Cu Thick
- Maximum Energy: 40 keV
- Warmup time: 5 seconds
- Current: 0.28 mA
- Counts Limit: 0
- Atmosphere: Air
- Count Rate: High

Results
<table>
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<tr>
<th>Element</th>
<th>Concentration</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
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<td>tennis ball inside</td>
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<tr>
<td>Ti</td>
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<td>61</td>
</tr>
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<td>Mn</td>
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</tr>
<tr>
<td>Fe</td>
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</tr>
<tr>
<td>Co</td>
<td>15.9 ppm</td>
<td>2.3</td>
</tr>
<tr>
<td>Ni</td>
<td>11.2 ppm</td>
<td>3.7</td>
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<tr>
<td>Cu</td>
<td>28.9 ppm</td>
<td>3.9</td>
</tr>
<tr>
<td>Zn</td>
<td>11666 ppm</td>
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<tr>
<td>Ga</td>
<td>15.3 ppm</td>
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<td>Pb</td>
<td>5.9 ppm</td>
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<tr>
<td>Th</td>
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</tbody>
</table>

References:

Project Green Ball http://projectgreenball.com/

LABOSPORT French lab raport to FFT translated by Kerri O’Keeffe


http://www.nikereuseashoe.com/using-nike-grind

http://www.groundrubber.com/

Office of Dietary Supplements National Institute of Health
http://ods.od.nih.gov/factsheets/Zinc-HealthProfessional/

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