State of California – The Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Bay Delta Region
7329 Silverado Trail
Napa, CA 94558
(707) 944-5500
www.wildlife.ca.gov

EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

MAR 2015
RECEIVED
Planning Dept. Admin
County of Santa Cruz

March 23, 2015

Mr. Todd Sexauer
Santa Cruz County Planning Department
701 Ocean Street
Santa Cruz, CA 95060

Dear Mr. Sexauer:

Subject: Proposed Davenport Recycled Water Project, Initial Study/Mitigated Negative Declaration, SCH #2015022075, Santa Cruz County

The California Department of Fish and Wildlife (CDFW) has reviewed the Initial Study/Mitigated Negative Declaration (IS/MND) for the Proposed Davenport Recycled Water Project (Project).

CDFW is submitting comments on the IS/MND as a means to inform the County of Santa Cruz Planning Department (County), as the Lead Agency, of our concerns regarding potentially significant impacts to biological resources associated with the proposed Project.

CDFW is a Trustee Agency pursuant to the California Environmental Quality Act (CEQA) § 15386 with responsibility under CEQA for commenting on projects that could affect biological resources. As Trustee for the state's fish and wildlife resources, CDFW has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and their habitat for the benefit and use by the people of California. CDFW also acts as a Responsible Agency based on its discretionary authority regarding Project activities that impact streams and lakes (Fish and Game Code §§ 1600 – 1616), or result in the "take" of any species listed as candidate, threatened, or endangered pursuant to the California Endangered Species Act (CESA, Fish and Game Code, § 2050 et seq.).

Project Location and Description

The Project is located in the unsectioned portion of the Arroyo de la Laguna Rancheria in the south central portion of the Davenport 7.5-minute topographic quadrangle, within Township 10 South and Range 3 West; within the Town of Davenport in Santa Cruz County, California; Assessor's Parcel Numbers 058-021 -03 and -07, 058-022-11, 058-071 -04, and 058-072-01. The proposed Project includes treatment plant upgrades consisting of the following: 1) dredging the treatment lagoon of accumulated solids; 2) installing alarms for the filtration and disinfection processes; and 3) adding redundancy for coagulant and hypochlorite dosing. The Project also includes: 4) construction of a storage pond within the Coast Dairies Agricultural Parcel Two located to the northwest of New Town Davenport to store treated water; 5) construction of a pump station and truck fill station constructed adjacent to the storage pond; 6) distribution piping constructed to provide recycled water to two irrigation ponds on the seaward side of Highway 1 across from the treatment plant.

The IS/MND does not provide a clear description on the sources of water coming into the existing waste water treatment plant. There exists a drinking water treatment plant on the same parcel as the proposed Project that obtains its water from a surface water diversion on San

Vicente Creek, a stream identified for focused recovery of Central California Coast coho salmon (*Oncorhynchus kisutch*), listed as endangered under both the federal Endangered Species Act (ESA) and CESA (National Marine Fisheries Service 2012) and currently serves as habitat for coho salmon, steelhead (*Oncorhynchus mykiss*, listed as threatened under the ESA and a State Species of Special Concern) and California red-legged frog (*Rana draytonii*, listed as threatened under the ESA and a State Species of Special Concern).

The IS/MND states that the proposed Project would not directly or indirectly impact any essential habitat for the coho salmon, that the Project may affect, but is not likely to adversely affect, steelhead or California red-legged frog, and that no impacts to San Vicente Creek, Agua Puera Creek or Stream 102 would occur. However, the IS/MND does not include sufficient information to determine whether water originating from the surface water diversion on San Vicente Creek is incorporated in any manner into the Project which could create potentially significantly impacts to sensitive stream resources. In written (email) correspondence with CDFW, the Lead Agency has stated that it was possible water was being passed from a lined pond at the drinking water treatment plant or the CEMEX facility to the wastewater treatment plant. CDFW recommends that additional information be incorporated into the Project Description of the MND for clarification on incoming sources of water used by the Project and a description of their pathways and conduits in order to evaluate any potential impacts of the Project on coho salmon and other special-status aquatic species in San Vicente Creek and their habitats.

CDFW also recommends that the Lead Agency provide information in the MND to clarify whether raw or treated water from the water treatment plant or CEMEX facility will be diverted or incorporated into the wastewater treatment plant in any form. If the Lead Agency has determined that water used for the Project originates from the surface water diversion on San Vicente Creek, then the MND should be revised to analyze potential impacts to the environment from the diversion and the increase or potential increase of surface water use.

CDFW appreciates the opportunity to provide comments on the IS/MND for the subject Project. If you have any questions, please contact Ms. Melissa Farinha, Environmental Scientist, at (707) 944-5579; or Ms. Brenda Blinn, Senior Environmental Scientist (Supervisory), at (707) 944-5541.

Sincerely,

Scott Wilson

Scott Wilson
Regional Manager
Bay Delta Region

cc: State Clearinghouse
Chad Mitcham, United States Fish and Wildlife Service
National Marine Fisheries Service, Santa Rosa Office

Reference:

National Marine Fisheries Service. 2012. Final Recovery Plan for Central California Coast Coho Salmon Evolutionarily Significant Unit. National Marine Fisheries Service, Southwest Region, Santa Rosa, California

Todd Sexauer

From:	Rachel Lather
Sent:	Thursday, March 19, 2015 11:32 AM
To:	Farinha, Melissa@Wildlife; Todd Sexauer
Subject:	RE: Davenport Recycled Water Project

Over the past 4 years we have received about 900 HCF per year of sewage from CEMEX. The water pond they use receives 90,000 HCF per year.

-----Original Message-----
From: Farinha, Melissa@Wildlife [mailto:Melissa.Farinha@wildlife.ca.gov]
Sent: Saturday, March 14, 2015 8:41 AM
To: Rachel Lather; Todd Sexauer
Subject: RE: Davenport Recycled Water Project

Hello Rachel and Todd,
Do we have any new information from the water plant operator?

Best,

Melissa A. Farinha
California Department of Fish and Wildlife Environmental Scientist - Santa Cruz County
7329 Silverado Trail
Napa, CA 94558
(707) 944-5579

-----Original Message-----
From: Farinha, Melissa@Wildlife
Sent: Thursday, March 05, 2015 4:08 PM
To: Rachel Lather; Todd Sexauer
Subject: RE: Davenport Recycled Water Project

Hi Rachel,
Yes. That would get at what my concern is. I believe the over flow from the surface water diversion goes to the lined pond there at the drinking water treatment plant and just wanted to make sure that wasn't incorporated in any way into the project. My understanding is that to keep the vacuum to the surface diversion going is that it is constantly on.

Thank You,

Melissa Farinha
CDFW Environmental Scientist Santa Cruz County
7329 Silverado Trail
Napa, CA 94558
(707) 944-5579

From: Rachel Lather [Rachel.Lather@santacruzcounty.us]
Sent: Thursday, March 05, 2015 2:56 PM
To: Farinha, Melissa@Wildlife; Todd Sexauer
Subject: RE: Davenport Recycled Water Project

We are continuing to receive sewage from the CEMEX property but I cannot verify where it is coming from. It is possible that they are passing the water in the lined pond they have through their system and then to our wastewater treatment plant. Is that where you are going with this question? I have asked our water plant operator to give me the total water going to CEMEX from the sandbox and the inflow from CEMEX for the same months. I will let you know if it looks comparable. Otherwise, we have no intent to mix raw water in the treatment process.

From: Farinha, Melissa@Wildlife [mailto:Melissa.Farinha@wildlife.ca.gov]
Sent: Wednesday, March 04, 2015 2:13 PM
To: Todd Sexauer
Cc: Rachel Lather
Subject: Davenport Recycled Water Project

Afternoon Todd and Rachel,
I was hoping either of you could answer a question regarding the project which is: does any part of the wastewater treatment process involve the use of raw water or treated drinking water including any inputs to the collection system or aerated lagoon?

Best,

Melissa A. Farinha
California Department of Fish and Wildlife Environmental Scientist - Santa Cruz County
7329 Silverado Trail
Napa, CA 94558
(707) 944-5579

From:	Farinha, Melissa@Wildlife [Melissa.Farinha@wildlife.ca.gov]
Sent:	Wednesday, March 25, 2015 11:50 AM
To:	Rachel Lather
Cc:	Todd Sexauer; Ana Maria Rebelo; John Swenson
Subject:	RE: Water From CEMEX

Good Morning Rachel,
Yes I did receive your response on March 19th . Please understand that the process for issuing a CEQA comment letter at CDFW involves coordinating five different staff members for multiple reviews and processing. Unfortunately there wasn't enough time left before the public comment period ended to edit the letter based on your response and reiterating the process. I believe the same recommendations for including the additional information in the MND are still valid though. As a note, it is less taxing on CDFW staff resources to consult on a project before the CEQA documents are circulated than to write a comment letter.

Please feel free to call me at any time to discuss future projects.

Melissa A. Farinha
California Department of Fish and Wildlife
Environmental Scientist - Santa Cruz County
7329 Silverado Trail
Napa, CA 94558
(707) 944-5579

From: Rachel Lather [mailto:Rachel.Lather@santacruzcounty.us]
Sent: Tuesday, March 24, 2015 1:21 PM
To: Farinha, Melissa@Wildlife
Cc: Todd Sexauer; Ana Maria Rebelo; John Swenson
Subject: Water From CEMEX

Melissa, I thought I had responded to your inquiry regarding the sewage from CEMEX but I cannot find it in my files. I received information from our operations manager regarding the flow to the Sandbox that is located at our water treatment plant. According to him, approximately 187,000 gallons per day flow into the pond that CEMEX uses for their water source. We receive around 2000 gpd from CEMEX at our treatment pond.

STATE OF CALIFORNIA—NATURAL RESOURCES AGENCY
EDMUND G. BROWN JR., *GOVERNOR*

CALIFORNIA COASTAL COMMISSION
CENTRAL COAST DISTRICT OFFICE
725 FRONT STREET, SUITE 300
SANTA CRUZ, CA 95060
PHONE: (831) 427-4863
FAX: (831) 427-4877
WEB: WWW.COASTAL.CA.GOV

March 18, 2015

Todd Sexauer
Santa Cruz County Planning Department
701 Ocean Street, 4th Floor
Santa Cruz, CA 95060

Subject: **Davenport Recycled Water Project**
Coastal Commission Comments on Draft Initial Study/Proposed MND

Dear Mr. Sexauer:

Thank you for providing the opportunity to review and comment on the Initial Study/Mitigated Negative Declaration (MND) pertaining to the Davenport Recycled Water Project (Project). The Project proposes to install treatment plant upgrades to an existing wastewater treatment plant located on the Cemex property, as well as new construction of a storage pond, pump station and truck filling station on the Coast Dairies "Agricultural Parcel Two" located to the northwest of New Town Davenport on the inland side of Highway 1. Piping would also be installed to connect the existing plant with the new storage pond as well as distribution piping to provide recycled water to two irrigation ponds on the seaward side of Highway 1 across from the treatment plant. The Project is located within the Coastal Zone and will therefore require a Coastal Development Permit (CDP) consistent with the County's certified Local Coastal Program (LCP). Additionally, the proposed development on the Coast Dairies property is required to be consistent with the conditions of Coastal Development Permit 3-11-035, which provided for the subdivision of the Coast Dairies property and includes restrictions on uses on the agricultural portions of the subdivided property.

Commission staff is highly supportive of projects to reuse treated wastewater, especially for coastal priority uses such as agriculture. Our comments below are primarily intended to ensure that the appropriate location for the various project components is chosen with respect to visual and agricultural impacts.

Comment 1: **Incomplete Alternatives Analysis**

The Biological Resources Assessment prepared for the MND identifies four potential project alternatives. Alternatives 1, 2 and 3 envision construction of the storage pond and related facilities immediately adjacent to the existing wastewater treatment plant (i.e. on Cemex property as opposed to Coast Dairies Agricultural Parcel Two) and provide different options and levels for wastewater reuse. Alternative 4 is the proposed project and envisions the new storage pond and facilities located on the Coast Dairies Agricultural Parcel Two. However, the MND does not appear to analyze why the proposed project is preferred over the alternatives that would site the new development directly adjacent to the existing wastewater treatment facility, which appears possibly better suited to avoid impacts to protected coastal resources.

Comment 2: **Aesthetic and Visual Resources – Coastal Viewsheds**
The MND notes that the proposed project has the potential to impact scenic resources, as designated in the County's Local Coastal Program. Highway 1 is designated as a scenic road under Section 5.10.10 of the LCP. In addition, Section 5.10 of the LCP establishes numerous additional policies and standards that govern development at this location, including, for example, 5.10.2 (development within visual resources areas), 5.10.3 (protection of public vistas), 5.10.5 (preserving agricultural vistas), 5.10.11 (development visible from rural scenic road), and 5.10.13 (landscaping requirements). Any proposed development at this location is required to be consistent with these policies.

New Storage Pond: The project description states that the pond would be constructed by excavating to a depth of about eight feet, and constructing a perimeter levee from the excavated material to create a two-acre pond with a usable water depth of 12 feet. It appears that an approximately four-foot-high berm would surround the storage pond. The MND notes that views from Highway 1 and Cement Plant Road could be significantly impacted due to the height of the proposed earthen berm supporting the storage pond, and proposes to mitigate such impacts by vegetating the north, south and west facing sides of the storage pond with Monterey pines. This visual impact could be substantially avoided by placing the pond on the inland Cemex property.

New Pump Station & power pole: The project description (and Figure 3) identifies a new pump station adjacent to the pond on the Coast Dairies Agricultural Parcel Two, and also identifies the need for a new power pole location off of Cement Road (which is visible from Highway 1) to provide electricity to the new pump station. However, the potential visual impacts of this development do not appear to be addressed in the aesthetic and visual resource section of the MND. **Section 5.10.24 of the LCP requires that all new utility transmission lines within views from scenic roads be placed underground.** In addition to the LCP, other State laws require the undergrounding of communication distribution facilities located along scenic highways whenever feasible. (See, e.g. Public Utilities Code Section 320.)

New Filling Station: Similarly, the project description (and Figure 3) identifies a new filling station on Coast Dairies Agricultural Parcel Two. Moreover, it would appear that the new filling station would require construction of a road to provide vehicular access. However the potential visual impacts of this road development are not addressed in the aesthetic and visual resources section of the MND.

New Distribution Pipes: The project description identifies development activities related to new distribution pipes. Based on Figure 2, piping will also be required to connect the existing wastewater facility plant to the new storage pond. The visual resource section of the MND notes that "all distribution lines would be buried." However, the project description notes that the pipe installed on the west side of Highway 1 "would have laterals rising above grade and topping over the edge of the existing irrigation ponds." However, the potential visual impacts of this pipe were not evaluated in the MND.

Based on the above, we do not believe that the potential visual resource impacts of the proposed project have been adequately identified, analyzed, avoided and/or mitigated at the current planning stage. At a minimum, we believe that a visual simulation of each of these project components would be necessary to adequately assess such impacts. Moreover, we believe that there may be alternatives to the proposed development identified above that could potentially avoid potential visual impacts; for example, by reducing the size of the storage pond berm, undergrounding the proposed utilities (including the pump station), and minimizing (or eliminating) the new filling station. Moreover, as identified in Comment #1, it appears that many of the potential visual resource impacts could be avoided by siting the proposed new development on the Cemex property adjacent to the existing wastewater facility plant.

Comment 3: **Agricultural Resources.** The MND identifies Coast Diaries Agricultural Parcel Two as Commercial Agriculture Preserve (AC) (Preserve) and as containing "Prime Farmland" as shown on the Maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Natural Resources Agency. Accordingly, the Project is required to be consistent with the coastal agricultural resource protection policies set forth in Section 5.13 of the LCP. Relevant policies include: 5.13.5 (Principal Permitted uses on Commercial Agricultural (CA) zoned land), 5.13.6 (conditional uses on Commercial Agricultural (CA) zoned lands), 5.13.7 (agriculturally oriented structures), 5.13.8 (location of agricultural support facilities), 5.13.10 (water and sewer lines in the Coastal Zone), 5.13.27 (siting to minimize conflicts).

The project proposes new development on Coastal Dairies Agricultural Parcel Two that includes a new two-acre storage pond, pump station (and associated above-ground utilities) and filling station (and presumably a road to provide vehicular access to these project components). While the proposed facilities are intended ultimately allow for the use of recycled wastewater for agricultural use, the main driver behind the proposed Project appears to be Title 22 water quality violations identified by the May 25, 2011 staff inspection by the Central Coast Region Water Quality Control Board, including: "1) the discharge of thousands of gallons of treated wastewater to the Pacific Ocean by runoff from disposal fields, 2) less than the required two feet of freeboard level in the treatment pond; 3) failure to post signage in areas of water reclamation use, etc,; and 4) failure to investigate and submit a spill response report within five days of the discovered spill." Thus, in at least some respects, the Project can be seen as an industrial wastewater treatment plant upgrade, inconsistent with the current CA zoning and LCP requirements for that zoning.

Additionally, we would note that the Coastal Development Permit for the Coast Dairies Property includes Special Conditions limited development on the Agricultural Parcels, including Special Condition 4.a set forth below:

> **Agricultural use in perpetuity.** Agricultural Parcels 1, 2, and 3 shall remain in agricultural use for the production of food, fiber, or other animal or plant products

> by preserving and protecting in perpetuity its agricultural values, use and utility, and preventing any use of the property that would materially impair or interfere with its agricultural values, use or utility. ***The only exceptions to this perpetual agricultural use requirement are*** [emphasis added] that: (1) should agricultural use become infeasible in whole or in part on these parcels, then such area shall be protected, used, and managed only for open space and public recreational access uses and development in a manner consistent with the protection and preservation of coastal resources; (2) habitat restoration and enhancement shall also be allowed (e.g., restoration/enhancement of creeks/riparian corridors that are located on the Agricultural Parcels); and (3) reclamation and restoration activities that support and facilitate agricultural (or in the alternative per (1) above, open space and public recreational access) uses and development (including by allowing areas to be so used and developed in these ways) are allowed.

Based on the above, and to ensure project consistency with the visual and agricultural policies of the LCP as well as with the use restrictions of CDP 3-11-035, Commission staff strongly suggests that the MND be revised to select an alternative that does not locate the new facilities on Coast Dairies Agricultural Parcel Two, but instead locates these facilities adjacent to the existing wastewater treatment plant on Cemex property.

Comment 4: **Biological Resources.** The Biological Resources Assessment accompanying the MND identifies extensive biological resources located on and adjacent to the proposed development, including numerous special status species potentially affected by the project. It also sets forth a series of mitigation measures to reduce or eliminate impacts to these resources. The project is required to conform to the biological resource objectives, policies and standards set forth in Sections 5.1 and 5.2 of the LCP. Unfortunately, given the time constraints, the Commission's ecological expert staff has not had an opportunity to review the project materials. However, we would preliminarily note the following:

Alternatives Analysis: The Biological Report identifies four project alternatives but does not appear to analyze these alternatives in terms of their relative potential impacts to biological resources. Such an analysis would be extremely useful.

No focused surveys: Moreover, the Biological Report indicates that "no focused surveys for this Biological Resources Assessment were conducted" and therefore "a lack of finding of a species in a particular area may not be the result of no occupancy but rather the result of no focused surveys." The lack of focused surveys is problematic because without such surveys it is not possible to adequately assess the project's potential biological impacts on sensitive species that might be present on the project site.

Wetland habitat on Agricultural Parcel Two. According to the Biological Resources Assessment, the Coast Dairies property has two constructed wetland ditches: "one cuts across the southern portion of the parcel and one that occurs in the extreme southeastern portion of the property." These wetlands also appear to be depicted on Figure 7 of the Biological Resources Assessment.

However, it is unclear how the proposed development activity would impact these resources. Please refer to LCP Policy 5.1.3 (Environmentally Sensitive Habitats), 5.1.6 (Development within Sensitive Habitats), 5.1.7 (Site Design and Use Regulations), 5.1.10 (Species Protection); 5.2.3 (Activities Within Riparian Corridors and Wetlands), (5.2.5 Setbacks From Wetlands); 5.2.8 (Environmental Review for Riparian Corridor and Wetland Protection), 5.2.9 (Management Plans for Wetland Protection.)

Comment 5: **Water Quality.** The MND indicates that a May 25, 2011 staff inspection by the Central Coast Region Water Quality Control Board that identified numerous "Title 22" Water Quality violations, including: "1) the discharge of thousands of gallons of treated wastewater to the Pacific Ocean by runoff from disposal fields, 2) less than the required two feet of freeboard level in the treatment pond; 3) failure to post signage in areas of water reclamation use, etc,; and 4) failure to investigate and submit a spill response report within five days of the discovered spill." This project proposes infrastructure improvements to the existing facilities to avoid future violations. The Project is required to be consistent with Sections 5.4 (Monterey Bay and Coastal Water Quality), and 5.5 (Water Resources), and 5.7 (Surface Water Quality Protection) of the LCP.

<u>Dredging the treatment lagoon of accumulated solids</u>. The MND states that the Project includes dredging the treatment lagoon of accumulated solids. However, it does not identify what will be done with the accumulated solids that are dredged from the treatment lagoon, nor does it appear that this material has been tested for potential pollutants.

<u>Chemical treatment of wastewater</u>. The MND indicates that the wastewater is currently treated with "coagulant and hyperchlorite," a chlorine contact chamber, and sodium bisulphate. The proposed project would include adding "redundancy for coagulant and hyperchlorite" dosing. Ultimately, the treated wastewater would be sent to irrigation ponds west of Highway 1 and used for agriculture, eventually running off into Monterey Bay and Pacific Ocean. The MND does not explain the potential impacts of these chemical treatment processes on the environment, particularly in light of the fact that the wastewater will be used for agricultural purposes west of Highway 1, and potentially run off into the Pacific Ocean. Section 5.4 of the LCP establishes strict requirements for wastewater discharge, including full disclosure of chemical and biological characteristics. (See, e.g. Policies 5.4.3, 5.4.4, 5.4.5, and 5.4.6.) Moreover, the MND does not appear to explain why this chemically intensive treatment is necessary and whether there are alternatives to such intensive chemical treatment.

Thank you for the opportunity to comment on the MND. We look forward to continuing to work with the County as this project moves through the local review process. If you would like to discuss the project, please do not hesitate to contact me at the address and phone number listed above.

Sincerely,

Ryan Moroney
Coastal Analyst
California Coastal Commission

COUNTY OF SANTA CRUZ **Planning Department**

MEMORANDUM

Date: March 26, 2015

To: Sheila McDaniel

From: Todd Sexauer

Re: Responses to the Davenport Recycled Water Project Coastal Commission Comments on the Draft IS/MND

Comment 1: Incomplete Alternatives Analysis

An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). An alternatives analysis is required when preparing an Environmental Impact Report (CEQA §15126.6). The contents of a Negative Declaration circulated for public review includes: a) A brief description of the project, including a commonly used name for the project, if any; b) The location of the project, preferably shown on a map, and the name of the project proponent; c) A proposed finding that the project will not have a significant effect on the environment; d) An attached copy of the Initial Study documenting reasons to support the finding; and e) Mitigation measures, if any, included in the project to avoid potentially significant effects. As stated in the Initial Study Project Description, "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

Comment 2: Aesthetic and Visual Resources – Coastal Viewsheds

New Storage Pond: See response to comment 1. The placement of the storage pond on the Cemex property (APN 058-071-04) is not a viable option; and therefore, has not been proposed.

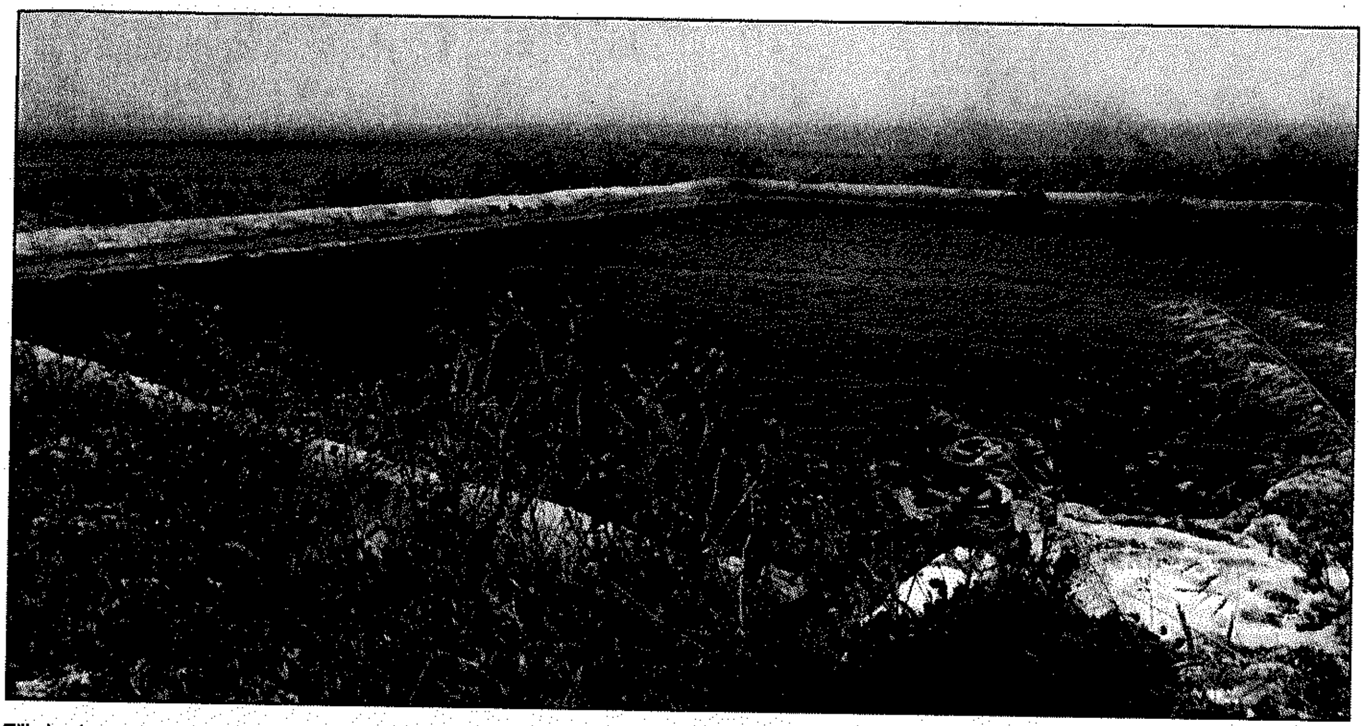
New Pump Station & Power Pole: The pump station would be constructed adjacent to the storage pond, and would be shielded from view by the placement of Monterey pines strategically located around the perimeter of the storage pond site. No significant visual impact would occur due to the construction of the pump station. General Plan Policy 5.10.24 Utility Service Lines, requires underground placement of all new or supplementary transmission lines within views from scenic roads where it is technically feasible, unless it can be shown that other alternatives are less environmentally damaging or would have unavoidable adverse impacts on agricultural operations. In order to comply with this Policy, the project has been conditioned to provide underground electrical service from the power pole to the pump station.

New Filling Station: The preliminary location of the truck fill station was located in front of the proposed storage pond. However, after further design, the location would be located at the existing Davenport Wastewater Treatment Plant site. The truck fill station would be located on existing pavement behind the existing screening of trees that surround the existing plant site.

New Distribution Pipes: The proposed fill pipes would be located at the existing storage ponds on the west side of Highway 1. The ponds currently have fill pipes that are not easily visible from Highway 1 due to their small size and amount of existing vegetation around the ponds (see photo below). No significant impact to visual resources would occur due to the installation of fill pipes at the existing storage ponds.

Comment 3: Agricultural Resources

The preliminary location of the truck fill station was located in front of the proposed storage pond. However, after further design, the location would be located at the existing Davenport Wastewater Treatment Plant site. The truck fill station would be located on existing pavement behind the existing screening of trees that surround the existing plant site.



Fill pipe located at agricultural pond located adjacent to Highway 1 on APN 058-021-03.

An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

Comment 4: Biological Resources

Alternatives Analysis: An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

No Focused Surveys: A literature search and focused surveys of the proposed project site were conducted as follows:

Literature Search: Information on special-status plant species was compiled through a review of the literature and database search. Database searches for known occurrences of special-status species focused on the Davenport and Santa Cruz U.S. Geologic Service 7.5-minute topographic quadrangles, which provided a 4.8 km (3 mi) radius around the proposed project area. The following sources were reviewed to determine which special-status plant and wildlife species have been documented in the vicinity of the project site:

- U.S. Fish and Wildlife Service (USFWS) quadrangle species lists (USFWS 2014)
- USFWS list of special-status animals for Sonoma County (USFWS 2014)
- California Natural Diversity Database records (CNDDB) (CNDDB 2014)
- California Department of Fish and Wildlife's (CDFW) Special Animals List (CDFW 2014),
- State and Federally Listed Endangered and Threatened Animals of California (CDFW 2014)
- California Native Plant Society (CNPS) Electronic Inventory records (CNPS 2014)
- Santa Cruz County General Plan Update 1994)
- CDFG publication "California's Wildlife, Volumes I-III" (Zeiner et al., 1990)

The U.S. Fish and Wildlife Service (USFWS) electronic list of Endangered and Threatened Species was queried electronically (www.fws.gov/sacramento/es_spp_lists-overview.htm). We also reviewed the CalFish IMAPS Viewer (www.calfish.org/DataandMaps/CalFishGeographicData), developed by CDFW Biogeographic Branch for analysis of fisheries.

The CDFW BIOS website and the California Essential Habitat Connectivity Project: A strategy for conserving a connected California (Spencer, et al., 2010) were reviewed for wildlife movement information. The CDFW BIOS website and the CNDDB were review for documented nursery sites.

Other sources of information regarding reported occurrences include locations previously reported to the U.C Berkeley Museum of Vertebrate Zoology and the California Academy of Sciences.

Personnel and Survey Dates: Trish Tatarian, wildlife biologist of Wildlife Research Associates, and Jane Valerius, botanist and wetland specialist of Jane Valerius Environmental Consulting, conducted an initial daytime survey of the project site on March 18, 2014, from 1030 to 1345 and on October 22, 2014 from 1130 to1315. Trish analyzed the on-site habitats for suitability for California red-legged frog (CRLF). No access to the Cemex Plant was allowed at the time of the survey. As a result, the water treatment plant, and the proposed disposal area were not surveyed or evaluated for this report.

Analysis of aerial photographs was conducted of adjacent habitat that could provide terrestrial habitat for CRLF, and ponds and water bodies that could provide potential breeding habitat for CRLF but from which have not been reported in the CNDDB. Habitats within 1.6 km were evaluated for their potential to provide connectivity between sites for CRLF. Jane evaluated the onsite vegetation communities for their potential to support special status plants and/or wetland communities.

Wetland habitat on Agricultural Parcel Two:

As stated in the Biological Resources Assessment, trenching for the pipelines that goes from the proposed storage pond south along Cement Plant Road to the treatment pond could potentially impact wetland ditches located both along the eastern edge of the Coast Dairy property and the willow wetland area on the west side of Cement Plant Road across from the Coastal Dairy property. These wetlands could be avoided if the trench was constructed within the roadway. As stated on page 15 of the Initial Study project description, "Pipe installed along Cement Plant Road would be constructed in trenches within the concrete road to avoid potential sensitive resources."

Page 42 of the Initial Study/MND under Wetland s and Waters states, "Trenching for the distribution pipelines connecting the treatment pond on the Cemex property with the proposed storage pond on the Coast Dairies property could potentially impact agricultural wetland ditches located both along the eastern edge of the Coast Dairy property and the willow shrubland located on the west side of Cement Plant Road across from the Coast Dairies property. However, these wetlands would be avoided by trenching for the distribution pipeline within Cement Plant Road. Agricultural wetland ditches located on the western side of Highway 1 could be avoided by trenching within the existing compacted agricultural road."

Page 45 of the Initial Study/MND requires the following mitigation measure to reduce potentially significant impacts to a less than significant level.

BIO-20 A formal jurisdictional delineation of wetlands and waters of the U.S. shall be conducted within project area stream crossings and ditches prior to implementation of the project. The project will be designed to avoid impacts to all jurisdictional areas. The proposed project will comply with the Santa Cruz County General Plan Chapter 5 Objective 5.2 and Section 16.30 of the County Code which covers Riparian Corridors and Wetlands.

Potential wetland and riparian impacts would be avoided.

Comment 5: Water Quality

Dredging the treatment lagoon of accumulated solids: A mobile (truck mounted) belt filter press would be used to remove water from the accumulated solids removed from the treatment lagoon to produce a non-liquid material for disposal in an authorized landfill. The water removed from the accumulated solids would be returned to the treatment lagoon. Belt filter presses can be used to dewater most biosolids generated at municipal wastewater treatment plants and are a common type of mechanical dewatering equipment.

Chemical treatment of wastewater: The comment suggests that tertiary treated water from the treatment plant is wastewater. Tertiary treated water is not wastewater and can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. Irrigation water would be applied to crops sparingly and would not runoff into the Pacific Ocean. General Plan Policies 5.4.3, 5.4.4, 5.4.5, and 4.4.6 apply specifically to wastewater and not recycled water. The State Water Resources Control Board Recycled Water Policy adopted in 2009 finds that "…the use of recycled water in accordance with this Policy, that is, which supports the sustainable use of groundwater and/or surface water, which is sufficiently treated so as not to adversely impact public health or the environment and which ideally substitutes for use of potable water, is presumed to have a beneficial impact." The tertiary treated recycled water would be treated to a high level that meets Title 22 requirements.

MBUAPCD
Monterey Bay Unified Air Pollution Control District
Serving Monterey, San Benito, and Santa Cruz Counties

24580 Silver Cloud Court
Monterey, CA 93940
PHONE: (831) 647-9411 • FAX: (831) 647-8501

March 24, 2015

Todd Sexauer, Project Planner
County of Santa Cruz, Department of Public Works
701 Ocean Street, 4th Floor
Santa Cruz, CA 95060

Todd.Sexauer@santacruzcounty.us

Re: Davenport Recycled Water Project Initial Study/Mitigated Negative Declaration (IS/MND), App # 151029

Dear Mr. Sexauer:

Thank you for providing the Monterey Bay Unified Air Pollution Control District (Air District) with the opportunity to comment on the above-referenced document. The Air District has reviewed the document and has the following comments:

- The evaluation does not support the conclusion of whether the project will have a significant effect on air quality. The lead agency determines that potential construction and operational air quality impacts would be less than significant without actually estimating project emissions to support its findings. The final MND should include an analysis of the potential air quality impacts compared to the significance thresholds as identified in the Air District's 2008 CEQA Guidelines (The guidelines are available to download at: http://mbuapcd.org/programs-resources/planning/ceqa). For example, indicate the size of the area that will be graded on a daily basis during construction for comparison with the 2.2 acre/day significance threshold for PM_{10}. The California Emission Estimator Model (CalEEMod) is a helpful tool for evaluating emissions from projects and can be downloaded at: http://www.caleemod.com/.

- The discussion under Section C.5. of the Environmental Review Checklist does not identify the potential odors from dredging the treatment lagoon. It is important to disclose the potential for odors and consider options to address odors prior to the start of construction in order to avoid impacts on the local population and to avoid operating in violation of Air District Rule 407, Public Nuisance. As the community of New Town Davenport is located 0.1 mile NW of the project and Old Town Davenport is roughly 0.5 mile to the SE, it is possible that objectionable odors released during the dredging process could affect a substantial number of people and cause a public nuisance. Possible approaches to mitigate the odors could be: 1) only dredge during favorable winds that direct odors away from the local communities and 2) immediately haul dredged material off-site. The measures implemented to mitigate the potential odors should be included in the final MND.

- Please verify that surfaces intended for vehicle use once the project is constructed will be paved to limit operational fugitive dust emissions and potential dust impacts on nearby residents. If the roads will be unpaved, please specify measures that will be implemented to minimize fugitive dust.

- The project proposes modifications to the facility that constitute a change in equipment operating under Air District Permit to Operate #12231 for the Wastewater Treatment Lagoon. Please submit an application to the Air District to modify the permit prior to the start of project construction. The Air

District's Engineering Division can be contacted at 647-9411 if you have questions about the permitting process.

- The Air District recommends including a quantitative analysis of potential greenhouse gas (GHG) emissions from the project. GHG emissions can be estimated using CalEEMod referenced above.
- The text states that the County adopted a Climate Action Plan but does not specify whether any measures from the plan will be implemented with the project. For example, in order to address increased GHG emissions due to the project's energy consumption, consider installing solar or wind energy generation to make progress towards meeting the County of Santa Cruz's ongoing Climate Action Strategy as itemized in strategy E-4.10 – "Increase renewable energy generation on other County facilities, as feasible."
- On page 52, please note that the California Air Resources Board regulates off-road equipment such as construction equipment, rather than a Regional Air Quality Control Board.

Please provide the Air District with written responses to all comments prior to adoption of the Final MND. Air District staff is available to work with the Lead Agency to address these issues and any other questions that may arise.

Best Regards,

Amy Clymo
Supervising Air Quality Planner
(831) 647-9418 ext. 227 or aclymo@mbuapcd.org

cc: David Frisbey, MBUAPCD Air Quality Planner

COUNTY OF SANTA CRUZ Planning Department

MEMORANDUM

Date: March 26, 2015

To: Sheila McDaniel

From: Todd Sexauer

Re: Responses to the Davenport Recycled Water Project MBUAPCD Comments on the Draft IS/MND

Comment 1:

No significant air quality impact would occur from ozone precursors and PM10. The entire site consists of approximately 2 acres of grading and excavation. No import of export of materials are proposed. As a result, the 2.2 acre per day threshold established by the MBUAPCD would not be exceeded. CalEEMod was not run for this reason.

Comment 2

Dredging of the treatment lagoon would have the potential to cause some odors. However, it is located away from sensitive receptors. In addition, sufficient coastal breezes are present in Davenport to mitigate any potential odor that may occur during the temporary operation of dredging. Impacts are not expected to be significant.

Comment 3

All road surfaces would be paved to reduce fugitive dust.

Comment 4

Comment noted.

Comment 5

CalEEMod would quantify the emissions generated during the construction and operational phases of the project. However, the MBUAPCD 2008 CEQA Guidelines currently do not provide a threshold of significance for greenhouse gas emissions. As a result, a qualitative analysis was provided.

Comment 6

The Climate Action Strategy was approved as a guidance document only. The current grant through the SWRCB does not provide for installing solar or wind energy generation facilities at the plant. When funding becomes available, the County would elect to do this. However, it is not currently part of this proposal.

Comment 7

Comment noted.

From:	Jude Todd [todd@ucsc.edu]
Sent:	Monday, March 23, 2015 10:00 AM
To:	Todd Sexauer
Cc:	Sheila McDaniel; John Leopold; Zach Friend; Ryan Coonerty; Greg Caput; Bruce McPherson
Subject:	Davenport Recycled Water Project, Mitigated Negative Declaration
Attachments:	J. Todd Davenport MND comments 3.23.15.pdf; Statement re recycled ww reuse.pdf; Becerra-Castro soil 2015.pdf

Dear Mr. Sexauer,

I am attaching three documents: my comments regarding the Davenport Recycled Water Project's MND, my paper entitled "Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz," and a recent review study by Cristina Becerra-Castro et al. entitled "Wastewater Reuse in Irrigation: A Microbial Perspective on Implications of Soil Fertility and Human and Environmental Health."

Please acknowledge receipt.

Thank you very much.

Jude Todd, PhD
2655 Brommer St. #18
Santa Cruz, CA 95062

2655 Brommer St. #18
Santa Cruz, CA 95062
March 23, 2015

Todd Sexauer, Environmental Coordinator
Santa Cruz County Planning Department
701 Ocean Street, 4th Floor
Santa Cruz, CA 95060

Subject: Davenport Recycled Water Project, Mitigated Negative Declaration

Dear Mr. Sexauer:

I appreciate the opportunity to comment on the Initial Study/Mitigated Negative Declaration (MND) pertaining to the Davenport Recycled Water Project. I have reviewed the MND and find that I have several concerns about the proposed project.

<u>Comment 1</u>: *The MND asserts that "The proposed project is designed to provide recycled water to farmlands on the north coast in an effort to increase their productivity" (MND, p. 21). (However, as I read the descriptions of the four project alternatives, that statement pertains to Alternatives 2, 3, and 4, but not to Alternative 1.)*

To the extent that the statement quoted above (from p. 21) does accurately describe the proposed project, the following conclusion affirmed in the MND is unwarranted: "on the basis of the whole record before the decision-making body (including this Mitigated Negative Declaration) ... there is no substantial evidence that the project as revised will have a significant effect on the environment" (MND, p. 2).

I do not believe that the "whole record" adequately supports that conclusion. In addition to subsequent comments on some specific portions of the MND below, I would call your attention to two attachments that provide substantial scientific evidence that discharge of tertiary-treated wastewater onto soils can negatively impact those soils and, in particular, using such treated wastewater to irrigate food crops can endanger both the soil microbiome and human health.

<u>The first attachment,</u> "Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz" (Todd 2015), a literature review and analysis that I completed just this month, provides extensive scientific evidence that contaminants of emerging concern (CECs) in tertiary-treated wastewater pose health hazards to people and to the environment. I refer you, in particular, to Section II, pp. 3-10, which discusses the following:

-- <u>endocrine disruptors (EDs)</u> and their characteristics, such as <u>nonmonotonicity</u> and lack of a <u>threshold dose</u> and their particularly worrisome capacity to <u>disrupt normal development for fetuses, infants, and children;</u>

-- health problems from <u>transgenerational epigenetic effects</u> of contact with EDs and other contaminants;

-- problems due to <u>mixture effects</u> (a serious problem in sewer water, where thousands of chemicals may contact one another in the course of transit and treatment);

-- problems with <u>drug metabolites</u> in the effluent and <u>transformation byproducts</u> created, in part, by the treatment process itself;

-- problems posed by incalculable numbers of <u>nanoparticles</u> that secondary and tertiary treatment processes have not been shown to remove.

The evidence in that section of my paper (Todd 2015:3-10) demonstrates that using tertiary-treated wastewater as proposed by the Davenport Recycled Water Project could – and likely would – "have significant effects" on people who might contact the plant's effluent through skin contact or by consuming produce irrigated with it.

Section III.A provides further evidence of potential "significant effects" on human health as well as on receiving soils (Todd 2015:10-12). It demonstrates that plants can take up synthetic chemicals, including EDs and nanoparticles, in treated wastewater through their roots into stems, leaves, and fruit, which would expose people who eat the produce to those contaminants. That section also briefly explores the problem of antibiotic resistance genes (ARGs) in treatment plant effluent (pp. 11-12). ARGs are now recognized as a significant means of spreading antibiotic resistance into soils and into people or other animals when they consume produce grown in those soils.

Section II.B explains that, while California Title 22 permits irrigation of food crops (including organic crops) with tertiary-treated wastewater, those regulations are based largely on salinity and live pathogen content. **Title 22 regulations ignore contaminants of emerging concern (CECs),** including many synthetic chemicals, nanoparticles, and ARGs (Todd 2015:12).

<u>The second attachment</u>, "Wastewater Reuse in Irrigation: A Microbiological Perspective on Implications in Soil Fertility and Human and Environmental Health: Review," by Becerra-Castro et al. (2015) reviews about 250 scientific studies pertaining to this topic. That literature review concludes, in part, as follows:

> The ... literature shows that irrigation with treated wastewater is not exempt of implications, some of them adverse. Alterations, such as the increase of organic matter related pools, salinity and soil accumulation of contaminants are the most commonly reported effects.... Also the responses of soil microbiota to wastewater irrigation are varied and include the increase of microbial biomass and activity and different types of alterations on the microbial community structure. However, the most evident outcome of the literature search is that **the effects on soil microbiota are neglected in the majority of studies on irrigation with wastewater**. This is a major gap in the knowledge, given the importance of soil microbiota on soil health and fertility. A critical review of the current knowledge on soil and wastewater microbiology gives **unequivocal indications that wastewater irrigation, in spite of the unquestionable benefits, may have adverse impacts on both physicochemical and microbiological properties of the soil.** These will influence **soil fertility and productivity**, raising **important concerns about the sustainability of continued reuse of treated wastewater in agriculture.** ...
>
> **The risks posed for human health** represent another question at the heart of any discussion on wastewater reuse. These risks cannot be accurately estimated at the moment, but **cannot be ignored.** The evidences reported in the literature, as well as the critical analyses on the limitations of some experimental approaches highlight **the importance of the accumulation and propagation of biological contaminants in soils due to wastewater irrigation. Human and animal pathogens, phytopathogens and antibiotic resistant bacteria and their genes are important biological contaminants that can be transported by wastewater and/or be enriched in soil.** Also numerous **chemical contaminants**, included in categories such as **xenobiotics, pharmaceuticals and metals, can threaten the environmental and human**

> **health.** The **mixture of these contaminants may have unpredictable consequences in both environmental and human health.** (Becerra-Castro et al. 2015:131, emphasis added)

Thus, the Becerra-Castro et al. (2015) review study contradicts the MND conclusion that "there is no substantial evidence that the project as revised will have a significant effect on the environment" (MND, p. 2). That review study alone provides "substantial evidence" to the contrary, and my own review (Todd 2015) regarding unregulated endocrine disruptors and other CECs in treated wastewater provides further evidence that irrigation of agricultural land with tertiary-treated wastewater poses hazards to the health of both people and the environment.

Comment 2: *The MND asserts that, "The proposed recycled water project would not create a significant hazard to the public or the environment. No routine transport or disposal of hazardous materials is proposed" (MND, p. 55).*

Evidence provided by the two attached documents and discussed briefly above indicate that the treated wastewater, which would be routinely moved through pipes onto cropland, is a substance that can pose hazards to the soil and to people who come into contact with it, including people who would eat the produce. As documented in my attached paper, this is especially true for fetuses, infants, and children (Todd 2015:4-5).

Comment 3: *The MND asserts that "The proposed recycled water project would ... [provide] reclaimed water for irrigation, thereby assisting with groundwater recharge.... Therefore, no impact to groundwater resources would occur from project implementation" (MND, p. 61).*

This assertion is not adequately supported. Without geo-hydrological evidence that the CECs in the treated effluent would not reach an aquifer, the assertion that it would not impact groundwater resources is premature. Some CECs have been shown to persist in groundwater for several years (Drewes et al. 2003; Cordy et al. 2004; Schumacher, Pi, and Jekel 2004; Ying and Kookana 2005; Chen et al. 2011; Raghav et al. 2013.)

Comment 4: *Regarding the potential impacts that "are individually limited, but cumulatively considerable," the MND asserts that "there is no substantial evidence that there are cumulative effects associated with this project" (MND, p. 77-78).*

This conclusion is contradicted by substantial evidence in the scientific literature that CECs can accumulate in soil. (See Comment 3 and references above.)

Comment 5: *The MND finds that only "Aesthetics and Visual Resources, Cultural Resources, and Noise" would be "potentially significant effects to human beings" (MND, p. 78).*

This conclusion rests on inadequate analysis of available evidence as discussed in Todd (2015), Becerra-Castro et al. (2015), and the extensive bibliographies in each of those review studies regarding CECs such as endocrine disruptors, nanoparticles, and antibiotic resistance genes (ARGs). (Regarding problems with ARGs, see also LaPara et al. 2011; Pruden 2013; Rizzo et al. 2013.)

***Comment 6**:* Finally, I would point out that my concerns discussed above pertain primarily to the three alternatives (numbers 2, 3, and 4) that include using recycled wastewater on agricultural land. Alternative 1, the minimum project alternative, appears to avoid the potential negative consequences of the three alternatives that "provide recycled water to farmlands on the north coast in an effort to increase their productivity" (MND, p. 21). However, in Alternative 1, the use of the truck to collect and distribute the treated wastewater from the spigot raises questions unanswered in the MND, including what, if any, limitations might be put on the uses for that wastewater. As noted in my attached paper (Todd 2015), all potential uses of recycled sewer water should be evaluated through the lens of the Precautionary Principle.

Thank you for the opportunity to express my concerns about this project and for your careful review, which, I hope, will be undertaken with the Precautionary Principle in mind.

Sincerely yours,
Jude Todd, PhD

Cc: Santa Cruz Board of Supervisors
Sheila McDaniel

References:

Becerra-Castro, Cristina et al. (2015) Wastewater Reuse in Irrigation: A Microbiological Perspective on Implications in Soil Fertility and Human and Environmental Health: Review. *Environment International.* 75: 117–135.

Chen, Feng et al. (2011) Distribution and Accumulation of Endocrine-Disrupting Chemicals and Pharmaceuticals in Wastewater Irrigated Soils in Hebei, China. *Environmental Pollution.* 159:1490-1498.

Cordy, Gail E. et al. (2004) Do Pharmaceuticals, Pathogens, and Other Organic Waste Water Compounds Persist When Waste Water Is Used for Recharge? *Ground Water Monitoring and Remediation.* 24(2):58-69.

Drewes, Jorg E, et al. (2004) Fate of Pharmaceuticals During Ground Water Recharge. *Ground Water Monitoring and Remediation.* 23(3):64-72.

LaPara, Timothy M. et al. (2011) Tertiary-Treated Municipal Wastewater Is a Significant Point Source of Antibiotic Resistance Genes into Duluth-Superior Harbor. *Environmental Science and Society.* 45:9543-9549.

Pruden, Amy. (2013) Balancing Water Sustainability and Public Health Goals in the Face of Growing Concerns About Antibiotic Resistance. *Environmental Science & Technology.* 48:5-14.

Raghav, Madhumitha et al. (2013) Contaminants of Emerging Concern in Water. *Arroyo.* 1-12.

Rizzo, L. et al. (2013) Urban Wastewater Treatment Plants as Hotspots for Antibiotic Resistant Bacteria and Genes Spread into the Environment: A Review. *Science of the Total Environment.* 447:345-360.

Schumacher, J., Y.Z. Pi, and M. Jekel. (2004) Ozonation of Persistent DOC in Municipal WWTP Effluent for Groundwater Recharge. *Water Science & Technology.* 49(4):305-310.

Todd, Jude. (2015) Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz. Unpublished ms.

Ying, Guang-Guo and Raj S. Kookana. (2005) Sorption and Degradation of Estrogen-Like-Endocrine Disrupting Chemicals in Soil. *Environmental Toxicology and Chemistry.* 24(10):2640-2645.

Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz

I. INTRODUCTION

A. Purpose

Recycled wastewater use is growing rapidly in California and other western states, largely in response to drought-inspired worries about water supply security. Growing concerns about the impacts of wastewater pollution on receiving waters also factor into the water-reuse equation in many communities. This is true in Santa Cruz as we explore ways to fortify our water supply. But important questions need to be carefully considered and satisfactorily answered before adopting any uses of recycled municipal wastewater water here in Santa Cruz, including:

-- What else besides water do the various types of recycled wastewater contain?

-- What are the possible human and environmental health impacts of proposals to use recycled municipal wastewater that are being considered by the Water Supply Advisory Committee (WSAC)?

-- How should we go about discerning between safe, beneficial uses of recycled municipal wastewater and those that pose more risks than benefits to environmental and public health?

This statement, endorsed by People Against Unsafe Wastewater Reuse and other community members, aims to provide information for policymakers regarding these challenging questions. After discussing problems posed by "contaminants of emerging concern" (CECs) in recycled municipal wastewater, it reviews California State regulations and policy regarding recycled wastewater and examines the two categories of uses that seem particularly problematic (food-crop irrigation and potable reuse). It then briefly explores two more general categories (landscape irrigation and commercial/industrial uses) as including promising candidates for safe, appropriate application of recycled municipal wastewater.

B. Scope of Discussion

Recycled municipal wastewater refers to water that is treated and recycled from the sewer system -- not to greywater or other decentralized wastewater recycling systems. Santa Cruz municipal wastewater comes from sinks, tubs, floor drains, showers, and toilets in homes, business and industrial establishments, hospitals (both human and veterinary), and other institutions such as research laboratories, schools (including college and university science labs), assisted-living communities, long-term care facilities, and the county jail. The Santa Cruz wastewater treatment plant processes this sewer water from "the City of Santa Cruz and the Santa Cruz County Sanitation District (includes Live Oak, Capitola, Soquel and Aptos)" (City of Santa Cruz 2015).

Recycled municipal wastewater use is divided into four categories:

-- potable reuse (including both indirect potable reuse (IPR) and direct potable reuse (DPR))

-- agricultural irrigation

-- landscape irrigation (e.g., irrigation of parks, playgrounds, golf courses, cemeteries, and other landscapes)

-- commercial and industrial purposes (e.g., flushing commercial toilets, controlling dust on roads or streets, mixing concrete, and many other possible uses).

C. The Precautionary Principle

In all cases, our assessments are guided by the Precautionary Principle. While there are many versions of the Precautionary Principle, it has three commonly accepted components:

> **(1) Where there is reliable scientific evidence that a product or practice may cause serious harm to either humans or the environment, the product or practice should not be used unless or until there is proof of its safety.**
>
> **(2) Those who advocate adopting the product or practice bear the burden of proof to demonstrate that it is safe before it is put on the market or adopted for use.** This second component is important because so many products, including those made with endocrine-disrupting chemicals or engineered nanoparticles, have been unleashed into the environment without adequate safety testing, leaving it up to those who are concerned about public and environmental welfare to spend years appealing to the EPA, FDA, or other agencies to appropriately regulate the product.
>
> **(3) The Precautionary Principle also requires democratic public participation as well as full transparency on the part of governing agencies regarding scientific evidence that informs a policy decision.**

II. CONTAMINANTS OF EMERGING CONCERN (CECs) IN RECYCLED MUNICIPAL WASTEWATER

Use of the Precautionary Principle is important because of increasing scientific evidence of contaminants heretofore unidentified in recycled wastewater that pose health concerns. These "contaminants of emerging concern" (CECs) in recycled municipal wastewater include personal care products, pharmaceuticals, industrial and agricultural chemicals, pathogenic agents, nanomaterials, and byproducts of any of the above that are not regulated but that are now known or strongly suspected to cause harm to either humans or wildlife. So, for example, DDT is not a contaminant of emerging concern because we already know that it is toxic. An itemized list of substances that scientific evidence indicates might be harmful in recycled wastewater would be too long to assemble, but characteristics of some types of CECs, including those that can disrupt endocrine systems, are summarized below to provide a brief documentation of the nature of that concern.

A. Number of Synthetic Chemicals

Over 100,000 synthetic chemicals have been registered in the U.S. including "more than 84,000 industrial chemicals, 9,000 food additives, 3,000 cosmetic ingredients, 1,000 pesticide active ingredients, and 3,000 pharmaceutical drugs" (Regional Monitoring 2013:49).

B. Trace Amounts of CECs Remain in Treated Municipal Wastewater

Currently, there is no wastewater treatment train, even those using reverse osmosis, that can remove all contaminants of emerging concern; **trace levels – i.e., amounts in the parts per billion or parts per trillion levels** -- of many CECs, including endocrine disruptors and an array of disinfection byproducts, **remain in the effluent** (Asano et al. 2007:113; see also WEF and AWWA 2008:1-6; Raghav et al. 2013:4,7; Schnoor 2014:12A).

C. Health Impacts of Endocrine Disruptors (EDs)

Our dependence on synthetic chemicals is problematic because, as endocrinologists and other independent scientists have shown, many such chemicals -- especially those that disrupt the endocrine systems of humans and other animals – are implicated in the etiology of diseases that now plague people all over the planet. As the term suggests, endocrine disruptors (EDs) can impact all the complex and delicate endocrine systems, including the pituitary gland, hypothalamus, thyroid, cardiovascular system, mammary glands, pancreas, ovaries, uterus, prostate, and testes, as well as the brain and adipose (fat) tissue (Diamanti-Kandarakis et al. 2009:4). EDs can impact an organism by either mimicking or antagonizing (or sometimes both) the animal's innate hormones, thus binding with hormone receptors. So, e.g., an ED that mimics estrogen can interfere with the functioning of both male and female reproductive organs; an ED that mimics insulin can throw off the delicate balance maintained by the pancreas; an ED that mimics or antagonizes thyroxin can unbalance the thyroid.

But mimicking or antagonizing endogenous hormones[1] is not the only mode of action for EDs; as Linda Birnbaum, the toxicologist who heads up both the National Toxicology Program and the National Institute of Environmental Health Services, explained in a recent interview, **an ED is "anything that affects the synthesis of a hormone, the breakdown of a hormone or how the hormone functions.** We

---

[1] "Endogenous hormones" are those produced within an organism. Exogenous hormones are those produced outside the organism itself.

used to think it had to bind with a hormone receptor but endocrine disruptors can perturb hormone action at other stages in the process" (qtd. in Borrell 2012, emphasis added). Such perturbations in hormone function can have wide-ranging impacts on our bodies. As the Environmental Working Group, an independent health research organization, explains:

> There is no end to the tricks that endocrine disruptors can play on our bodies: increasing production of certain hormones; decreasing production of others; imitating hormones; turning one hormone into another; interfering with hormone signaling; telling cells to die prematurely; competing with essential nutrients; binding to essential hormones; accumulating in organs that produce hormones. (Environmental Working Group 2013)

Given this list of ways that EDs can stymie our normal bodily functions, we can begin to see how they can precipitate childhood leukemia and other cancers, allergies, asthma and other respiratory problems, genital malformations in baby boys, early puberty in girls, ADHD, lowered IQ, autism, obesity, diabetes, cardio-pulmonary diseases, immune-system dysfunction, and Parkinsonism; evidence is mounting that endocrine disruptors may also play a role in development of Alzheimer's disease and other mental illnesses (Alonso-Magdalena 2006; Grandjean et al. 2007; Diamanti-Kandarakis et al. 2009; Birnbaum 2010; Burkardt-Holm 2010; Landrigan 2010; Soto and Sonnenschein 2010; Karoutsou and Polymeris 2012; Sargis et al. 2012; Weiss 2012; Zoeller et al. 2012; Birnbaum 2013; Carpenter 2013; Welshons 2013; Blaszczak-Boxe 2014; Grandjean and Landrigan 2014; Hamblin 2014; Richardson et al. 2014; Schiffer et al. 2014; Bellanger et al. 2015; Konkel 2014a,b, 2015; Genuis and Kelln 2015; Grossman 2015; Scutti 2015; Trasande et al. 2015).

D. Trace Quantities of Endocrine Disruptors and the Developmental Basis of Disease

Endocrine disruptors in only trace amounts -- the same amounts present in recycled sewer water -- are especially dangerous for fetuses, infants, and small children. As American Water Resources Association researchers David Norris and Alan Vajda write in their article "Endocrine Active Chemicals (EACs) in Wastewater: Effects on Health of Wildlife and Humans," **"...ample evidence of endocrine disruption of reproduction related to nano-quantities (parts per billion and parts per trillion) of human-based xenoestrogens in wastewater effluents appeared in the late 1980s and early 1990s"** (Norris and Vajda 2007:15, emphasis added).[2] Since that time, evidence of the impacts of EDs on health of both wildlife and humans has grown substantially.

Those health impacts are more likely when the organism is exposed to the ED during the early stages of development. Illnesses triggered by chemicals during those vulnerable formative years are often irreversible (Zoeller et al. 2012:4101). When present in the body of a pregnant woman, endocrine disruptors can be passed on via the placenta to the fetus and via breast milk to the infant. Maternal transmission of EDs is particularly important because, as explained in the Endocrine Society's comprehensive review and analysis, *Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement,* the age at which one is exposed to these chemicals can make the health impacts more or less significant, and fetal and early postnatal-infant stages are developmental periods when mammals are most vulnerable (Diamanti-Kandarakis et al. 2009). The brain and nervous system, immune system, reproductive system, heart, lungs, and all other crucial organs are being developed at those times; **illnesses due to malfunction of those systems and organs that are precipitated during those early months and years may not become apparent until years or even decades later** (Diamanti-Kandarakis et al. 2009:3; see also Colborn, vom Saal, and Soto 1993; Colborn 1997, 2004a; Shapley 2009; Burkhardt-Holm 2010; Landrigan and Goldman 2011; Zoeller et al. 2012; Braun 2014; Williams 2013/2014; Grandjean and Landrigan 2014; Whyatt et al. 2014).

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[2] The analogy commonly used to illustrate one "part per trillion," or one nanogram per liter, is that it is like one drop of water diluted into 20 Olympic-sized swimming pools. "Xenoestrogens" are chemical compounds, such as those in some pesticides, drugs, and industrial products like plasticizers, that mimic estrogen and can thus disrupt the endocrine system.

Among the many scientific articles demonstrating greater susceptibility to endocrine disruptors by fetuses and children is Philip J. Landrigan and Lynn R. Goldman's (2011) study, "Children's Vulnerability to Toxic Chemicals: A Challenge and Opportunity to Strengthen Health and Environmental Policy." Landrigan, a pediatrician and epidemiologist, is dean of global health and a professor of preventive medicine and pediatrics at the Mount Sinai School of Medicine; Goldman is dean of the School of Public Health and professor of environmental and occupational health at George Washington University. Their review article on this topic explains that children are more susceptible than adults to health impairments from chemical exposure for four reasons:

> First, children have greater exposures to toxic chemicals for their body weight than adults. **A six-month-old infant drinks seven times more water per pound than an adult**....Children's hand-to-mouth behavior and play on the ground further magnify their exposures.
>
> Second, children's metabolic pathways are immature, and a child's ability to metabolize toxic chemicals is different from an adult's.... **[Children] lack the enzymes needed to break down and remove toxic chemicals from the body.**
>
> Third, children's early developmental processes are easily disrupted. Rapid, complex, and highly choreographed development takes place in prenatal life and in the first years after birth... In the brain, for example, billions of cells must form, move to their assigned positions, and establish trillions of precise interconnections.... [3] **[Exposures to chemicals during crucial "windows of vulnerability"] can disrupt organ formation and cause lifelong functional impairments....**
>
> Fourth, children have more time than adults to develop chronic diseases. **Many diseases triggered by toxic chemicals, such as cancer and neurodegenerative diseases [including dyslexia, mental retardation, attention deficit hyperactivity disorder [ADHD], and autism],...evolve through multistage, multiyear processes that may be initiated by exposures in infancy [or in utero].** (Landrigan and Goldman 2011:843, emphasis added)

Chemical-induced diseases set in motion during gestation or infancy often do not show up until years or even decades after exposure. **This "long delay between the time point of exposure and measurable effects" makes tracing causative factors for particular instances of cancer, Parkinsonism, Alzheimer's Disease, or other diseases that appear in later years very challenging** (Burkhardt-Holm 2010, emphasis added).

E. Transgenerational Epigenetic Inheritance of Disease

The long delay between exposure to harmful chemicals and their health consequences is turning out to be even longer than once thought. **Research in the last couple of decades has indicated that in some instances harms inflicted by endocrine disruptors and some other chemicals may be passed on to subsequent generations via a process known as transgenerational epigenetic inheritance** (Edwards and Myers 2007; Grandjean et al. 2007; Diamanti-Kandarakis et al. 2009:4,7-8; Burkhardt-Holm 2010:484-487; Birnbaum 2010; Daughton 2010:54-55; Birnbaum and Jung 2011; Francis 2011; Guerrero-Bosagna and Skinner 2012; Martin 2013; Head 2014; Tollefsbol 2014).

The concept of transgenerational epigenetic inheritance can seem puzzling at first, but it is not as strange as it might initially seem. We are familiar with the "nature vs. nurture" debate, which most scientists readily resolve by saying that health is a result of both nature (our genes) and nurture (factors in

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[3] As Lauren K. Wolff (2014), writing for the *Chemical and Engineering News*, explains, "**Nerve cells** grow and connect, sometimes **forming 40,000 new junctures [synapses] per second, until a baby reaches about two years of age**" (Wolff 2014, emphasis added).

our environment). Most people would likely agree that environmental influences (e.g., diet, exercise, exposure to toxic substances) interact with genetics to influence health.[4] The term "epigenetics" refers to those environmental factors – factors outside the genome itself -- that influence gene expression without causing a genetic mutation. Sometimes those environmental factors, particularly exposure to chemicals such as endocrine disruptors, can result in "methylation" of one or more genes, and that, in turn, influences gene expression. Methylation is a chemical reaction in which a carbon atom and three hydrogen atoms, known in organic chemistry as a methyl group, attach to a molecule. Gene methylation is one of several epigenetic mechanisms by which exposure to endocrine disruptors and other chemicals can alter genetic expression, sometimes resulting in disease or diminished capacity.

"Transgenerational epigenetics" – the newer and more surprising concept -- refers to heritable changes in gene expression that are not due to a mutation. As Jessica Head, with the University of Michigan School of Natural Resources and Environment in Ann Arbor, explains:

> Epigenetics is not a newly discovered phenomenon; we have known about the role of DNA methylation in regulating gene expression for over 35 years.... What is new is our developing epigenetic perspective on how early life experiences can have lasting impacts on health that may even be inherited by future generations.... **With epigenetic modes of action, level of exposure to contaminants, intermediary sub-clinical responses, and the overt toxic response may be temporarily separated throughout an individual's lifetime, or even between generations, a possibility that most risk assessment does not take into account.** (Head 2014:83-84, emphasis added)

Linda Birnbaum, Director of the National Institute of Environmental Health Sciences (NIEHS) and National Toxicology Program, shares Head's concern about the shortfall of risk assessment and outdated toxicological methods in evaluating the ways that endocrine disruptors and other synthetic chemicals can impact health (Birnbaum 2010). Birnbaum and her colleague Paul Jung, chief of staff at NIEHS, explain transgenerational epigenetics as follows:

> ...we're born with our genes, but epigenetic changes occur because of environmental influences during development and throughout life. Epigenetics thus provides a measurable "imprint" on DNA expression that may be useful as a biomarker for disease susceptibility. And these imprints can be carried and expressed across generations. (Birnbaum and Jung 2011:818)

It would thus seem advisable for people considering the possible health impacts of trace amounts of drugs and other chemicals in recycled wastewater to attend to epigenetics, but the topic is rarely addressed in the water-reuse literature.

One exception is the comprehensive review study by C. G. Daughton (2010), "Pharmaceutical Ingredients in Drinking Water: Overview of Occurrence and Significance of Human Exposure." Daughton, who is the U.S. EPA Chief of the Environmental Chemistry Branch at the National Exposure Research Laboratory, explains epigenetics as follows:

> Unlike the genome, the epigenome is plastic, dynamic, extraordinarily complex, and varies across tissues and individuals.... **[E]pigenetic alterations can accumulate, resulting in delayed-onset outcomes that can persist long after exposure has ceased – even across several generations**. (Daughton 2010:54, emphasis added)

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[4] Stephen Rappaport and Martyn Smith, with the UC Berkeley School of Public Health, sum up the relative proportion of chronic disease attributable to genes vs. environment as follows: "Although the risks of developing chronic diseases are attributed to both genetic and environmental factors, 70 to 90% of disease risks are probably due to differences in environments" (Rappoprt and Smith 2012:460).

Daughton also comments on the dearth of attention to the health implications of epigenetics when considering drugs as drinking-water contaminants:

> Given the thousands of publications devoted to APIs [active pharmaceutical ingredients] as environmental pollutants, few address the possible role of epigenetics in human (or even aquatic) health. Epigenetics has been mentioned only in passing in perhaps a dozen or so of the thousands of published works; most of these have been published since 2006. (Daughton 2010:54)

Transgenerational epigenetic effects of trace pharmaceuticals and other chemicals of emerging concern in recycled municipal wastewater should be receiving – but, to date, have not received – serious attention from both the water-reuse industry and its regulators.

F. Nonmonotonicity and Lack of a Threshold Dose

While most synthetic chemicals remaining in the effluent of state-of-the art treatment plants may be present only in "trace" amounts (parts per billion or parts per trillion), such low doses do not protect people or other animals who drink or bathe in it. As we've seen, chemicals that can disrupt endocrine systems are bioactive in the parts per billion or parts per trillion levels, and in some cases even less (Norris and Vajda 2007:15; Myers and Hessler 2007:3; Vandenberg et al. 2012; Welshons 2013). As surprising as this may seem, there is abundant scientific evidence demonstrating that endocrine disruptors can be even more harmful in miniscule amounts than in slightly larger amounts, depending on the target organism and age at time of contact with the chemical; this phenomenon, known as nonmonotonicity, is evidenced by the chemical's nonmonotonic dosage-response curve (Sheehan 2006; Myers and Hessler 2007; Diamanti-Kandarakis et al. 2009:4; Fagin 2012; Schettler et al. 2012; Vandenberg et al. 2012; Welshons 2013; Birnbaum and Jung 2014:816-818; Vandenberg 2014).

Nonmonotonicity seems counter-intuitive. Traditional toxicologists and the regulators whom they advise tend to operate according to the more "common sense" maxim, coined by Paracelsus, the 16th-century Father of Toxicology, that "The dose makes the poison." However, endocrinologists and other independent scientists in the 20th and 21st centuries have shown that this "common sense" maxim does not always hold true. In their article, "Does 'The Dose Make the Poison?' Extensive Results Challenge a Core Assumption in Toxicology," Myers and Hessler (2007) explain that some chemicals, including endocrine disruptors,

> ...cause different effects at different levels, including impacts at low levels that do not occur at high doses.... **Because all regulatory testing has been designed assuming that 'the dose makes the poison,' it is highly likely to have missed low dose effects, and led to *health standards that are too weak*.** (Myers and Hessler 2007:1, emphasis added)

In fact, there may be no "threshold dose" (an amount below which the chemical causes no harm) for some chemicals, especially for fetuses, infants, and children, as explained in the preceding section (Sheehan 2006; Grandjean et al. 2007; Vandenberg, Zoeller, and Myers 2012; Zoeller 2012; Birnbaum and Jung 2014:817-818).

Laura Vandenberg, PhD, molecular and developmental biologist with the Center for Regenerative and Developmental Biology, Tufts University, and eleven other independent scientists whose research has demonstrated nonmonotonicity conclude their review of the topic with the following assessment:

> We understand that [our findings of nonmonotonic dosage-response curves for endocrine-disrupting chemicals] challenge risk assessment dogma, but **society's tendency to maintain the *status quo* is insufficient as an argument to rebut scientific data**.... [T]here is...much evidence within the field of endocrinology to support the interpretation that low doses exert adverse effects

> on the human population. **<u>Data must trump theories, hypotheses, models and assumptions, and not the reverse.</u>** (Vandenberg et al. 2012:16, emphasis added)

In other words, ideologies or other cherished beliefs -- whether that belief is that "the dose makes the poison" or that "only genetic information can be passed on to future generations" -- should be trumped by <u>scientific evidence produced by independent researchers</u>, particularly when public health is at stake.

<u>G. Mixture Effects</u>

Chemicals that mix together in sewer water can interact with one another unpredictably; the **effects of mixing several chemicals** that have a similar physiological effect (e.g., estrogenic) can be **additive, antagonistic,** or **synergistic** (Rajapaske, Silva, and Kortenkamp 2002). Andreas Kortenkamp, with the School of Pharmacy at the University of London, has been studying the problem of mixture effects, particularly in estrogenic chemicals, for many years. He explains that, "In toxicology, 'additivity' describes the case in which chemicals 'act together' to produce effects without enhancing or diminishing each other's action..." (Kortenkamp 2007:98). "Synergism" refers to effects greater than additive, while antagonistic effects are those that are less than additive (Kortenkamp 2007:99).

The numbers of chemicals in sewer water at any given time that can potentially interact with each other (out of the possible tens of thousands) are incalculable. What happens when the innumerable drugs and other chemicals discharged from hospitals, industries, residences, veterinary clinics, long-term-care facilities, or chem labs bump up against each other in sewers? What are the physiological effects on humans and wildlife of these chemical mixtures? Insufficient research has been done to address such vexing questions, but the research that has been done demonstrates that chemicals – even those that pose little or no threat individually – can be more hazardous when mixed with other chemicals (Yang 1994; Biello 2006; Sheehan 2006; Kortenkamp 2007, 2008; Backhaus, Sumpter, and Blanck 2008; Diamanti-Kandarakis et al. 2009; Payne-Sturges et al. 2009; Birnbaum and Jung 2011).

Traditional toxicological methods used to develop "maximum contaminant levels" (MCLs) for regulatory purposes **ignore these mixture effects, relying instead on animal tests of one chemical at a time.** Studying antibiotics in wastewater treatment plants, Sungpyo Kim and Diana S. Aga, chemists at the State University of New York at Buffalo, note:

> Although a few environmental risk assessment studies suggest that the levels of pharmaceuticals in the environment, including antibiotics, are not a major threat to human health...,**the chronic effects of mixtures of these microcontaminants remain unknown. Typical health risk calculations are based on a single drug exposure in a lifetime. The synergistic and antagonistic effects of pharmaceutical mixtures on human[s] and ecology cannot be ruled out, and need to be addressed in risk assessment.** For instance, it was demonstrated that a mixture of ibuprofen, prozac, and ciprofloxacin produced 10- to 200-fold higher toxicity in plankton, aquatic plants, and fish .... These results imply that a more sophisticated approach for the risk assessment of antibiotics... might be necessary to obtain a more accurate assessment of health and ecological risks associated with antibiotics in the environment. (Kim and Aga 2007:568-570, emphasis added)

Research done by endocrinologists, chemists, and many other independent scientists who have considered this issue indicates the need for "a more sophisticated approach for the risk assessment" not only for drugs but also for personal care products, pesticides, and industrial chemicals that find their way into sewer water, small amounts of which can remain in treatment plants' effluent.

H. Drug Metabolites and Transformation Byproducts

Some consumed drugs may pass through our bodies into sewers largely unchanged. For example, "Most antibiotics are poorly metabolized after administration.... Thus, relatively high fractions of the drug are excreted" (Jjemba 2008:172). However, many other drugs create ***metabolic byproducts*** after consumption, further complicating risk assessment of chemicals – and chemical mixtures – in recycled municipal wastewater. For example, the anticonvulsant drug carbamazepine is often found in wastewater treatment effluents, though its several metabolites are usually not included in assessments of wastewater plant efficacy. One exception is the study by Miao et al. (2005), which examined wastewater samples for caffeine, carbamazepine, and five of its known 33 metabolites, at least one of which "has been shown to possess similar anti-epileptic properties [to carbamazepine], and it may cause neurotoxic effects" (Miao et al. 2005:7470; see also La Farre et al. 2008). The authors found the treatment process to be effective in removing caffeine but not in removing the carbamazepine metabolites (Miao et al. 2005:7474). This result is significant because **if a treatment plant's efficacy is assessed looking only for the original drug and not its metabolites, then the analysis could overestimate the plant's treatment efficacy.**

Complicating matters further, "some excreted metabolites can also be transformed back into the parent compound" (Jjemba 2008:172; see also Escher and Fenner 2011). A recent study by Qu et al. (2013) on metabolites of the steroid trenbolone indicates that some drugs are transformed into other compounds by light but then revert to the parent drug in darkness. That study, "Product-to-Parent Reversion of Trenbolone: Unrecognized Risks for Endocrine Disruption," found that, while light breaks down trenbolone (TBA) metabolites, the **phototransformation products re-convert to the parent compounds in dark conditions;** this process "results in the enhanced persistence of TBA metabolites via a dynamic exposure regime that defies current fate models and ecotoxicology study designs" (Qu et al. 2013:350). The authors explain the implications:

> This product-to-parent reversion mechanism results in diurnal cycling and substantial regeneration of TBA metabolites at rates that are strongly temperature- and pH-dependent. Photoproducts can also react to produce structural analogs of TBA metabolites. **These reactions also occur in structurally similar steroids, including human pharmaceuticals, which suggests that predictive fate models and regulatory risk assessment paradigms must account for transformation products of high-risk environmental contaminants such as endocrine-disrupting steroids**. (Qu et al. 2013:347, emphasis added)

The ability of some endocrine disruptors' transformation products to revert to the original chemical in darkness has implications for proposals to inject treated wastewater into aquifers. If testing for these revertible chemicals were done only under light conditions, that could lead to erroneous conclusions about the amount of drugs being introduced into aquifers, which are pretty dark places.

Similar studies need to be undertaken for a wide range of pharmaceuticals that may remain even in trace amounts in recycled municipal wastewater, which contains every type of drug taken by people in the community: statins, beta blockers, antidepressants, radiotherapeutic agents, sedatives, bronchodilators, antibiotics, diuretics, cytotoxic cancer drugs, anti-psychotics, analgesics, narcotics, drugs to facilitate gender changes, drugs to address erectile dysfunction, "recreational" drugs, etc. Some research has been done on transformation byproducts of X-ray contrast media (Schulz et al. 2008; Kormos, Schultz, and Ternes 2011). Chemotherapeutic cancer drugs have also received some attention (Kosjek and Heath 2011; Zhang et al. 2013).

Other chemicals besides drugs also undergo changes during wastewater treatment (Cwiertny et al. 2014; Ortiz de Garcia et al. 2014). While not much is known about the fate of chemical transformation byproducts in wastewater treatment plants, enough is known to conclude that this phenomenon contributes in important ways to the problem of mixture effects discussed in Section G above. But this area of metabolites and transformation byproducts needs more research – and much more attention from the water-reuse industry and the agencies that regulate it.

I. Engineered Nanoparticles

Unimaginable numbers of engineered nanoparticles, particles with at least one dimension smaller than 100 nanometers, are present in our sewer water. Without regulation by the EPA or any other regulatory agency, the use of nanoparticles – especially the antibiotic nanosilver -- has spread widely and rapidly. Engineered nanoparticles are now used in some personal care products (e.g., toothpaste, sunscreens, baby wipes), clothing (e.g., socks, shoe insoles, underwear), kitchen utensils (e.g., knives, cutting boards, ceramic-coated pots and pans), and other products. When those products are washed, nanoparticles can get flushed down drains into sewers. Nanoparticles are also used in drugs and even in diet drinks, allowing them to be excreted into sewers (Reed et al. 2014).

Furthermore, some washing machines use nanosilver to eliminate mold. One such washer, made by Samsung, releases 100 quadrillion silver nanoparticles (that's 100,000,000,000,000,000 of them) into sewers with each wash (Feder 2007).

Engineered nanoparticles, another contaminant of emerging concern, pose a problem for potable reuse of sewer water because they are potentially harmful to humans (Gwinn and Vallyathan 2006; Birnbaum and Jung 2011; Abbott Chalew and Schwab 2013), and their presence in the effluent of wastewater treatment plants has **not been adequately studied.** Consequently, we do not know the extent to which various treatment trains remove nanoparticles. As R. Rhodes Trussell et al. (2013) write in *Potable Reuse: State of the Science Report and Equivalency Criteria for Treatment Trains*, "only a limited number of studies have been performed in this research area, but the preliminary data indicate that this may be an important issue to consider in potable reuse applications" (39). Trussell and colleagues express concern about the type of washing machine discussed above, as well as other sources of nanoparticles in sewer water, and they acknowledge the "potential for nanoparticles to persist through [advanced wastewater treatment] trains" (39). They conclude that "There is currently little evidence to determine whether nanoparticles pose a significant public health threat in potable reuse applications. The reuse community would be wise to keep a watchful eye on this issue in the future" (Trussell et al. (2013:39).

Bottom line: Given the inadequate study of the health effects of drinking and bathing with recycled municipal wastewater that may contain unknown numbers of nanoparticles, EDs, and other CECs; studies that suggest harmful effects of many CECs on human health; and the absence of evidence that any wastewater treatment train can effectively remove these contaminants to levels that are safe for fetuses, infants, and children,[5] the Precautionary Principle requires that we in Santa Cruz not use recycled municipal wastewater for drinking or bathing.

III. STATE REGULATIONS AND POLICY REGARDING RECYCLED WASTEWATER

Given the known presence of trace amounts of chemical contaminants in even the most advanced municipal wastewater treatment systems as discussed above and the scientific evidence of potentially serious health impacts, how is it possible that the State permits potable reuse of such water? And how is it possible that less thoroughly treated sewer water can be used to irrigate food crops, including organic produce? As briefly explained below, the State overlooked sound scientific evidence when they wrote

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[5] This caution also applies regarding members of other "sensitive populations" not addressed here, including the elderly, people who are chemically sensitive, girls going through puberty, and people in ill health.

Title 22 regulations for non-potable reuse and again when they formulated the 2013 *Recycled Water Policy*, which addresses indirect potable reuse (IPR) via aquifer recharge. This section also explains why Governor Brown's efforts to fast-track regulations for direct potable reuse (DPR) appear likely to repeat the State's history of ignoring important scientific evidence regarding the potential health effects of emerging contaminants in recycled municipal wastewater.

A. Title 22 Regulation of Recycled Wastewater for Food-Crop Irrigation

There are no federal regulations of recycled municipal wastewater. That task is left up to the states. Here, non-potable uses of recycled sewer water are governed by "Title 22: California Recycling Criteria." Title 22 governs irrigation for all agricultural purposes, including ornamental plants, pasture for milk animals, fodder and fiber crops for animals, etc. This paper focuses on the portions of Title 22 that regulate food-crop irrigation.

Title 22 permits irrigating food crops, including organic crops, with either secondary- or tertiary-treated recycled wastewater, depending upon the type of crop and the method of irrigation. The Precautionary Principle rules out irrigating food crops with recycled sewer water for the following reasons:

1. Uptake of Chemicals

Both secondary- and tertiary-treated wastewater contain small amounts of synthetic chemicals, including endocrine disruptors. It is well known that plants can and do take various synthetic chemicals up into their roots, stems, leaves, and fruits (Schneider 2008; Calderon-Preciado, Matamoros, and Bayona 2011; Malchi et al. 2014). When children and adults, including pregnant women, eat the plants, they would also ingest small amounts of these potentially harmful chemicals. As noted above, endocrine disruptors are especially hazardous for fetuses, infants, and small children. Such risk of serious harm to future generations is unacceptable; instead, farmers could use drip irrigation and employ other conservation methods, including considering crop choices that make sense in a drought-prone region.

2. Engineered Nanoparticles

Both secondary- and tertiary-treated wastewater would also likely contain high quantities of engineered nanoparticles, including antimicrobials such as nanosilver, which is known to harm soil organisms and suspected of causing health problems for higher animals, including humans (Navarro et al. 2008; Gajjar et al. 2009; Birnbaum and Jung 2011; Abbot Chalew and Schwab 2013).

3. Antibiotic Resistance Genes

It is well known that antibiotic-resistant bacteria (ARB), such as methicillin-resistant *Staphylococcus aureus* (MRSA) -- which alone kills about 19,000 people in the U.S. annually – are on the rise and pose a serious health threat, particularly in hospitals (Krasner et al. 2006). Such dangerous bacteria are killed by disinfectants, including those used in hospitals and homes as well as chlorine and all other types of wastewater disinfection. Disinfection of recycled sewer water is, of course, essential. However, researchers have now demonstrated that killing the ARB permits the bacteria's antibiotic-resistance genes (ARGs) to be released into the wastewater. By a process known as ***horizontal gene transfer***, these ARGs can be taken up by other living bacteria, causing those bacteria to become antibiotic resistant (Jjemba 2008:171-179; Dodd 2012; McKinney and Pruden 2012; Fahrenfeld et al. 2013; Fatta-Kasinos and Michael 2013; Pruden et al. 2013; Hong et al. 2014; Mole 2014). Consequently, wastewater disinfection, which leads to production of "approximately 600-700" chemical byproducts (Krasner et al. 2006), also contributes to the spread of antibiotic resistance. As medical geo-hydrologist Edo McGowan, M.D., explains, "Pathogens that in nature might never get together for gene exchange are thrust into each other in a sewer plant" (McGowan, posted in Olena 2013).

In his December 2010 comments to the SWRCB regarding CEC monitoring for recycled wastewater, McGowan explains at length how horizontal transfer of ARGs into the human intestine can result in development of antibiotic resistance, why this is dangerous, and why the source of the problem would be untraceable (California State Water Recourses Control Board 2011).

4. Title 22 Regulations of Non-Potable Reuse Ignore Important Scientific Evidence

How is it possible that food-crop irrigation is this fraught with problems? One might assume that California regulations would be sufficiently protective. However, those regulations do not take into account scientific evidence available at the time.

In the year 2000, when the Title 22 regulations of recycled wastewater were put in place, synthetic chemicals were disregarded, even though prior to that year, there was already reliable scientific evidence that endocrine disruptors (EDs) can harm wildlife and can lead to an array of serious illnesses in humans, including infertility, genital abnormalities, breast cancer, and other health problems, as discussed earlier (Colborn, vom Saal, and Soto 1993; Jobling 1996; Sharpe et al. 1996; Kelce and Wilson 1997; Daugton and Ternes 1999).

As noted earlier, Norris and Vajda (2007) have pointed out that there was already "ample evidence of endocrine disruption of reproduction related to nano-quantities (parts per billion and parts per trillion) of human-based xenoextrogens in wastewater effluents... in the late 1980s and early 1990s" (Norris and Vajda 2007:15, emphasis added). A study by Bitman and Cecil (1970) on polychlorinated biphenols and chemicals like DDT demonstrated estrogenic activity even three decades prior to enactment of Title 22's regulations of recycled wastewater.

Although Title 22 permits use of recycled wastewater on food crops, prior to enactment of the recycled wastewater regulation, it was already known that plants can take synthetic chemicals up into their roots, stems, leaves, and fruits (Briggs, Bromilow, and Evans 1982; Ryan et al. 1988; Hsu, Marxmiller, and Yang 1990; Paterson et al. 1990; Simonich and Hites 1995; Sicbaldi et al. 1997; Burken and Schnoor 1998; Wilson 1998).

The fact that chemical mixtures can have additive, antagonistic, or synergistic effects, as discussed earlier, was also known prior to enactment of recycled wastewater regulations in Title 22 -- even as early as 1939 (Bliss 1939; Calabrese 1991; Yang 1994).

Even the fact that some endocrine disruptors have nonmonotonic dosage-response curves was also recognized prior to enactment of the Title 22 regulations of recycled wastewater (Mehendale 1994; Svendsgaard and Hertzbert 1994; vom Sal and Sheehan 1998; Nawaz et al. 1999).

Bottom line: California Title 22 regulations for non-potable reuse of recycled wastewater are inadequate to protect the health of both humans and other organisms because regulators ignored sound science that warned about health impacts of endocrine disruptors and other contaminants of emerging concern. The potential for irrigation with treated wastewater to spread antibiotic resistance has come to light more recently, as have problems with nanoparticles, adding to the concerns about this practice, especially in irrigation of food crops.

B. Recycled Municipal Wastewater for Potable Reuse

Potable reuse of wastewater is divided into two types: indirect and direct. While exact definitions vary, currently in California, **indirect potable reuse (IPR)** refers to treated municipal wastewater that is sent to an aquifer, either by direct injection or by surface spreading.[6] The recycled wastewater gradually mixes with the rest of the water in the aquifer; it is subsequently drawn out and processed in the drinking-water treatment plant before being sent to people's taps. **Direct potable reuse (DPR)**, which is not yet permitted in California, refers to treated wastewater that is sent from an advanced wastewater treatment facility directly to either the municipal water treatment plant (where it undergoes the usual treatment for drinking water) or directly into the distribution system that supplies tap water. In either scenario, DPR differs from IPR in that there is no intermediate step where the treated water is first put into an aquifer.

There are no federal regulations of recycled municipal wastewater for potable reuse. However, drinking water is federally regulated via the Safe Drinking Water Act. The State of California has somewhat stricter drinking-water standards than the federal government requires. The combined Federal and State regulation of potable reuse are inadequate to protect public health. The number of synthetic chemicals regulated under the Federal Safe Drinking Water Act plus those added to the list by the California EPA add up to just 60, plus an additional 11 disinfection byproducts (California Department of Health 2014). That still leaves about 100,000 other man-made chemicals unregulated, and thus largely untested, in drinking-water treatment plants.[7] **When recycled wastewater advocates assert that a treatment plant's effluent "meets or exceeds" all Federal and State drinking-water requirements, the claim may sound reassuring, but it is hollow.**

C. State Policy Regarding Indirect Potable Reuse

Thirteen years after the Title 22 regulations of non-potable reuse were enacted, the State Water Resources Control Board (SWRCB) published its ***Policy for Water Quality Control for Recycled Water (Recycled Water Policy), 2013***. This policy, intended to "streamline" the permitting process for non-potable uses as well as for indirect potable reuse (IPR), purports to address the chemical contamination of recycled wastewater. However, this 2013 policy, like the Title 22 regulations before it, fails to adequately protect environmental and public health.

In spite of scientific evidence of potential harms to humans and other organisms posed by CECs, the 2013 *Recycled Water Policy* permits recycled wastewater for indirect potable reuse with minimal monitoring of CECs to indicate treatment-plant efficacy. That policy requires monitoring **only eight chemicals out of the tens of thousands** of the drugs, personal care products, food additives, pesticides, industrial chemicals, disinfection byproducts, and household chemicals that may be present in tertiary-treated wastewater used to replenish aquifers by surface spreading. For advance-treated wastewater using reverse osmosis, **only six** of those chemicals must be monitored for direct injection into aquifers.

Like the Title 22 regulations described earlier, this 2013 policy still relies on **traditional approaches to toxicology:** test one chemical at a time on lab animals, looking for acute toxic reactions, then reduce the dosage downward with each round of testing to the point where the "no observable adverse effect level" (NOAEL) is found; then extrapolate from those animal studies, using "uncertainty factors," to determine the "safe" dosage for humans.

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[6] At this time, the State has no regulations for IPR involving a reservoir rather than an aquifer, although the City of San Diego was permitted by the CDPH to test this alternative in a demonstration plant using microfiltration, RO, UV, and hydrogen peroxide (Gerrity et al. 2013:332). Regulations for reservoir augmentation with treated municipal wastewater may be developed pending the 2016 recommendations of an expert panel (California State Water Resources Control Board 2014).

[7] EPA and other government agencies have some programs for occasional additional testing of drinking water and sources for some other contaminants such as EPA's Contaminant Candidate List Program http://www2.epa.gov/ccl/basic-information-ccl-and-regulatory-determination and the USDA Pesticide Data Program, which studied the Santa Cruz municipal water system in 2012-2013.

-- This **traditional toxicological** approach:

-- **ignores additive, antagonistic, and synergistic mixture effects;**

-- **ignores epigenetic transgenerational inheritance**;

-- **ignores nonmonotonic dose-response curves**;

-- **ignores** the corollary **that there often is** **<u>no threshold dose for EDs and some other chemicals</u>**;

-- **ignores scientists' warnings that ingesting <u>trace amounts (parts per trillion or even less)</u> of EDs and other CECs can have serious health consequences, <u>especially for fetuses, infants, and children</u>**.

This neglect of substantial bodies of scientific evidence regarding the characteristics and potential health impacts of endocrine disruptors and other CECs raises the question: Why would the State set aside scientific evidence in formulating the 2013 *Recycled Water Policy*?

One answer is that the State Water Resources Control Board gave too much credence to the report of six "blue ribbon" panelists who were appointed in 2009 by the Southern California Coastal Water Research Project to advise the SWRCB on how to address CECs in recycled wastewater (Anderson et al. 2010). The only expert in human toxicology on that panel, Paul Anderson, a traditional toxicologist, had co-authored at least three industry-funded, industry-informed studies concluding that there are no health concerns from pharmaceuticals in drinking water (Schwab et al. 2005; Hannah et al. 2009; Caldwell et al. 2010). At the time of his appointment to the "blue ribbon" panel, Anderson was also employed by ARCADIS U.S., a southern-California company that sells water-reuse services and technologies (ARCADIS U.S. 2014). This apparent **conflict of interest** was overlooked by the SWRCB.

The "blue ribbon" panel's guidelines recommend monitoring just eight indicator chemicals for tertiary-treated recycled wastewater that would be surface-spread to replenish aquifers. Those eight indicators for monitoring chemicals in wastewater used in surface application for groundwater recharge are N-nitrosodimethylalamine (NDMA, a disinfection byproduct), 17beta-estradiol, caffeine, triclosan, DEET, gemfibrozil, iopromide, and sucralose (Anderson et al. 2010:66). For advance-treated wastewater directly injected into aquifers, the two pharmaceuticals, gemfibrozil and iopromide, were removed from the list of indicator chemicals, leaving only six indicators for subsurface injection of treated sewer water into aquifers.

Prior to the State's acceptance of the expert panel's recommendations, the list of indicators was questioned by Dr. Andrew Eaton, Technical Director of MWH Laboratories in Monrovia, California, which specializes in testing for CECs in water (Eaton 2010). In his comments for the public hearing on the topic held December 15, 2010, Eaton notes that caffeine "is detected in only about 50% of effluent samples ... and is subject to extensive biodegradation," so it is "potentially a poor indicator" (Eaton 2010). Similarly, because gemfibrozil only turns up in about 40% of the effluents, "using this compound as an indicator of treatment performance would run the risk of measuring a compound that was frequently not present at all..." (Eaton 2010). Eaton also lists iopromide as a poor indicator because "it is not commonly used as an X-ray contrast medium. Instead iohexol ... occurs much more frequently and at higher concentrations" (Eaton 2010). In each instance, **using the indicator chemicals recommended by Anderson et al. (2010) could lead to false-negative conclusions about the existence of CECs in a treatment plant's effluent.** Given that Eaton's lab is "the largest in the U.S. that is focused solely on water analysis, specifically CECs in water" (Eaton 2010), his comments regarding the panel's choice of indicators suggest that their research into that topic may not have been sufficiently careful.[8]

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[8] See also Eaton's more recent co-authored studies, "The List of Lists – Are We Measuring the Best PPCPs for Detecting Wastewater Impact on a Receiving Water?" (Eaton and Haghani 2012) and "How Reliable Is the Recycled Water Monitoring List?" (Eaton and Wilson 2013). Those publications

The SWRCB set aside Eaton's comments on the choice of indicator chemicals, McGowan's warnings about antibiotic resistance genes, and other letters raising scientifically grounded concerns with the "blue ribbon" panel's recommendations. The SWRCB adopted the panel's recommendations into the 2013 *Recycled Water Policy.*

D. The Next Wave: Direct Potable Reuse (DPR)

Governor Brown's intent to use ever more recycled wastewater prompted a provision in SB 322 to form another expert panel to advise the CA Department of Public Health (CDPH)[9] on developing guidelines for both indirect and direct potable reuse (DPR). The charge to this new expert panel was described on the SWRCB website, as of February 23, 2015, as follows:

1. Assess what, if any, additional areas of research are needed to be able to establish uniform water recycling criteria for direct potable reuse;
2. Advise on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation; and
3. Advise on public health issues and scientific and technical matters regarding the feasibility of developing uniform water recycling criteria for direct potable reuse. (California State Water Resources Control Board 2015)

Given that two of the three tasks include offering advice regarding "public health issues," one might expect the panel to include several experts in public health, such as people with advanced degrees in that field, endocrinologists, and others who understand the potential health impacts of contact with the EDs and other CECs remaining in trace levels in potable-reuse wastewater. Such is not the case. About half of the panelists are engineers. There is only one epidemiologist (Tim Wade). While another panelist, Joan Rose, has much-needed expertise in water pathogens, she is not an expert in chemical contaminants. **Absent from the panel are endocrinologists and other independent scientists with expertise in the public-health implications of EDs' nonmonotonic dose-response curves, likely absence of a threshold dose, or the transgenerational epigenetic consequences of early-life exposure to phthalates, cosmetics, pesticides, pharmaceuticals, and other chemical contaminants.**

On the contrary, the panel includes Richard Bull, of MoBull Consulting, who, with James Crook (fellow panelist) and two others, wrote an extensive defense of using "therapeutic dose" as the point of departure for determining safe levels of drugs in drinking water (Bull et al. 2010). Bull and Crook argue that risk assessors should use the dose of a drug intended for a patient who needs that drug as the basis for calculating the amount of that drug that would be safe for members of the public to consume in drinking water.[10] Subsequently, Bull, Crook, and the same colleagues authored *Health Effects Concerns of Water Reuse with Research Recommendations,* published by the WateReuse Foundation (Cotruvo et al. 2012). In both publications, they write: "it is difficult to articulate a [human]-health-based concern that would even require municipal wastewater to be treated to remove drugs" (Bull et al. 2010:16; Cotruvo et al.

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recommend that a very different and much longer list of indicators be used instead of those few identified in the SWRCB's *Recycled Water Policy.*

[9] On July 1, 2014, the Drinking Water Program transferred from CDPH to the State Water Resources Control Board (http://www.waterboards.ca.gov/drinking_water/programs/DW_PreJuly2014.shtml Accessed January 15, 2015). The wording of the expert panel's charge was edited to reflect that change.

[10] Using therapeutic dose as the point of departure for determining safe daily consumption levels for people who do not need those drugs flies in the face of all the evidence regarding characteristics of EDs discussed in this paper. For a critique of the many questionable assumptions inherent in this practice, see C. G. Daughton (2010:49-51).

2012:xx). Crook and Bull's statement might baffle endocrinologists and other independent scientists familiar with the ways EDs impact health. But endocrinologists and other scientists with expertise to challenge Crook and Bull's views are not on the State's panel charged with evaluating potable reuse.

In their more recent monograph, Crook, Bull, and colleagues describe "the very low concentrations of" pharmaceuticals and personal care products (PPCPs) in recycled municipal wastewater as follows:

> These chemicals do not necessarily pose a significant health hazard at concentrations found in [recycled] drinking water, but they serve as reminders of where the water comes from.... [Therefore] the issue **may not be a need for health research, but a need for the regulatory agency to make a formal judgment** on whether the levels even approach those at which adverse health effects would be expected with an adequate margin of safety. (Cotruvo et al. 2012:7, emphasis added)

Crook and Bull's statement implies that a regulatory agency simply needs to *write* that the water "is safe," and it shall be so. Bizarre as that idea sounds, that same approach – determine that a recycled-wastewater process "is safe" by fiat rather than by unbiased scientific investigation – would not be new, since it was used for the State's Title 22 regulations of non-potable recycled wastewater and for the 2013 *Recycled Water Policy*.

Since **both Crook and Bull are on the panel that will recommend the new (2016) State policy regarding both IPR and DPR** – in fact, **Crook is now the panel's co-chair** -- it appears that wastewater-reuse regulators may again ignore the warnings of many members of the Endocrine Society and other prominent scientists whose work demonstrates that even trace amounts – the amounts of some CECs found in advance-treated municipal wastewater -- of drugs, cosmetics, pesticides, plasicizers, and other EDs can have serious, long-term health effects, especially for fetuses, infants, and children.

Bottom line: Unless and until there is much more rigorous, science-based regulation of contaminants of emerging concern in recycled wastewater destined for potable reuse, whether as IPR or DPR, we cannot rely on either Federal or State regulations to protect people who would be drinking and bathing in it.

IV. OTHER USES FOR RECYCLED MUNICIPAL WASTEWATER

Although reliable scientific evidence indicates that using recycled municipal wastewater for food-crop irrigation or for drinking is not worth the health risks, there are other possible uses of this water that may not pose undue risk to humans or other organisms. This section looks very briefly at some examples of reuse in landscape irrigation and for commercial or industrial purposes.

A. Landscape Irrigation

Each proposal for using recycled sewer water for landscape irrigation should be carefully studied in light of the Precautionary Principle. In each case, possible impacts on the health of humans, other animals, plants, insects, and soil microorganisms should be considered, along with any pertinent issues relating to run-off or penetration of the effluent into aquifers. **In light of the heightened vulnerability of fetuses, infants, and children to endocrine disruptors and other contaminants of emerging concern, particular attention should be given to potential exposure of children and pregnant women to recycled municipal wastewater.** Accordingly, although specific conclusions about the advisability of any particular application would depend on information about the treatment train, the effluent quality, the irrigation site, and other parameters of application, it seems likely that irrigation of freeway landscaping might be a more appropriate use of recycled wastewater than would irrigation of children's playgrounds.

Applying the Precautionary Principle and studying specific features of each proposal on a case-by-case basis is a sensible way to proceed.

B. Commercial and Industrial Uses

Other possible uses for recycled sewer water include flushing commercial toilets, mixing concrete, fire-fighting, settling road dust, etc. To briefly explore a few examples: Assuming proper protection of workers and others who might potentially contact the recycled wastewater were put in place, it seems that using recycled wastewater to flush sanitary sewers would be a good application, and using it to flush commercial toilets and mix concrete might also be promising candidates for using recycled sewer water. However, using it to settle dust on roads or streets might be more problematic (depending on the setting) due to contaminant accumulation and potential runoff into a sensitive stream or other habitat. Particularly in populated areas, the nanoparticles, antibiotic resistance genes, and some chemical contaminants could also become a future airborne health threat if the dust were not adequately controlled. However, these hypothetical scenarios are just general sketches, and decisions would need to be made in light of the Precautionary Principle and factors specific to each proposal.

V. CONCLUSION

To summarize: Given that current wastewater treatment technology leaves trace amounts of endocrine disruptors and other contaminants of emerging concern in the effluent; that some of those trace contaminants can be especially harmful for fetuses, infants, and children; that existing regulations fail to adequately protect public health from such contaminants; and that using recycled municipal wastewater for either food-crop irrigation or for drinking is not aligned with the Precautionary Principle, both of those ways of using recycled sewer water should be avoided. For all other purposes, including landscape irrigation and commercial/industrial uses, policymakers should apply the Precautionary Principle to each proposal on a case-by-case basis, taking into account the specific parameters of the proposed application.

There are alternatives: The Water Supply Advisory Committee, City Council, County Board of Supervisors, and other policymaking bodies have an obligation to the community to fully and fairly explore the many viable alternatives to potable reuse and irrigating food-crops with recycled wastewater. There are several promising proposals currently before the Santa Cruz WSAC that should be considered thoroughly and objectively before pursuing recycled municipal wastewater for drinking or other contact uses. For example, Desal Alternatives has submitted nine strategies to WSAC for making the City's water system more reliable and resilient. They include water conservation methods (conservation pricing; water-neutral growth; building-code revisions; measures to reduce landscape irrigation); aquifer restoration through inter-district collaboration; watershed restoration; and infrastructure that would enable better use of existing resources (e.g. a second pipeline from Felton to Loch Lomond). Other groups and individuals have also submitted strategies, such as using abandoned quarries for aquifer recharge and storage, and engineer Jerry Paul's Lochquifer and Spill-Over plans, among others. All of these strategies to make better use of rainfall are also lower in energy intensity and cost than potable reuse of sewer water.

The big picture: Toxic chemicals are ubiquitous in contemporary environments. Drinking clean water is one of the few ways our bodies have to eliminate such chemicals once ingested, so increasing both the *numbers* of different chemicals and the *quantities* of them in our diets by daily consumption of recycled wastewater is a step in the wrong direction. Instead, we should be working to reduce both the numbers and amounts of man-made chemicals in our diets and in the environment.

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Review

Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health

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ABSTRACT

The reuse of treated wastewater, in particular for irrigation, is an increasingly common practice, encouraged by governments and official entities worldwide. Irrigation with wastewater may have implications at two different levels: alter the physicochemical and microbiological properties of the soil and/or introduce and contribute to the accumulation of chemical and biological contaminants in soil. The first may affect soil productivity and fertility; the second may pose serious risks to the human and environmental health. The sustainable wastewater reuse in agriculture should prevent both types of effects, requiring a holistic and integrated risk assessment. In this article we critically review possible effects of irrigation with treated wastewater, with special emphasis on soil microbiota. The maintenance of a rich and diversified autochthonous soil microbiota and the use of treated wastewater with minimal levels of potential soil contaminants are proposed as *sine qua non* conditions to achieve a sustainable wastewater reuse for irrigation.

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1. Reasons behind the use of wastewater for irrigation

Water is essential for life, and although covering approximately 70% of the terrestrial crust area, only a small fraction of the water is actually compatible with terrestrial life forms (Shiklomanov, 1993). The small fraction of freshwater, i.e., with low salt concentration (2.5% of the total stock of water in the hydrosphere), is mainly in the form of ice and permanent snow coating in the Antarctic and Arctic regions (68.7%) (Shiklomanov, 1993). One of the first reasons for the observed water scarcity is that the fraction of water available for the human consumption, in rivers and streams, lakes, reservoirs and groundwater aquifers, is not distributed uniformly around the world (Shiklomanov, 1993). As a consequence, 40% of the total land area is dry and includes climate zones classified as arid, semi-arid and dry sub-humid (FAO, 2008). Simultaneously, the increasing need of water resources is a consequence of the demographic growth, the economic development and the improvement of living standards, climate change and pollution (FAO, 2012). It is estimated that at least in some world regions, water use has been growing more than twice faster than the human population. For instance, the total annual water withdrawal suffered a 6.3-fold increase, rising from less than 600 km^3/year, at the beginning of the twentieth century, to more than 3800 km^3/year by the beginning of the twenty-first century. The irrigation practices consume up to 70% of this withdrawal (FAO, 2013). Therefore, the use of freshwater has been exceeding the minimum recharge levels, leading to the desiccation of water streams and depletion of groundwater (UNDP, 2006). Water scarcity and droughts are emerging as major issues worldwide, not only in dry lands, but also in world regions where freshwater is abundant (Bixio et al., 2006; EU, 2007; FAO, 2012). For instance, half of the European countries are facing water stress (Bixio et al., 2006) with water scarcity being observed across Europe (EU, 2007). It is estimated that more than 40% of the world's population will face water stress or scarcity within the next 50 years, a serious incentive to achieve sustainable management options of the water resources (WHO, 2006a). In this context, the reuse of treated wastewater represents a valid option, in some cases urged by the absence of viable alternatives (Niemczynowicz, 1999; WHO, 2006a). Besides the reduction in the use and abstraction of freshwater, wastewater reuse will also contribute to reduce the discharge of effluents into freshwater ecosystems (Bixio et al., 2006; Toze, 2006). This scenario makes wastewater an increasingly valuable resource rather than a waste product. Indeed, irrigation with treated wastewater is already implemented, mainly for agriculture and landscaping, in countries such as France, Italy, Spain, Cyprus, Malta, Israel, Jordan or the USA (Aquarec, 2006; EMWIS, 2007; EPA, 2012; Kalavrouziotis et al., 2013; Ndour et al., 2008; Pedrero et al., 2010). However, despite the aforementioned benefits, the reuse of wastewater involves both health and environmental risks. In this review, we will discuss some implications of the reuse of treated wastewater for irrigation purposes, giving special emphasis to microbiological aspects.

2. Framework of guidelines and policies on wastewater reuse

Wastewater is produced as a result of the multiple human activities, such as domestic, commercial and industrial uses. The quantity and composition of urban wastewater are determined by several factors, including the inhabitant's lifestyle and standard of living, the proportion of domestic and industrial effluents, or even the design of the sewer and of the treatment systems (Henze and Comeau, 2008; Metcalf and Eddy, 2003). Treated urban wastewater is mainly composed by particulate and dissolved organic matter, and inorganic substances (e.g., N, P, K, Na, Ca, Mg, Cl and B), containing also microorganisms, including pathogens and antibiotic resistant bacteria (Henze and Comeau, 2008; Rizzo et al., 2013; Varela and Manaia, 2013). Additionally, toxic, recalcitrant and/or bioaccumulative chemicals (e.g., trace metals, xenobiotics and natural or semi-synthetic compounds) are normally present, although representing minor components, often designated as micropollutants or microcontaminants (Henze and Comeau, 2008; Metcalf and Eddy, 2003). Given such complexity, the detailed chemical and biological characterisation of treated wastewater is essential to assess its quality, being always difficult to fully predict the effects that may arise from its reuse.

The recommendations on wastewater reuse established by the State of California, the World Health Organisation (WHO) and the US Environmental Protection Agency (EPA) (Aquarec, 2006; EPA, 2012; WHO, 2006a) constitute the background of most of the legal guidelines proposed in countries such as the USA, Portugal, Spain, Italy, Cyprus, France, Australia, Israel, Jordan, Kuwait, Oman, Saudi Arabia, and China (Table 1). Compliance with these regulatory frameworks requires the analysis of the treated wastewater prior to its reuse. Although the reviewed guidelines and policies cover different applications for the wastewater reuse (e.g. irrigation, groundwater recharge, impoundments and industrial reuse) we will focus our discussion on the use of wastewater for irrigation purposes.

In general, standards are based on the evaluation of physicochemical and microbiological parameters. A summary of the main parameters considered in the different guidelines and policies is given in Table 1. Several countries (e.g. the USA, Spain, Jordan) establish different threshold values in function of the type of irrigated crops. For raw-consumed food crops the recommended values are generally stricter than for other crops that will be further processed (processed food) or used as pasture or energy crops. On the other hand, some countries, such as Italy or Israel do not define irrigation categories, and hence the established threshold values should be accomplished regardless the intended use for the irrigated crops (Table 1).

Physicochemical characterisation of wastewater includes the evaluation of several properties such as turbidity [Nephelometric Turbidity Units (NTU) or suspended solids (SS)], acidity (pH), salinity [electrical conductivity (EC), sodium absorption rate (SAR)], organic load [biological (BOD) or chemical oxygen demand (COD)], and nutrients [total N and/or NO_3^- and P in form of PO_4^{3-} phosphate] (Table 1). In addition to these parameters, some regulations (e.g. the USA, Italy, Mexico, Oman) require or recommend the determination of potentially toxic agents such as metals or organic contaminants (Table 1). The microbiological characterisation of wastewater is mainly focused on the presence of potential human pathogens and parasites, and is generally based on the enumeration of faecal indicators and nematode eggs (Table 1). In general, the guidelines aim at preventing potential effects on soil productivity and fertility, due to disturbance of physicochemical properties of soil, and possible risks for human health, through the presence of toxic compounds and pathogens (Aquarec, 2006; EPA, 2012; WHO, 2006a). However, the impact of wastewater irrigation on soil ecosystem services, which relies on an adequate equilibrium of diversity and activity of soil microbiota, crucial for soil health (Anderson, 2003; Torsvik and Ovreas, 2002), may be not properly covered by the available guidelines. Another relevant omission refers to the risks of introduction of biological contaminants, such as pathogens and antibiotic resistance genes, through the transmission pathways environment–plants–humans.

Much attention has been given to the potential of different wastewater treatment technologies to overcome the emerging challenges, as the removal of novel classes of contaminants or the sustainable reuse of wastewater for irrigation. In particular, pharmaceutical products, pesticides and disinfectants are foresighted in most of the discussions around wastewater treatment and quality (Michael et al., 2013; Pal et al., 2014; Rivera-Utrilla et al., 2013). A recent literature review by Norton-Brandão et al. (2013) offers a comprehensive overview of the technologies commonly used to treat wastewater reused for irrigation, making a comparison based on the parameter's salinity, pathogens, nutrients and heavy metals. The use of technologies based on sedimentation, filtration or disinfection processes, such as chlorine dioxide, UV, ozone or TiO_2 seems adequate for wastewater treatment for irrigation, depending on the raw wastewater quality and application demands (Norton-Brandão et al., 2013). Regarding the removal of microorganisms, membrane bioreactor (MBR) systems show high efficiency, meeting also other relevant

Table 1
Guidelines on wastewater reuse for irrigation in different world regions.

Country or organism (year)	Irrigation categories	pH	EC (µS/cm)	SAR	NTU	SS (mg/L)	BOD (mg/L)	COD (mg/L)	DO (mg/L)	TNK or TN (mg/L)	N-NO$_3$ (mg/L)	P (mg/L)	Sulphate (mg/L)	Total coliform (CFU/100 mL)	Faecal coliform (CFU/100 mL)	*Escherichia coli* (CFU/100 mL)	Nematode eggs (no./L)
US-EPA (2012) [1]	UR	6–9			2	30	10								Absent		
	R	6–9			–	–	10								2×10^2		
WHO (2006a) [2]	UR															10^3	≤1
	R															–	≤1
California (1978) [1]	ND	6–9			2				Present						2.2×10^2		
Italy (2003) [3]	ND	6–9.5	3000	10		10	20	100		15		2	500			10^2	
France (2010) [4]	UR					15		60							4°	2.5×10^2	
	R					–		–							$2\text{–}3^{\circ}$	$10^4\text{–}10^5$	
Spain (2007) [5]	UR				10	20										10^2	0.1
	R				–	35										$10^3\text{–}10^4$	0.1
Portugal (2006) [6]	UR	6.5–8.4	1000	8		60					50		575		10^2		
	R	6.5–8.4	1000	8		60					50		575		$2 \times 10^2\text{–}10^4$		
Australia (2000) [7]	UR	6.5–8.5			2									10			
	R	6.5–8.5			–									$10^2\text{–}10^4$		$10^2\text{–}10^4$	
Israel (1999) [8]	ND				5	10	20								10		
Tunisia (1989) [9]	ND	6.5–8.5	7000			30	30	90									≤1
Jordan (2002) [9]	UR	6–9		9	10	50	30	100	>2	45	30	30	500			10^{2*}	<1
	R	6–9		9	–	150	200–300	500	–	70	45	30	500			10^3–n.d.*	<1
Kuwait (2001) [9]	ND	6.5–8.5				15	200	100	≥2.0	35		30	0.1	$4 \times 10^{2*}$	20*		<1
Oman (1993) [9]	UR	6–9	2000	10		15	15	150			50	30	400		2×10^2		<1
	R	6–9	2700	10		30	20	200			50	30	400		10^3		<1
Saudi Arabia (2000) [9]	UR	6.0–8.5			5	10	10				10		600	2.2*			1
	R	–			–	40	40				–		–	10^{3*}			1
China (2007) [10]	UR	5.5–8.5				60	40		≥0.5						2×10^4		
	R	5.5–8.5				80–100	60–100		≥0.5						4×10^4		
Mexico (1987) [11]	UR					20	20								240*		
	R					30	30								10^{3*}		

UR, unrestricted irrigation; R, restricted irrigation; EC, electrical conductivity; SAR, sodium absorption rate; NTU, Nephelometric Turbidity Unit; TSS, total suspended solids; BOD, biological oxygen demand; COD, chemical oxygen demand; DO, dissolved oxygen; TNK, total nitrogen Kjeldahl; TN, total nitrogen; N-NO$_3$, nitrate nitrogen; P, phosphate; $^{\circ}$log reduction value; *MPN/100 mL; n.d. no determination.

References: 1. EPA (2012); 2. WHO (2006a); 3. Decreto Ministeriale (15/2003); 4. NOR-SASP1013629A (2010); 5. Real Decreto (1620/2007); 6. Marecos do Monte (2007); 7. NWQMS (2000); 8. Arlosoroff (2007); 9. WHO (2006b); 10. Yi et al. (2011); 11. NOM-001-ECOL-1996.

objectives such as the removal of heavy metals. Other processes such as constructed wetlands, ponds and disinfection oxidants may also offer good removal rates of microorganisms, although may be not so efficient on the achievement of adequate levels of other parameters, in particular salinity (Norton-Brandão et al., 2013). The choice of the best methods for the wastewater treatments must represent a compromise between cost effectivity and the production of water with adequate quality for irrigation. In this respect, nowadays, binding quality criteria should include also the absence of emerging contaminants as pharmaceuticals or antibiotic resistant bacteria. Since the implementation and maintenance costs and the environmental impacts cannot be ignored, sometimes it may be challenging to achieve an ideal compromise.

3. Influence of wastewater irrigation on soil microbial communities

Soil microbial communities are established on basis of a complex network of interrelations between abiotic (physical and chemical soil properties) and biotic factors (macro- and microbiological soil components). The impact of wastewater on soil microbial communities is supposed to depend on direct inputs of exogenous microbiota, which, in an improbable worst case scenario, would lead to the elimination of autochthonous microorganisms by competition. In addition, and probably not less relevant, are the indirect effects produced by wastewater, which may contribute to change the physicochemical soil properties and, therefore, induce microbial community disturbances. Both types of impact are almost uncharacterized, constituting deep gaps of knowledge. To the best of our knowledge, up to now few studies have applied commonly used methodological approaches to assess microbial community structure and activity on the evaluation of effects of wastewater irrigation on the soil microbiota (Table 2). However, nowadays, some methodological limitations are becoming easier to overcome thanks to the multiple applications of the next generation sequencing methods. In the next sections the direct and indirect effects that wastewater irrigation may have on soil microbiota and, therefore, on its properties will be discussed.

3.1. Physicochemical soil properties versus soil microbiota

Several physicochemical parameters, such as pH or organic matter content, have been shown to influence both abiotic and biotic soil parameters (Table 3). Because wastewater irrigation has the potential to

Table 2
Overview of methodological approaches used to assess soil microbial community composition, structure and activity.

Main goal	Approach	Specific goal	Outcome	Methods	E.g. References
Community activity and function	Biochemical assays	Detection or quantification of specific activities	Respiratory activity	Quantification of CO_2 evolution	[1]
			Activity of enzymes involved in biogeochemical cycles (e.g., dehydrogenase, laccase, urease, alkaline phosphatase, arylsulfatase)	Enzymatic assays	[2–5]
			Detection of compounds produced during specific microbiological transformations (e.g., nitrite for nitrifiers, ammonia for ammonifiers)	Colorimetric assays; chromatography	[6]
	Culture dependent	Quantification of specific activities	Enumeration of total cultivable metabolic groups of organisms (e.g., ammonifiers, denitrifiers, diazotrophs, autotrophs)	MPN, plating or membrane filtration techniques	[3, 7, 8]
		Profiling	Enumeration of total metabolic active cells (e.g. community level physiological profiling)	MPN, (e.g. eco-BIOLOG)	[7, 9]
	Nucleic acid dependent	Quantification of specific activities (targeted)	Detection or quantification of genes involved in particular reactions (e.g., C or N cycle)	FISH-Confocal/epifluorescence microscopy; qPCR; clone libraries	[10–13]
				Functional gene microarrays (e.g. GeoChip)	[14]
		Quantification and identification of total potential activities (non-targeted)	Metagenomics	Total DNA sequencing	[12, 15–18]
			Metatranscriptomics	Total mRNA (cDNA) sequencing	[19, 20]
Community size, composition and structure	Culture dependent	Estimation of size and composition	Enumeration of total cultivable organisms or groups of organisms (e.g., total heterotrophic aerobic/anaerobic bacteria, fungi, actimomycetes)	MPN, plating or membrane filtration techniques	[3, 7, 8]
	Culture independent	Estimation of size	Enumeration of total cells	Nucleic acid staining (e.g. DAPI), Confocal/ epifluorescence microscopy	[3]
			Quantification of microbial biomass (C and/ or N)	Chloroform fumigation extraction	[2, 9, 18, 21]
		Profiling	Small subunit rRNA gene sequence based (16S or 18S rRNA genes)	DGGE, tRFLP, microarray (e.g. PhyloChip)	[9, 11, 22]
			Phospholipid-derived fatty acids based	PFLA extraction, chromatography	[18, 23–25]
		Assessment of taxonomic diversity and abundance of each taxa	Small subunit rRNA gene sequence based (16S or 18S rRNA genes)	Clone libraries; high throughput technologies	[12, 15–18]
		Identification of community members involved in the degradation of specific substrates	Isotope labelled small subunit rRNA gene sequence based (16S or 18S rRNA genes)	Stable isotope probing assays	[26–28]

MPN, most probable number; FISH, fluorescence in situ hybridization; DAPI, 4′,6-diamidino-2-phenylindole; DGGE, denaturing gradient gel electrophoresis; tRFLP, terminal restriction fragment length polymorphism; PLFA, phospholipid-derived fatty acids.

References: 1. Cheng et al. (2013); 2. Trasar-Cepeda et al. (2008b); 3. Lopes et al. (2011); 4. Hopkins et al. (2008); 5. López-Gutiérrez et al. (2004); 6. Roger and Ladha (1992); 7. Kidd et al. (2008); 8. Lin et al. (2008); 9. Widmer et al. (2006); 10. Eickhorst and Tippkötter (2008); 11. DeAngelis et al. (2011); 12. Jones et al. (2009); 13. Henry et al. (2006); 14. He et al. (2007); 15. Hansel et al. (2008); 16. Lopes et al. (2014); 17. Rui et al. (2009); 18. Baldrian et al. (2012); 19. Shrestha et al. (2009); 20. Helbling et al. (2012); 21. Zhong and Cai (2007); 22. Wartiainen et al. (2008); 23. Bai et al. (2000); 24. Bossio et al. (1998); 25. Hjort et al. (2007); 26. Radajewski et al. (2002); 27. Eichorst et al., 2011; 28. Hori et al. (2010).

Table 3
Examples of soil physicochemical, biochemical and microbiological properties influenced by the variation of selected parameters.

Parameters	Associated effects in the soil (and environment)		References
	Physicochemical and biochemical properties	Microbiological properties	
pH	Availability of nutrients and trace metals Mineralisation of organic matter Cation exchange capacity (CEC)	Community richness and diversity	[1–6]
Organic matter	Aggregate formation and stabilisation of soil structure Water retention Content of nutrients (N, P and S) Buffer capacity Cation exchange capacity Enzymatic activity Availability of organic and inorganic contaminants	Selection of specific populations Soil microhabitats	[2, 7–11]
Nutrients (N, P, K)	Improvement of soil fertility Increase of soil organic matter Water retention Elements cycling Leaching to groundwater and risk of eutrophication of aquatic environments	Disturbance of soil microbial communities Microbial catabolic activity	[12–20]
Salinity	Soil salinisation or sodification Decrease of aggregate stability and soil structure Soil permeability and water retention Increase of soil compaction Soil pH Negative impact on soil fertility Dynamics of organic and inorganic compounds Leaching of heavy metals	Soil microhabitats Community diversity and activity	[2, 9, 21–25]
Contaminants	Soil toxicity, terraccumulation, leaching Negative impact on soil fertility Potential direct or indirect contamination of the food chain	Community structure and diversity Increase of microbial tolerance to contaminants and/or biodegradation Spread of antibiotic resistance	[26–35]
	Examples of specific effects:		
	Metals: - Enhance effects of antibiotics		[10, 11]
	Boron: - Plant toxicity		[12]
	Surfactants: - Water repellency		[13]
	Antibiotics: - Contribute for antibiotic resistance		[14]
	Endocrine-disrupting products and other pharmaceutical products: - Interfere with normal functioning of hormone systems in wildlife - Influence plants development		[15]

References: 1. Fierer and Jackson (2006); 2. Lauber et al. (2009); 3. Rousk et al. (2010); 4. White and Greenwood (2013); 5. Sparks (2003); 6. Bloom (2000); 7. Torsvik and Ovreas (2002); 8. Sun et al. (2014); 9. Smit et al. (2001); 10. Baldock and Nelson (2000); 11. Van-Camp et al. (2004); 12. DeForest et al. (2004); 13. Kuramae et al. (2011); 14. Ramírez et al. (2012); 15. Habteselassie et al. (2013); 16. Turlapati et al. (2013); 17. Knobeloch et al. (2000); 18. Zörb et al. (2014); 19. Haynes and Naidu (1998); 20. Wu (1999); 21. Ayers and Westcot (1994); 22. Sarig et al. (1993); 23. Rietz and Haynes (2003); 24. Wong et al. (2008); 25. Ke et al. (2013); 26. Correa et al. (2010); 27. Ding et al. (2012); 28. Müller et al. (2002); 29. Sánchez-Peinado et al. (2010); 30. Bååth (1989); 31. DeRito et al. (2005); 32. Chee-Sanford et al. (2009); 33. Rooklidge (2004); 34. Swartjes (2011); 35. Parks and Edwards (2005).

cause variation in those physicochemical parameters, possible effects on soil properties and microbiota will be discussed in the next sections.

3.1.1. pH

Soil pH influences the availability of nutrients and metals, the cation exchange capacity, as well as the mineralisation of organic matter (Table 3). The increase of soil pH was observed after long-term irrigation with wastewater (4 to 60 years), in soils with distinct management regimens (arable or in grazed pastoral soils) and irrigated with different types of wastewater (secondary-treated municipal wastewater and dairy wastewater) (Table 4). In opposition, the decrease of soil pH was reported in agricultural soils dedicated to lettuce, livestock fodder and orange production irrigated with wastewater for more than 15, 20 and 40 years, respectively (Table 4). Although the effects on soil microbiota due to the abovementioned pH variations were not explored in those studies, this parameter seems to be an important determinant of the richness (number of different species) and diversity (variety of organisms) of soil bacterial communities (Fierer and Jackson, 2006; Lauber et al., 2009; Rousk et al., 2010). In a comprehensive study comparing soil bacterial communities from distinct ecosystems it was observed that communities of sites with identical pH values share similar indices of bacterial diversity and richness, irrespective of other factors such as climate conditions or edaphic properties (Fierer and Jackson, 2006). In general, soil habitats with pH values in the neutrality range tend to present a higher bacterial diversity than those more acidic or alkaline (Fierer and Jackson, 2006; Lauber et al., 2009). In contrast, fungal communities may be not so vulnerable to pH variations (Rousk et al., 2010). Variations on pH can also influence the solubility of different soil components, such as metals (Bloom, 2000; Sparks, 2003) (Table 3). The increase of free metals in soil irrigated with wastewater was related to a decrease of soil pH (Rattan et al., 2005). In turn, the concentration and availability of metals have the potential to affect the microbial communities (Bååth, 1989; Brookes, 1995; Chander and Brookes, 1991; Müller et al., 2002).

3.1.2. Organic matter

Soil organic matter is essential as nutrient reservoir and in soil structure. Through the formation and stabilisation of aggregates, organic matter content contributes for the capacity of soil to retain water, affecting the drainage properties and resistance to compaction. Organic matter is also a reservoir of nutrients (such as N, P and S) important for plant growth, providing also a substantial part of the soil's cation exchange capacity (CEC) (Baldock and Nelson, 2000; Powlson et al., 2013; Sparks, 2003) (Table 3). In this way, organic matter content is of vital importance for soil fertility.

Table 4
Observed effects of wastewater (WW) irrigation on soil properties.

WW	Soil description*/ culture/period of irrigation (years)/country	Effects on physicochemical parameters					Effects on microbiological parameters			Reported implications formicrobiota and/or plant production	Reference
		Organic matter pools	pH	Salinity	Metals	Others	Biomass	Enzyme activity	Others		
U, la	Vertic Xerocrept (USDA)/ citrus orchard/15/Italy	ON				NH_4–N, NO_3–N	▨	AP, HD		Increment of available nutrients improves metabolic efficiency of soil microbiota.	[1]
U, st	Calcisols (WRB)/alfalfa, maize, barley, oats/>20/ Spain	OC	■			AvP	■	AP, BG		Increment of available P and water-soluble organic carbon is related with the increases of soil microbial biomass and activity.	[2]
U	Vertisols (WRB)/cereals and vegetables/< 80/Mexico	OC	▨	■	Pb, Cd, Cu, Zn		■	DH	Denitrification activity Adenylate energy charge ratios	Increment of available decomposable organic material increases soil microbial biomass and activity.	[3]
U	Typic Haplustand (USDA)/ hazel orchard/20/Italy	OC, TN	■				■		Diversity of the ammonia-oxidizing bacteria	Wastewater flooding leads to the functional uniformisation of soil microbiota.	[4]
U, st	Xerorthent (USDA)/ orange-tree orchard/43/ Spain	OC				AvP		AP, BG, DH, PR, UR	Diversity of arbuscular mycorrhizal fungi	Reduction of the arbscular mycorrhizal fungi diversity but crop vitality and productivity is not affected.	[5]
U	NR/cereals, millets, vegetable and fodder crops/5/India	OC	░		Fe					Metals may be accumulated by plants.	[6]
	NR/cereals, millets, vegetable and fodder crops/10/India	OC, TN	░		Zn, Fe, Ni, Pb						
	NR/cereals, millets, vegetable and fodder crops/20/India	OC	░		Zn, Cu, Fe, Ni, Pb Mn						
U, st	Loamy fine sand texture/ alfalfa hay, sudan grass and winter grains/3, 8, 20 /USA	OM	░	■	Cr, Cu, Ni, Zn					Metals may be accumulated by plants and may also be leached.	[7]
U, st	Fine clay and silt loam texture/corn/NR/China	OC, TN				AvP				Organic inputs of wastewater increases the total organic C and total N in soils.	[8]

U, st	Fine texture/forage crops /2, 5, 10/Jordan	OM, TN	▨	■	Cu, Pb, Cd	AvP, K				Monitorisation of soil and plant is needed for a safe use of wastwater.	[9]
U, st	NR/persimmon orchard/4 /Israel	OC				NO_3-N	■	DH, HD	Bacterial abundance Denitrification Abundance and diversity of actinobacteria	Soil bacterial composition and function are affected by wastewater irrigation.	[10,11]
U, st	NR/orange grove/4, 8, 16, 26/Tunisia	OC	■		Ni, Cr, Co				Microbial abundance	Modification of the genetic structure of soil bacterial and fungal communities.	[12]
U	Xerorthent (USDA)/grape crop/20/Spain	OC	░	▨		CEC, WR, AvP AgSt		AP, UR BG		Modification of soil quality indices	[13]
	Xerofluvent (USDA)/ "green filter"/20/Spain	OC	░	■		CEC, AgSt, AvP WR		AP, BG, UR			
	Xerorthent (USDA)/ orange-tree orchard/40/ Spain	OC	░	■		AvP CEC, WR, AgSt		AP BG, UR			
	Xerofluvent (USDA)/ grape crop/2/Spain	OC	■	■		AvP CEC, WR, AgSt		AP, BG, UR			
Sy	Sandy loam texture/ Mangrove swamp/0.25/China	TN			Cu, Zn, Cd, Mn	NH_4-N, NO_3-N, AvP		AP, DH	Aerobic and anaerobic bacteria Ammonia-and nitrite-oxidizing bacteria	Increment of available nutrients stimulates microbial growth and activity.	[14]

Table 4 (*continued*)

U	Leptosols (WRB)/cereals and vegetables/< -80/ Mexico	OC			Pb, Cd, Cu, Zn			DH	Denitrification activity Adenylate energy charge ratios	Increment of available nutrients and easily decomposable organic material increases soil microbial biomass and activity.	[3]
U, st	Vertic Xerofluvent (USDA)/ maize/0.25/Turkey	OC						AS, AP, DH, UR		Short-term irrigation affects oil enzymatic activities.	[15]
I	Chromasols and Tenosols (ASC)/grazed pastoral/>60 /Australia	OC, TN				C/N ratio AvP, Ex Na, K			Metabolic quotient	The community structure and catabolic capability of irrigated soil are resilient.	[16]
U, tt	Horticultural soil/NR/1/ France	OM						Laccase, cellulase, PR, UR	Functional diversity of soil microorganisms	Increase of soil enzymatic activity is involved in the degradation of the organic matter brought by waste water.	[17]
U	Typic Haplustox (USDA)/ sugarcane/> 1/Brazil	OC, TN				NO_3-N				Wastewater irrigation increases the crop productivity.	[18]
U	Eutric Arenosol (WRB)/ lettuce/15/Senegal	OC, TN				NH_4-N, NO_3-N		HD	Bacterial community structure Ammonia - oxidizing	Ammonia-oxidizing bacterial community is stimulated by wastewater supply.	[19]
I	Loamy texture/Fodder, cereals/NR/Pakistan	OM			Zn, Cu, Ni, Cr	Ex SO_4, NO_3-N, AvP			Heavy metal resistant bacteria Vesicular arbuscular mycorrhizae	Metal intrinsic endurance of bacterial and vesicular arbuscular mycorrhizae populations is enhanced.	[20]
U, st	Argosols and Cambosols (CST)/cereals and vegetables/> -40/China				Cd, Cr, Cu, Ni Pb, Zn	HA				Metals may be accumulated by plants.	[21]
U	NR/barley, corn, cotton, alfalfa, sorghum/80/USA				Zn	SoilCom AvP Mg				Crop production is not affected.	[22]

U	Silty sand texture/perennial ryegrass/3/Spain			■					Microbial abundance (total aerobic bacteria)	Low risk of microbial aquifer contamination	[23]
U	Quartzarenic Neosol (SiBCS)/eucalyptus/5/ Brazil			■		Ex Na				Crop productivity increases	[24]
I, sy	NR/mangrove/0.5/China				Cd, Cr, Cu, Ni, Zn			AP		Heavy metals reduce plant production and decrease alkaline AP activity.	[25]
I	Rhizosphere soil/wheat/ ~10/India				Fe, Cr, Zn, Pb, Ni, Cd, Cu				Metal resistant *Azotobacter chroococcum* isolates	Wastewater leads to an increase of metal resistance in rhizospheric *A. chroococcum*.	[26]
U	Mollic Leptosol and Eutric Vertisol (WRB)/maize/5, 90/Mexico				Cr, Cu, Ni, Zn, Pb	AvP			Arbuscular mycorrhizal fungi free spores	Heavy metal content and arbuscular mycorrhizal fungi free spores were negatively correlated.	[27]
I	NR/agricultural/12/India				Fe, Ni, Zn				Microbial abundance and diversity	The microbiological properties of the soil in the long-term exposure were not affected.	[28]
U, st	Eutric Histosol (WRB)/ different grasses/3/Poland					WC; Eh	▨	UR AP, DH		Effects of wastewater on enzyme activities are dependent of plant type.	[29]
	Eutric Histosol (WRB)/salix /3/Poland					WC Eh	▨	UR AP AP, DH			
U	NR/Parks/NR/China					AB, DP			Diversity and abundance of ARG and integrase genes	Possible propagation of antibiotic resistance	[30]
U; I	Silty clay loam texture/ crops/50/China					ED, Ph				Irrigation could lead to the accumulation of some emerging contaminants.	[31]

Table 4 (*continued*)

U, st	Dune quartz sand/citrus orchard (lysimeter)/12/ Israel							▨ ARB; ARG	Wastewater bacteria do not significantly contribute to the soil microbiome and resistome.	[32]
	Vertisol (60 % clay)/ avocado orchard/12/ Israel									
	Loam (20 % clay)/cotton, wheat/15/Israel									
	Vertisol (52 % clay)/olive trees/6/Israel									

*According to the information reported in the reference. Soil classification was used when available and indicated in parenthesis USDA, United States Department of Agriculture; WRB, World Reference Base for soil resources; CST, Chinese Soil Taxonomy; ASC, Australian Soil Classification, SiBCS, Brazilian Soil Classification.

■Increase; ▨No variation; ☐Decrease.

U, urban; I, industrial; st, secondary treated; tt, tertiary treated; la, lagoon; sy, synthetic; NR, not reported; OC, organic carbon; OM, organic matter; TN, total nitrogen; AvP, available phosphate; CEC, cation exchange capacity; WR, water retention; AgSt, aggregate stability; Ex, exchangeable; SoilCom, soil compaction; WC, water content; Eh, redox potential; AB, antibiotics; DP, degradation products; ED, endocrine disruptors; ARB, antibiotic resistant bacteria; ARG, antibiotic resistant genes; HA, humic acids; AP, alkaline (or acid) phosphatase; BG; beta-glucosidase; DH, dehydrogenase; HD, hydrolase; UR, urease.

References: 1. Meli et al. (2002); 2. Adrover et al. (2012); 3. Friedel et al. (2000); 4. Gelsomino et al. (2006); 5. Alguacil et al. (2012); 6. Rattan et al. (2005); 7. Xu et al. (2010); 8. Yao et al. (2013); 9. Rusan et al. (2007); 10. Elifantz et al. (2011); 11. Frenk et al. (2014); 12. Hidri et al. (2010); 13. Morugán-Coronado et al. (2013); 14. Tam (1998); 15. Kayikcioglu (2012); 16. Liu and Haynes (2011); 17. Chevremont et al. (2013); 18. Leal et al. (2010); 19. Ndour et al. (2008); 20. Faryal et al. (2007); 21. Khan et al. (2008); 22. Wang et al. (2003); 23. Candela et al. (2007); 24. Marinho et al. (2014); 25. Yim and Tam (1999); 26. Aleem et al. (2003); 27. Ortega-Larrocea et al. (2001); 28. Hayat et al. (2002); 29. Brzezinska et al. (2006); 30. Wang et al. (2014); 31. Chen et al. (2011); 32. Negreanu et al. (2012).

The organic matter-related pools are amongst the soil properties most affected by wastewater irrigation, as has been suggested by different studies reporting an increase of total organic C and/or N in irrigated soil (Table 4). Depending on the type of organic matter inputs, an increase in the organic matter availability may promote the selection of specific bacterial populations (Sun et al., 2014; Torsvik and Ovreas, 2002). For instance, the supplying of easily metabolisable nutrients may contribute to select bacterial groups with high growth rates, such as members of the classes *Alpha-* and *Beta-Proteobacteria* (Smit et al., 2001). Effects on soil aggregate stability and water retention capacity due to inputs of organic matter from irrigation with wastewater has been described (Levy et al., 2013; Vogeler, 2008). However, these effects may depend on the concentration and composition of organic matter and on soil texture. While in loamy sand soils wastewater irrigation led to an increase in the aggregate stability, in sandy clay and clay soils resulted in a decrease (Levy et al., 2013). The characteristics of the soil aggregates are very important, since 40–70% of the soil bacteria are associated with stable microaggregates and clay particles with sizes lower than 20 μm (Ranjard and Richaume, 2001). Therefore, the interference on the formation of soil aggregates due to wastewater irrigation is expected to modify soil microhabitats and, hence, influence the soil microbial communities (Torsvik and Ovreas, 2002). In general, the increase of soil organic matter was associated with a positive effect on soil structure and water retention (Baldock and Nelson, 2000; Sparks, 2003). However, this is not a general rule, and the opposite effect may be observed. The coating of soil particles with organic matter or even microbial biofilms can, in some circumstances, promote the hydrophobicity of the soil and therefore the water repellence (Doerr et al., 2000; Nadav et al., 2013; Tarchitzky et al., 2007). The complexity of implications of wastewater irrigation limits the establishment of possible cause–effect relationships, and the supplying of organic matter is of this a good example. Although most of the studies report an increase on organic matter due to wastewater irrigation, some did not detect significant variations but still reported alterations on microbiogical and biochemical parameters (Table 4). The influence of organic matter supply on the microbiota is suggested by the fact that wastewater irrigation was sometimes associated with an increase in soil microbial biomass and in soil enzyme activities (Table 4). Examples are the activities of enzymes such as dehydrogenase, laccase, cellulase, protease and urease (Chevremont et al., 2013; Friedel et al., 2000; Liu and Haynes, 2011; Morugán-Coronado et al., 2013). These effects are probably due to the stimulation of microbial growth and activity, boosted by the organic matter and nutrients supplied by wastewater (Adrover et al., 2012; Chevremont et al., 2013; Friedel et al., 2000; Liu and Haynes, 2011; Morugán-Coronado et al., 2013; Tam, 1998).

3.1.3. *Nitrogen, phosphorus and other plant nutrients*

The availability of plant nutrients such as N, P or K is essential for plant growth (Haygarth et al., 2013; White and Greenwood, 2013). One of the advantages of wastewater irrigation is the supplying of nutrients that may be sufficient to replace, or at least to reduce, the use of synthetic fertilizers in agriculture (Adrover et al., 2012; Fatta-Kassinos et al., 2011; Toze, 2006). The fertilizing potential of the wastewater (assuming an application rate of 5000 m^3/ha year) can reach annual values as high as 250 kg/ha for N, 50 kg/ha for P and 150 kg/ha for K (Pescod, 1992). In addition, wastewater can also be a source of other macro- and micronutrients such as Ca, Mg, B, Mg, Fe, Mn or Zn (Henze and Comeau, 2008). Indeed, irrigation with wastewater has been shown to significantly increase the yields of non-edible crops such as lemon grass or rosebushes (Lal et al., 2013; Marinho et al., 2013), and to have a positive impact on oil's quality recovered from sunflower and castor crops (Tsoutous et al., 2013).

The increase of different N forms, i.e. NO_3-N, NH_4-N or total N, has been observed after wastewater irrigation of orchards (citrus or hazel), sugarcane, corn, forage crops and mangrove for less than 1 year up to 20 years (Table 4). Identically, long term wastewater

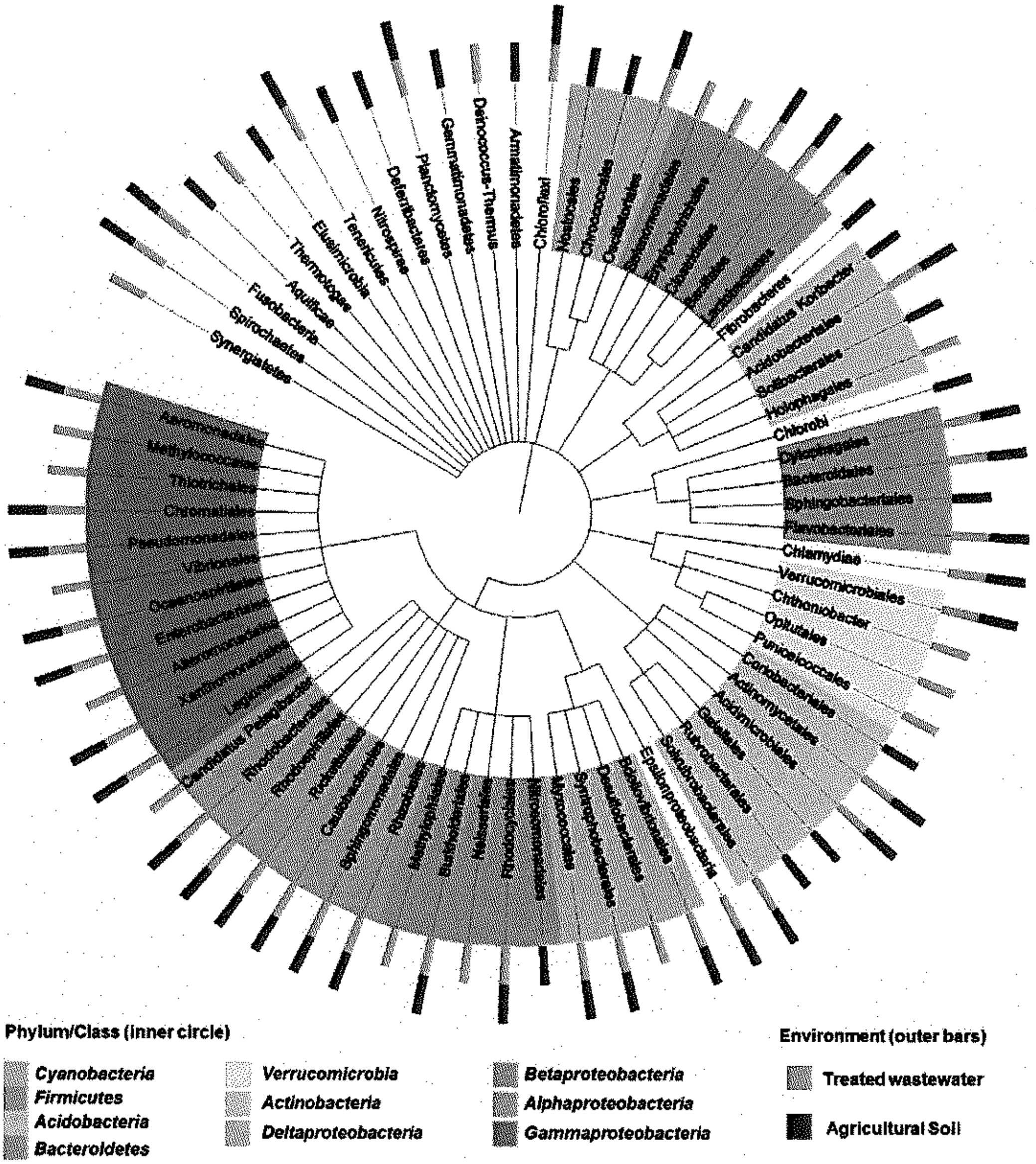

Fig. 1. Dendrogram representation of the bacterial diversity observed in treated wastewater and agricultural soil. The dendrogram was constructed with the iTOL – interactive tree of life (Letunic and Bork, 2007, 2011), based on the taxon ID codes, corresponding to the identifications provided in each of the publications cited (see Table S1).

irrigation contributes to increase the available P (Table 4). Both N and P contents may impact soil microbial communities, in particular the activity associated with the cycling of these elements. Tam (1998) observed a concomitant increase of inorganic forms of N (NO_3-N and NH_4-N) and of ammonia and nitrite-oxidizing bacterial counts in wastewater irrigated soils. Similar findings were reported by Habteselassie et al. (2013) when N sources, from different origins including dairy wastes, were added to agricultural soils. N availability is also reported as able to interfere, either increasing or decreasing the bacterial richness. Gelsomino et al. (2006) reported that the increase of total N observed in soils flooded with wastewater was concomitant with a decrease in the genetic diversity of ammonia-oxidizing bacteria when compared to controls. However, the addition of ammonium nitrate to soils was shown to increase the bacterial richness (Turlapati et al., 2013). Friedel et al. (2000) studying a soil irrigated with wastewater for more than 18 years demonstrated that denitrifying activity was stimulated comparing to those under rainfed agriculture. This difference was probably due to the availability of NO_3-N released as product of the activity ammonia and nitrite-oxidizing bacterial groups.

Despite the possible benefits for crop productivity, the excessive provision of nutrients in soil may have adverse effects. Nutrients such as available P and nitrate may be leached into the surface and groundwater, causing eutrophication or toxicity in other habitats (Candela et al., 2007; Knobeloch et al., 2000; Wu, 1999) (Table 3). The excess of nutrients can also disturb the autochthonous soil microbial communities. For example, the accumulation of inorganic-N in soils may affect the microbial catabolic activity, in particular the biodegradation of recalcitrant carbon compounds present in soil (DeForest et al., 2004; Ramírez et al., 2012).

3.1.4. Salinity

Wastewater contains higher concentrations of dissolved inorganic substances, including soluble salts, than freshwater. Therefore, wastewater irrigation may promote soil salinisation (increase of soluble salts concentration) or sodification (increase of sodium ions relative to other cations). In turn, salinisation and sodification are also associated with the increase of electrical conductivity. These are the most commonly reported negative effects caused by wastewater irrigation (EPA, 2012; Pescod, 1992; WHO, 2006a) (Table 4). Excessive soil salinity imposes hyperosmotic, oxidative stress and ion toxicity, constituting a limiting factor for plant growth, development and productivity (Levy and Tai, 2013; Ngara et al., 2012). On the other hand, sodification affects negatively the stability of soil aggregates and soil structure, leading to an increase of soil compaction, loss of soil permeability and reduction of hydraulic conductivity (Sparks, 2003) (Table 3). These factors will interfere not only with plant growth but also with soil microbiota. Effects on microbial communities are mainly related with the alteration of the soil structure and with the decrease of osmotic potential (Chowdhury et al., 2011; Sarig et al., 1993; Torsvik and Ovreas, 2002; Wong et al., 2008). Increase in soil salinity has been shown to reduce fungal and bacterial counts (Omar et al., 1994; Pankhurst et al., 2001), as well as, to reduce microbial diversity and microbial biomass (Ke et al., 2013; Tripathi et al., 2006). Rietz and Haynes (2003) related salinity and sodicity with increased levels of microbial stress and a reduction on the metabolical efficiency of the microbial community. Indeed, soil salinity seems to influence the C and N mineralization, and the retardation of nitrification (Azam and Ifzal, 2006; Sarig et al., 1993).

3.1.5. Contaminants

Wastewater transports different types of contaminants (e.g., metals, organic micropollutants), which through irrigation may accumulate in soil. These contaminants may diffuse or propagate to the surrounding environment and in soil may hinder its fertility and/or disturb the microbial communities (Table 3). The incapacity of the soil ecosystem to eliminate contaminants supplied by biosolids or water has been designated terraccumulation (Rooklidge, 2004) (Table 3). Metals such as Fe, Cr, Zn, Pb, Ni, Cd and Cu, abundant in wastewater, are on the top list of potential contaminants accumulating due to wastewater irrigation (Table 4). Besides the potential phytotoxicity and consequent effects on plant growth and/or contamination, metals may also disturb the autochthonous microbial communities (e.g. reduction of microbial biomass or alteration of the community structure, Table 3). In addition, microbial functions impaired by metal contamination, include C and N mineralization, soil enzyme activity and litter decomposition (Bååth, 1989; Brookes, 1995; Chander and Brookes, 1991; Müller et al., 2002) (Table 3). Some studies reporting metal accumulation in soil after irrigation with wastewater related this accumulation with the reduction of alkaline phosphatase activity and soil ATP content, the suppression of the sporulation and diversity alteration of arbuscular mycorrhizal fungi and the emergence of metal resistance in bacteria (Faryal et al., 2007; Ortega-Larrocea et al., 2001; Yim and Tam, 1999). Leaching is another possible consequence of metal accumulation in soils, mainly after long periods (~20 years) of irrigation with wastewater (Xu et al., 2010). Moreover, accumulated metals may interact synergistically with other contaminants, such as antibiotics, exacerbating their potential effects (Kong et al., 2006; Peltier et al., 2010). Boron is a semi-metallic element and also a pollutant commonly present in wastewater (EPA, 2012; WHO, 2006a). Besides its toxicity to human and plants (Nable et al., 1997; Parks and Edwards, 2005), B may also affect microbial communities, although the reported effects due to its excess in soils are scarce in literature and commonly associated with effects of soil salinity. Nevertheless, B has been shown to reduce bacterial diversity and dehydrogenase activity of soils (Ibekwe et al., 2010; Khan et al., 2012; Nelson and Mele, 2007).

Organic contaminants transported by wastewater, such as phenolic compounds, surfactants, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pharmaceutical products may also accumulate in soils due to long-term irrigation with wastewater. These compounds may increase soil toxicity and represent a potential ecological risk in the soil ecosystem (Fatta-Kassinos et al., 2011; Song et al., 2006b). Potential adverse effects include also the disturbance of soil microbiota (Table 3). Phenolic compounds may promote changes in the soil microbial community structure and function, for instance through the stimulation of primary phenol degraders and trophically related populations (DeRito et al., 2005; Sinsabaugh, 2010). Surfactants, such as linear alkylbenzene sulfonate (LAS), are other common wastewater contaminants, which accumulation in soil may have adverse effects. Although these effects are not always observed and depend on the surfactant type (Abu-Zreig et al., 2003; Sklarz et al., 2013), their accumulation may generate water-repellent soils, with effects in hydraulic properties and crop productivity (Doerr et al., 2000; Wiel-Shafran et al., 2006). In addition, changes in the structure of soil bacterial communities due to surfactant contamination have been reported (Sánchez-Peinado et al., 2010). Also the exposure to PCBs is capable of diminishing soil bacterial abundance (Correa et al., 2010), and phenanthrene, a model compound for PAHs, has negative effects on several bacterial groups, reducing soil richness and evenness (Ding et al., 2012).

Endocrine-disruptors and a myriad of pharmaceutical products (e.g. antimicrobials, personal care products, lipid regulator agents, anti-inflammatory drugs, betablockers, cancer therapeutics, contraceptives and other hormones) are contaminants of emerging concern (Chen et al., 2011; Fatta-Kassinos et al., 2011; Kinney et al., 2006; Muñoz et al., 2009; Shi et al., 2012; Thiele-Bruhn, 2003; Toze, 2006). The fate and effect of these compounds in soils will depend on several key factors, which go far behind the chemical properties of each one or of the soil characteristics. Compounds with low mobility, such as the antimicrobials ciprofloxacin, sulfamethoxazole, and carbamazepine, were shown to accumulate in soils with the irrigation period (0–100 years), in contrast with others highly mobile (diclofenac, naproxen, bezafibrate) (Chefetz et al., 2008; Dalkmann et al., 2012; Gibson et al., 2010; Kinney et al., 2006).

Antimicrobial compounds in soils may disturb the structure and activity of microbial communities (Ding and He, 2010; Kong et al., 2006; Liu et al., 2012; Müller et al., 2002) (Table 3). Indeed, disturbances on N transformation, methanogenesis, and sulphate reduction were reported (Ding and He, 2010). Oxytetracycline and sulfamethoxazole have been shown to decrease the functional diversity of soil microbial community (Kong et al., 2006; Liu et al., 2012), and tylosin, to alter the bacterial structure of soil (Müller et al., 2002). Such effects may be more pronounced for antimicrobials with high tendency to adsorb to soil particles, since adsorption promotes the concentration of the compound without loss of activity (Chander et al., 2005). Some antimicrobial compounds are known to suffer degradation in soils (Lin and Gan, 2011; Monteiro and Boxall, 2009; Xu et al., 2009; Zhang et al., 2012). However, highly mobile contaminants and/or degradation products thereof are not of less concern, since due to leaching processes can contaminate groundwater. For instance, amoxicillin degradation products were observed to contaminate groundwater in an agricultural field irrigated with wastewater (Gozlan et al., 2013).

The discussion about the effects of environmental contaminants is often oversimplified since most of the times a single compound and target function or parameter are assessed. However, contaminants seldom occur alone in wastewater and, thus, the combination of different compounds may make the prediction of possible effects, even more complex. It is arguable that in soil, antimicrobial compounds may interact with other contaminants. Indeed, it is documented that antibiotics may favour the soil adsorption of metals such as Cu and Cd, reducing their toxicity to plants (Jia et al., 2008; Wan et al., 2010). In turn, metals can also enhance the effects of antibiotics accumulation in soils (Kong et al., 2006; Peltier et al., 2010). In comparison with the individual contaminants, the combination of oxytetracycline and Cu was observed to significantly decrease the bacterial diversity, evenness and soil microbial community function (Kong et al., 2006). Last but not least, the possibility that these pollutants contribute for antibiotic resistance selection cannot be ignored (Chee-Sanford et al., 2009; Wang et al., 2014).

3.2. Effects on microbial abundance and activity

The increase of soil microbial biomass due to wastewater irrigation was observed in several studies (Table 4). As described above, this effect may be due to the provision of organic carbon, as is suggested by the simultaneous increase in the activity of dehydrogenase, a parameter generally indicative of biological oxidation of organic compounds (Alguacil et al., 2012; Elifantz et al., 2011; Frenk et al., 2014; Friedel et al., 2000) (Table 2). Through the supplying of organic matter and nutrients, soil irrigation with wastewater is expected to stimulate different organisms and metabolic pathways. The increase in the activity of some enzymes (e.g. hydrolytic, proteolytic, laccases, cellulases, phosphatase) has been reported in soils irrigated with treated wastewater (Adrover et al., 2012; Alguacil et al., 2012; Chevremont et al., 2013; Elifantz et al., 2011; Frenk et al., 2014; Friedel et al., 2000; Meli et al., 2002; Morugán-Coronado et al., 2013). It is, thus, suggested that wastewater irrigation may stimulate the activity of microorganisms involved in the biochemical balance of elements such as C, N and P. In addition, organic matter may stabilize the enzymes, which remain active in the extracellular medium, independently of the soil microbial (Trasar-Cepeda et al., 2008a). However, these modifications are not necessarily beneficial and the stimulation of the soil microbial abundance and activity may have negative impacts on soil properties. For instance, Magesan et al. (1999) observed that the bacterial growth stimulated by irrigation with wastewater led to the formation of biofilms, with the concomitant clogging of the pore spaces between particles, with implications in the soil hydraulic conductivity. Again, the complexity of the cause–effect relationships associated with wastewater irrigation is emphasized. In the literature available it is not possible to find a general agreement about the promotion of microbial abundance and activity in soils irrigated with wastewater. Indeed, either a decrease or no noticeable effects on the microbial biomass or enzymatic activity were reported by several authors (Table 4). Tam (1998) did not observe changes in phosphatase or dehydrogenase activities in mangrove soils irrigated with wastewater. Kayikcioglu (2012) reported a decrease of the activities of enzymes aryl sulfatase, dehydrogenase, urease, alkaline phosphatase and β-glucosidase in wastewater irrigated agricultural soil. The inhibition of microbial growth or activity after wastewater irrigation is probably explained by the fact that besides nutrients also contaminants, such as heavy metals, are being supplied (Kayikcioglu, 2012; Yim and Tam, 1999).

4. Autochthonous versus exogenous microbiota

4.1. Soil and wastewater bacterial diversity

Soil and wastewater have quite different characteristics, but both are inhabited by a wide diversity of bacteria. A first glance to evaluate the likelihood of disturbances in soil microbial communities due to the introduction of exogenous bacteria through irrigation with wastewater can be given by a comparative diversity assessment (Fig. 1). Most of the recent studies on the bacterial diversity of these habitats are based on culture independent methods (16S rRNA gene-PCR-DGGE, clone libraries and high-throughput sequencing methods). Although these approaches may offer a reliable overview of the bacterial community, microbial identification is only possible above the genus level, a fact that hinders a thorough comparison of the microbiota of soil and wastewater. A summary of studies reporting the bacterial diversity of agricultural soils and treated wastewaters is shown in Fig. 1 and Table S1. Due to the lack of a consensual soil classification, the data herein reported for agricultural soils is independent of soil texture, edaphic characteristics and type of crops. The data of treated wastewater include those treated in lagoons and/or in wastewater treatment plants, treating municipal, industrial, including pharmaceutical, and/or animal wastewater.

At the phylum level, *Proteobacteria*, *Actinobacteria*, *Firmicutes*, *Bacteroidetes*, *Acidobacteria* and *Verrucomicrobia* are amongst the most abundant bacterial groups thriving in both types of habitat (Fig. 1, Table S1). In contrast, some bacterial groups commonly found in treated wastewater are seldom, if ever, detected in agricultural soil. This was the case for the phyla *Deinococcus-Thermus*, *Thermotogae*, *Synergistetes* or for members of the orders *Methylophilales*, *Neisseriales*, *Alteromonadales*, *Methylococcales*, *Thiotrichales*, *Vibrionales*, *Desulfobacterales*, *Erysipelotrichales*, *Selenomonadales*, *Holophagales*, *Opitutales*, *Puniceicoccales*, *Phycisphaerales*, *Planctomycetales*, and *Spirochaetales* (Fig. 1, Table S1). Not surprisingly, some of these bacteria comprise members of the human microbiome, i.e. are commensal or pathogenic bacteria, and were detected in the human gastrointestinal or urogenital tracts (*Vibrionales*, *Erysipelotrichales*, *Selenomonadales*, *Spirochaetales*) (NIH Human Microbiome Project catalog, http://www.hmpdacc.org/catalog/). It is thus suggested that, if not outcompeted, bacteria of human origin may become part of the soil microbiome through the use of treated wastewater for irrigation. Although some bacteria inhabiting wastewater are ubiquitous and may occur in different habitats, their passage through the human body may increase the chances of acquisition of exogenous genetic material. In this respect, mobile genetic elements, antibiotic resistance and virulence genes are of special concern. For instance, members of the orders *Aeromonadales*, *Alteromonadales*, *Enterobacteriales*, *Legionellales*, *Pseudomonadales*, *Vibrionales*, *Xanthomonadales*, *Actinomycetales*, *Bacillales*, *Clostridiales*, *Lactobacillales* and *Bacteroidales* are common members of the human microbiome (NIH Human Microbiome Project catalog, http://www.hmpdacc.org/catalog/) and described as carriers of multiple determinants of antibiotic resistance (Vaz-Moreira et al., 2014).

On the other hand, the use of wastewater for irrigation may be a source of beneficial bacteria for the soils. For example, the introduction of bacteria involved in the N cycling or other with the ability to remediate soil contaminants (e.g. pesticides, heavy metals or antibiotics) may contribute for the improvement of the soil quality (Hanjra et al., 2012; Oved et al., 2001). Oved et al. (2001) reported that soils irrigated with treated wastewater were enriched with different *Nitrosomonas*-like species. Although bacterial groups such as the ammonia- and nitrite oxidizing bacteria (e.g. *Nitrosomonas* and *Nitrobacter* or *Nitrospirae*, respectively) are not frequently detected in bacterial diversity studies of treated wastewaters (Table S1, Fig. 1), they may eventually be enriched in soils explaining the results of Oved et al. (2001).

One of the challenges concerning the microbiological impacts of wastewater irrigation is to understand if and how the introduced microorganisms will affect the soil microbial community. These effects may be related not only with the interference that exogenous populations may have on the soil microbial community, but also with the capacity of the exogenous organisms to survive in soil and constitute a health risk to humans and livestock. To the best of our knowledge, there are no studies reporting the fate of wastewater microorganisms introduced in soil through irrigation, neither describing their influence on the soil native microbial communities. Because plant and human health risks posed by wastewater irrigation are relevant issues, some inferences based on the literature available are the subject of the next subsections.

4.2. Risk of dissemination of pathogens through wastewater reuse

The occurrence of pathogens in treated domestic wastewater is well documented (Okoh et al., 2007; Varela and Manaia, 2013) and their transmission to humans by direct contact or through the food chain is of concern (Hussain et al., 2002; Solomon et al., 2002; Steele and Odumeru, 2004; Wachtel et al., 2002). In addition, indirect transmission pathways include the air, due to the formation of aerosols, or water, due to runoff or leaching (Hussain et al., 2002). The risks posed to humans by pathogens transmitted through wastewater irrigation are difficult to estimate, but will depend, amongst other factors, on the survival of pathogens in the environment, the infective dose, and the host immunity (Hussain et al., 2002; Shuval and Fattal, 2003). In the environment, in particular in soil, the survival of exogenous microorganisms, including pathogens, depends on factors such as the antagonism with native microbiota, moisture content, organic matter, pH, and temperature (Brandl, 2006; Shuval and Fattal, 2003). The survival periods in soil or crops for some pathogenic bacteria and parasites may vary from only few days (e.g. *Campylobacter* spp.) up to one year for the highly resistant eggs of the helminth *Ascaris* (Shuval and Fattal, 2003), or much longer periods for fungi spores (e.g. *Hemileia vastatrix*, *Puccinia melanocephala*, *Puccinia striiformis* f. sp. *tritici*) or highly resistant bacterial endospores (e.g. *Bacillus cereus*, *Clostridium botulinum* or *Clostridium perfringens*) produced by some phyto- and human pathogens, respectively (Brown and Hovmoller, 2002; Brown, 2000; Harris et al., 2003).

When considering transmission of human pathogens through the food chain, one important parameter to be considered is the type of plants produced by the irrigated soil and the method employed for irrigation. For fruit trees or vegetables cultivated on vines and not in direct contact with irrigation water, the risks of transmission may be lower than for vegetables which grow in direct contact with the soil and irrigation wastewater (Cirelli et al., 2012; Melloul et al., 2001). In addition, methods that increase the probability of direct contact between wastewater and edible part of plants (e.g., furrow irrigation) seem to promote greater contamination of plants than subsurface drip irrigation (Song et al., 2006a). However, Christou et al. (2014) reused a tertiary treated effluent for irrigation of tomato crops and did not find evidences of microbiological contamination of the edible parts.

Rhizosphere is a habitat for plant-beneficial bacteria, however it may also host potential human pathogens (Berg et al., 2005; Holden et al., 2013). Bacterial genera such as *Burkholderia*, *Enterobacter*, *Herbaspirillum*, *Ochrobactrum*, *Pseudomonas*, *Ralstonia*, *Staphylococcus* and *Stenotrophomonas* are inhabitants of plant roots also able to colonize humans (Berg et al., 2005). Besides colonizing the vegetables surface, some bacteria may live inside the plants (endophytes). A positive correlation between plant contamination and irrigation with wastewater has been described, suggesting that wastewater can be an important source of bacteria that will colonize plants (Armon et al., 1994; Howard and Hutcheson, 2003; Ibenyassine et al., 2006; Tyler and Triplett, 2008). Part of these bacteria can be transmitted to the consumers, mainly through uncooked vegetables. Opportunistic human pathogens described as endophytic bacteria include members of the genus *Staphylococcus* and family *Enterobacteriaceae* (e.g., *Hafnia*, *Yersinia*, *Pantoea*, *Salmonella*, *Enterobacter*, *Citrobacter* and *Klebsiella*) (Markova et al., 2005; Opelt et al., 2007; Rosenblueth and Martínez-Romero, 2006; Sturz et al., 2000; Wang et al., 2006). Although some *Enterobaceriaceae* have the ability to promote plant growth (Rosenblueth and Martínez-Romero, 2006; Tyler and Triplett, 2008), risks for human health cannot be ignored. Species comprising opportunistic pathogens such as *Escherichia coli*, *Enterobacter cloacae* and *Klebsiella pneumoniae* were detected in vegetables after irrigation with wastewater (Al-Lahham et al., 2003; Ibenyassine et al., 2007). A good example is the enterohemorrhagic strain *E. coli* O157:H7 that can be internalized into lettuce when exposed to contaminated irrigation water or soil (Solomon et al., 2002; Wachtel et al., 2002). Moreover, because plants are privileged hosts for these bacteria, if supplied in irrigation water, they can proliferate and survive for longer periods when plants are present than in their absence (Gagliardi and Karns, 2002; Ibekwe et al., 2004; Tyler and Triplett, 2008). Another risk is that bacteria transmitted by this pathway may be inherited through plant seeds, as has been described for some endophytic bacteria (Burnett et al., 2000; Cooley et al., 2003; Guo et al., 2001; Rosenblueth and Martínez-Romero, 2006; Tyler and Triplett, 2008; Wang et al., 2006). The risks associated with the dissemination of human pathogens due to the use of treated wastewater for irrigation can be considered low (Bichai et al., 2012; Shuval and Fattal, 2003). However, a pathway of transmission, comprising treated wastewater, soil-vegetables and human consumers, can be defined and should be considered when the implications of wastewater irrigation are discussed.

Another possible adverse effect of wastewater irrigation is the introduction of phytopathogens in the soils. Although the risks of propagation of phytopathogens to soils through wastewater are scarcely addressed in literature, it is recognised that several plant pathogens, either bacteria, fungi, viruses, parasitic nematodes or oomycetes (e.g. *Phytophthora* and *Pythium*) are waterborne (Bush et al., 2003; Hong and Moorman, 2005). Evidences of possible risks are supported by reports involving the use of recycled freshwater in plant nurseries and greenhouses, concluding that this can be identified as an important source and vehicle for the spread of plant pathogens (Stewart-Wade, 2011). Also the cross checking of potential phytopathogens in the list of microorganisms normally occurring in treated wastewater, suggests some candidates. Bacterial phytopathogens found in irrigation systems include *Corynebacterium flaccumfaciens*, *Erwinia* spp., *Pseudomonas syringae*, *Ralstonia solanacearum* and *Xanthomonas* spp. (Hong and Moorman, 2005). Some members of these genera (e.g. *Pseudomonas* and *Xanthomonas*) and other plant pathogens, such as members of the genera *Acidovorax* and *Herbaspirillum* and plant viruses (families *Tombusviridae*, *Geminiviridae*, *Nanoviridae* and the genus *Tobamovirus*) (Alhamlan et al., 2013; Fegan, 2006; Rosario et al., 2009) are also common inhabitants of treated wastewater. The scant information on the presence of phytopathogens in treated wastewater hampers decisive conclusions on the risks posed by wastewater irrigation. However, the introduction of plant pathogens through irrigation with wastewater cannot be ruled out until further studies are conducted focusing this issue.

4.3. Risks and precautions associated with antibiotic resistance

Treated wastewater contains high loads of bacteria. Most of these are of environmental origin and a non-negligible fraction (up to10^3 colony forming units per mL) is derived from human and animal guts (Novo and Manaia, 2010; Varela and Manaia, 2013). Inevitably, these bacteria harbour antibiotic resistance genes, frequently associated with mobile genetic elements, which means that these genes have a high potential to be propagated amongst the bacterial community (Rizzo et al., 2013; Vaz-Moreira et al., 2014). In part this situation can be attributed to the fact that although conventional secondary wastewater treatment processes can reduce the cultivable bacterial loads around 2 logarithmic cycles, it fails to reduce the prevalence of antibiotic resistance and, sometimes, can even contribute for its increase (Ferreira da Silva et al., 2006; Luczkiewicz et al., 2010; Manaia et al., 2010; Novo et al., 2013; Rizzo et al., 2013; Zhang et al., 2009). This means that treated wastewater will contain high doses of antibiotic resistant bacteria. An estimate made for ciprofloxacin resistant coliforms, suggests that, per minute, a treatment plant will discharge 10^9 resistant bacteria (Vaz-Moreira et al., 2014). Over the years, antibiotic resistance has accumulated in the environment, humans and other animals. In particular old antibiotics such as aminopenicillins, sulfonamides, tetracyclines or erythromycin are nowadays inactive against bacterial groups formerly susceptible to those drugs. The prevalence of resistance to these old antibiotics can reach more that 50% of some bacterial populations discharged in the final effluents of wastewater treatment plants with conventional treatment (Manaia et al., 2012; Rizzo et al., 2013). The time elapsed between the emergence of a new resistance gene in clinical settings and its detection in municipal wastewater is frighteningly short (Szczepanowski et al., 2009). For instance, bacteria resistant to last resort antibiotics mainly or exclusively used in hospitals, such as carbapenems resistant Gram-negative bacteria, vancomycin resistant entereococci (VRE), or methicillin resistant *Staphylococcus aureus* (MRSA) are nowadays detected in municipal wastewater worldwide (Manaia et al., 2012; Rizzo et al., 2013; Baker-Austin et al., 2006; Fluit and Schmitz, 2004; Hernández et al., 1998; Miyahara et al., 2011). The wide contamination of the environment and the food chain with these genetic determinants may represent a public health calamity. Even if no emerging resistance types occur in wastewater, the dose of bacteria resistant to currently used and old antibiotics that will be discharged in an irrigated field is very high, and the possibility that these organisms can proliferate in soils and/or plants cannot be over ruled. The fate of antibiotic resistant bacteria and resistance genes in soils after wastewater irrigation is still poorly understood. Even though some wastewater bacteria will be outcompeted in soil, two types of negative consequences can be anticipated: i) some antibiotic resistant populations can proliferate in soil or plants, behaving as invasive species; and ii) some antibiotic resistance genes can be horizontally transferred (by conjugation, transduction or transformation) from wastewater bacteria to soil or plant bacteria. Hypothetically, both can take place simultaneously. However, the studies available do not strongly support those effects. Instead, the few publications available on the subject, show some controversial findings. While Negreanu et al. (2012) and Gatica and Cytryn (2013) failed to find any evidences that antibiotic resistant bacteria from treated wastewater could compete or survive in soils after for 6–8 years of irrigation, Wang et al. (2014) reported opposite results (Table 4). Wang et al. (2014) observed higher diversity and abundance of antibiotic resistance genes in soils irrigated with wastewater than in a pristine soil. Furthermore, soils irrigated with wastewater presented higher abundance of the gene encoding a class 1 integrase (*intI*1). Confirming the hypothesis that the abundance of the gene *intI*1 could indicate a high potential for horizontal gene transfer in soils, Wang et al. (2014) observed significant positive correlations between that gene and genes encoding resistance for tetracycline and sulfonamide (*tet*G, *sul*1, and *sul*2). One of the concerns associated with the continuous discharges of antibiotic resistant bacteria in soils is the high stability that some resistance genotypes may have. Although it might be generally assumed that antibiotic resistant bacteria or their genes can only persist if they have a competitive advantage, being selected by the presence of antibiotics, it has been demonstrated that this is not the case. Indeed, even in the absence of selective pressures or at concentrations found in many natural environments antibiotic resistant bacteria can be maintained or even enriched (Andersson and Hughes, 2010; Gullberg et al., 2011; Heuer et al., 2008). In addition, antibiotic resistance genes may occur in the environment also as naked DNA. It is known that extracellular DNA easily adsorbs to the sediment matrix and organic matter, prevalent in soils, and when adsorbed, DNA may be more resistant against DNase I degradation than the free naked DNA (Crecchio and Stotzky, 1998; Lorenz and Wackernagel, 1994). Hence, the persistence of antibiotic resistance genes in the soils irrigated with wastewater will depend mainly on the ability of the host bacteria to survive and proliferate in the receiving habitat or on the ability of the native microbiota to acquire the naked DNA fragments and proliferate after the acquisition. Although it is still very difficult to predict what may be the effect of the naked DNA in the soil, it was possible to demonstrate that antibiotic resistance genes (from both intra- and extracellular DNA) could be detected in soil in high doses by quantitative PCR after 16 months of environmental exposure (Hong et al., 2013; Selvam et al., 2012). These arguments show that even if immediate impacts are not observed, long term effects of accumulation of resistant bacteria, resistance genes and antibiotic residues should not be ignored (Dalkmann et al., 2012).

The apparent controversial results on the detection of contaminant antibiotic resistance in soil due to wastewater irrigation can be attributed to several factors, which obviously include the quality of the wastewater and of the soil. However, it is important to note that the detection of soil contamination with antibiotic resistance genes and/or bacteria in soil is technically challenging. In first place, since antibiotic resistance is a natural property of bacteria that can be observed in natural communities, it is critical to define in each case the resistance background naturally existing in soil in order to assess the level of contamination coming from wastewater (Cytryn, 2013; Knapp et al., 2010). On the other hand, contamination by antibiotic resistant bacteria or genes may occur at very low levels, which in spite of the potential biological impact (e.g. facilitating horizontal gene transfer) may be below the quantification limits of the techniques commonly used (e.g. qPCR of DNA extracts produced from less than one gram of soil).

Antibiotic resistance is increasingly recognised as a global threat for human health and efforts to contain the dissemination of resistance genes and resistant bacteria are urgently needed (WHO, 2014). Wastewater reuse for irrigation poses a serious risk of contamination of soils, ground- and surface water, the wild life and the food-chain. Therefore, the current state of knowledge alerts for the need to apply the precautionary principle, i.e. avoid the irrigation with wastewater containing high levels of antibiotic resistance, as those normally resultant from most conventional wastewater treatment processes. In this respect, it seems advisable to assume that advanced treatment processes may be required for a safe wastewater reuse in irrigation.

5. Conclusions

The use of wastewater for irrigation is regarded as a way to address the imbalance between water demand and water supply. However the literature shows that irrigation with treated wastewater is not exempt of implications, some of them adverse. Alterations, such as the increase of organic matter related pools, salinity and soil accumulation of contaminants are the most commonly reported effects, with several examples being found in literature. Also the responses of soil microbiota to wastewater irrigation are varied and include the increase of microbial biomass and activity and different types of alterations on the microbial community structure. However, the most evident outcome of the literature search is that the effects on soil microbiota are neglected in the majority of studies on irrigation with wastewater. This is a major gap in the knowledge, given the importance of soil microbiota on soil health and fertility. A critical review of the current knowledge on soil and wastewater microbiology gives unequivocal indications that wastewater irrigation, in spite of the unquestionable benefits, may have adverse impacts on both physicochemical and microbiological properties of the soil. These will influence soil fertility and productivity, raising important concerns about the sustainability of continued reuse of treated wastewater in agriculture. Studies on the effects on soil of wastewater irrigation are challenging, since direct cause–effect relationships can hardly be found. It is suggested that multi-parametric analyses and holistic studies may bring additional and reliable insights into this problem.

The risks posed for human health represent another question at the heart of any discussion on wastewater reuse. These risks cannot be accurately estimated at the moment, but cannot be ignored. The evidences reported in the literature, as well as the critical analyses on the limitations of some experimental approaches highlight the importance of the accumulation and propagation of biological contaminants in soils due to wastewater irrigation. Human and animal pathogens, phytopathogens and antibiotic resistant bacteria and their genes are important biological contaminants that can be transported by wastewater and/or be enriched in soil. Also numerous chemical contaminants, included in categories such as xenobiotics, pharmaceuticals and metals, can threaten the environmental and human health. The mixture of these contaminants may have unpredictable consequences in both environmental and human health.

For a sustainable and safe wastewater reuse, parameters affecting both soil health and safety should be included in the quality standards, avoiding the disturbance of soil properties and the dissemination of emerging chemical and biological contaminants. Simultaneously, affordable technological solutions with minimal environmental impacts must be developed in order to assure wastewater treatment processes compatible with sustainable uses.

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COUNTY OF SANTA CRUZ | Planning Department

MEMORANDUM

Date: April 15, 2015

To: Sheila McDaniel

From: Todd Sexauer

Re: Responses to Jude Todd's Comments on the Draft IS/MND for the Davenport Recycled Water Project

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Comment 1: *The MND asserts that "The proposed project is designed to provide recycled water to farmlands on the north coast in an effort to increase their productivity" (MND, p. 21). (However, as I read the descriptions of the four project alternatives, that statement pertains to Alternatives 2, 3, and 4, but not to Alternative 1.)*

Response: An alternatives analysis of the four project alternatives evaluated in the Recycled Water Study Draft Facilities Planning/Project Report (study) was not conducted in the Initial Study/MND. Alternative 4 of the study was chosen as the proposed project analyzed in the Initial Study. An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). An alternatives analysis is required when preparing an Environmental Impact Report (CEQA §15126.6). As stated in the Initial Study Project Description, "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

Tertiary treated water can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations. The State Water Resources Control Board (SWRCB) Recycled Water Policy adopted on February 3, 2009 (modified January 2013), finds that "...the use of recycled water in accordance with this Policy, that is, which supports the sustainable use of groundwater and/or surface water, which is sufficiently treated so as not to adversely impact public health or the environment and which ideally substitutes for use of potable water, is presumed to have a beneficial impact." The tertiary treated recycled water would be treated to a high level that meets Title 22 requirements.

The SWRCB Adopted Recycled Water Policy Section 10(b) states, "The State Water Board, in consultation with the California Department of Public Health (CDPH) and within 90 days of the adoption of this Policy, shall convene a "blue-ribbon" advisory panel to guide future actions relating to constituents of emerging concern (CEC). These include endocrine disruptors, personal care products, pharmaceuticals, and other constituents such as antibiotic resistant bacteria or genes that may potentially be harmful to human health or the environment." Section 10(b)(2) states, "The panel shall review the scientific literature and, within one year from its appointment, shall submit a report to the State Water Board and the CDPH describing the current state of scientific knowledge regarding the risks of emerging constituents to public health and the environment. Within six months of receipt of the panel's report the State Water Board, in coordination with CDPH, shall hold a public hearing to consider recommendations from staff and shall endorse the recommendations, as appropriate, after making any necessary modifications. The panel or a similarly constituted panel shall update this report every five years. Section 10(b)(3) states, "Each report shall recommend actions that the State of California should take to improve our understanding of emerging constituents and, as may be appropriate, to protect public health and the environment."

Section 10(b)(4) states, "The panel report shall answer the following questions:

- What are the appropriate constituents to be monitored in recycled water, including analytical methods and method detection limits?
- What is the known toxicological information for the above constituents?

- Would the above lists change based on level of treatment and use? If so, how?
- What are possible indicators that represent a suite of CECs?
- What levels of CECs should trigger enhanced monitoring of CECs in recycled water, groundwater and/or surface waters?

According to the Final Report prepared by the Science Advisory Panel, dated June 25, 2010, "Given that thousands of chemicals are potentially present in recycled water and that information about those chemicals is rapidly evolving, the Panel recommends that the state rely on a transparent, science-based framework to guide prioritization of which CECs should be included in recycled water monitoring programs both now and in the future as additional data become available. ...which includes four steps:

1. Compile environmental concentrations (e.g., measured environmental concentration or MEC) of CECs in the source water for reuse project;
2. Develop a monitor triggering level (MTL) for each of these compounds (or groups thereof) based on toxicological relevance;
3. Compare the environmental concentration (e.g., MEC) to the MTL. CECs with a MEC/MTL ratio greater than "1" should be prioritized for monitoring. Compounds with a ratio less than "1" should only be considered if they represent viable treatment process performance indicators; and,
4. Screen the priority list to ensure that a commercially-available robust analytical method is available for that compound."

The SWRCB has recognized that assessing how CECs affect both recycled and ambient discharged water cannot be achieved through chemical monitoring alone. In 2011, the SWRCB contracted the Southern California Coastal Water Research Project (SCCWRP) to establish and manage a team of investigators to develop bioassays to identify known and unknown CECs that may potentially be found in recycled water as envisioned by the CEC Advisory Panel. The Bioanalytical Investigative Team identified an appropriate extraction protocol for isolating and concentrating the CECs from recycled water. The Bioanalytical Investigative Team then identified and tested currently available bioanalytical kits with a variety of modes of action that could potentially be used to assess CECs in recycled water. The Bioanalytical Investigative Team also included an interpretive framework in their report to facilitate the decision making process when identifying threats to human health. The Bioanalytical Investigative Team's Final Report titled *Development of Bioanalytical Techniques for Monitoring of Constituents/chemicals of Emerging Concern (CECs) in Recycled Water Applications for the State of California* includes additional details and recommendations for next steps.

The Davenport County Sanitation District is required to comply with the California Department of Public Health's Recycled Water Regulations under Title 22 of the California Code of Regulations for all recycled water distributed for irrigation or other non-potable use.

Section 26 of the State Water Resources Control Board Order WQ 2014-0090-DWQ General Waste Discharge Requirements for Recycled Water Use, Adopted on June 3, 2014, states the following regarding common constituents associated with recycled water:

26. Constituents associated with recycled water that have the potential to degrade groundwater include salinity, nutrients, pathogens (represented by coliform bacteria), and disinfection by-products (DBPs). If the discharge is not consistent with Basin Plan requirements, the applicant may elect to improve treatment to enroll under this General Order, or to apply for a site-specific order from the Regional Water Board. The State Water Board finds that the use of recycled water permitted under this General Order will not unreasonably affect beneficial uses or result in water quality that is less than that prescribed in applicable policies because of the following characteristics and requirements associated with each of the recycled water constituents of concern. Each of the recycled water constituents are discussed below:
    a. Salinity is measured in water through various measurements, including but not limited to, total dissolved solids (TDS) and electrical conductivity. Excessive salinity can impair the beneficial uses of water. Salinity levels in the receiving water can be affected by the use of recycled water if the recycled water has elevated concentrations of salinity. However, it is anticipated that in most cases, the use of recycled water for irrigation will consist of a portion of the total applied irrigation water. Other sources of irrigation water are likely to be potable water, imported water, agricultural water supply wells, irrigation districts (surface water supplies), and precipitation. The blending of sources of irrigation water will generally reduce concentrations of, and/or loading rates of salinity constituents. As a result, salinity increases are unlikely to impair an existing and/or potential beneficial use of groundwater.

b. Nitrogen is a nutrient that may be present in recycled water at a concentration that can degrade groundwater quality. This General Order requires application of recycled water to take into consideration nutrient levels in recycled water and nutrient demand by plants. Application of recycled water at an agronomic rate and considering soil, climate, and plant demand minimizes the movement of nutrients below the plants' root zone. When applied to cropped (or landscaped) land, some of the nitrogen in recycled water will be taken up by the plants, lost to the atmosphere through volatilization of ammonia or denitrification, or stored in the soil matrix. As a result, nitrogen increases are unlikely to impair an existing and/or potential beneficial use of groundwater.

c. Pathogens and other microorganisms may be present in recycled water based on the disinfection status. Coliform bacteria are used as a surrogate (indicator) because they are present in untreated wastewater, survive in the environment similar to pathogenic bacteria, and are easy to detect and quantify. Pathogens are generally limited in their mobility when applied to land. Setbacks from recycled water use areas are required in title 22 as a means of reducing pathogenic risks by coupling pathogen inactivation rates with groundwater travel time to a well or other potential exposure route (e.g. water contact activities). In general, a substantial unsaturated zone reduces pathogen survival compared to saturated soil conditions. Fine grained soil particles (silt or clay) reduce the rate of groundwater transport and therefore are generally less likely to transport pathogens. Setbacks also provide attenuation of other recycled water constituents through physical, chemical, and biological processes. When needed, disinfection can be performed in a number of ways. Title 22 contains water recycling criteria, which lists disinfection requirements for specifically listed activities.

d. Disinfection by-products consist of organic and inorganic substances produced by the interaction of chemical disinfectants with naturally occurring substances in the water source. Common disinfection by-products include trihalomethanes, haloacetic acids, bromate, and chlorite. DBPs present in recycled water receive additional treatment when applied to land. Biodegradation, adsorption, volatilization, and other attenuative processes that occur naturally in soil will reduce the concentrations and retard migration of DBPs in the subsurface.

Comment 2: *The MND asserts that, "The proposed recycled water project would not create a significant hazard to the public or the environment. No routine transport or disposal of hazardous materials is proposed" (MND, p. 55).*

Response: Agricultural reuse in California represents a large percentage of the total recycled water in the state: approximately 37 percent (or roughly 240,000 acre-feet per year). Estimated future demand could increase agricultural reuse by a factor of 3.2 to 3.5 times current reuse levels by 2030. Current estimates indicate that approximately 2 percent of edible food crops are irrigated with reclaimed water and, based on a linear extrapolation; estimated food crop use could increase to 8 percent.

Recycled wastewater in California is mainly regulated by the following state agencies: California Department of Public Health (CDPH), State Water Resources Control Board (SWRCB), and the nine Regional Water Quality Control Boards (RWQCBs). The State and Regional Water Boards have the primary responsibility for the protection and enhancement of the waters of the State. CDPH has the authority and responsibility to establish public health criteria for wastewater reclamation, including groundwater recharge, and reviews all proposals and plans for such projects throughout the State. Local health agencies and water districts can develop policies and programs that are more stringent than those specified by CDPH.

The CDPH Water Recycling Criteria governing the production and use of recycled water are contained in Title 22, Division 4, of the California Code of Regulations (CCR). The regulations include process standards for crop irrigation (unrestricted) to ensure that the recycled water has a total coliform concentration of less than or equal to 2.2 MPN per 100 milliliters (mL). Water meeting these criteria is considered safe for human contact, and is based on the past experience of health professionals and on a lack of detectable health problems associated with agricultural irrigation (NWRI 2012).

Also see response to Comment 1.

Comment 3: *The MND asserts that "The proposed recycled water project would ... [provide] reclaimed water for irrigation, thereby assisting with groundwater recharge... Therefore, no impact to groundwater resources would occur from project implementation" (MND, p. 61).*

Response: By supplementing irrigation water with recycled water, the amount of groundwater extracted from the aquifer would likely be reduced allowing for the natural recharge of the system. It is estimated that approximately 20 acre-feet of tertiary treated recycled water would be produced. Also, see response to Comment 1.

Comment 4: *Regarding the potential impacts that "are individually limited, but cumulatively considerable," the MND asserts that "there is no substantial evidence that there are cumulative effects associated with this project" (MND, p 77-78).*

Response: See response to Comment 1.

Comment 5: *The MND finds that only "Aesthetics and Visual Resources, Cultural Resources, and Noise" would be "potentially significant effects to human beings" (MND, p.78).*

Response: See response to Comment 1.

Comment 6: *Finally, I would point out that my concerns discussed above pertain primarily to the three alternatives (numbers 2, 3, and 4) that include using recycled wastewater on agricultural land. Alternative 1, the minimum project alternative, appears to avoid the potential negative consequences of the three alternatives that "provide recycled water to farmlands on the north coast in an effort to increase their productivity" (MND, p.21). However, in Alternative 1, the use of the truck to collect and distribute the treated wastewater from the spigot raises questions unanswered in the MND, including what, if any, limitations might be put on the uses for that wastewater. As noted in my attached paper (Todd 2015), all potential uses of recycled sewer water should be evaluated through the lens of the Precautionary Principle.*

Response: Tertiary treated water produced by the plant and transported by water truck can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations.

Todd Sexauer

From: d wirkman [debrawirkman@sbcglobal.net]
Sent: Monday, March 23, 2015 3:36 PM
To: Todd Sexauer
Cc: Bruce McPherson; Greg Caput; John Leopold; Ryan Coonerty; Sheila McDaniel; Zach Friend
Subject: Davenport Recycled Water Mitigated Negative Declaration, Public Comment
Attachments: Statement re recycled ww reuse.pdf

From the desk of
Debra Wirkman
Santa Cruz, California 95060
debrawirkman@sbcglobal.net

Todd Sexauer, Environmental Coordinator
Santa Cruz County Planning Department
701 Ocean Street, 4th Floor
Santa Cruz, CA 95060

RE: NOTICE OF INTENT TO ADOPT A MITIGATED NEGATIVE DECLARATION
PROJECT: Davenport Recycled Water Project APP #: 151029
PROJECT PLANNER: Todd Sexauer

Public Comments submitted by Debra Wirkman, Santa Cruz city resident and former AWWA certified water quality chemist

March 23, 2015
Please Note: Prompt acknowledgement of receipt of this public comment is requested.

I am disappointed that this Mitigated Negative Declaration (MND) does not evaluate crucial health and environmental impacts of all 4 options put forward in this proposal. In fact, there is no meaningful discussion of the quality of the wastewater that is the main subject of this proposal. Bearing in mind that the public review/comment period is short and there was a lot of material to review, including the MND, the draft Davenport Recycled Water Study, and routine operational data from the Davenport Sanitation District, (the latter 2 resources were available for a much shorter period) my brief comments will be as specific as possible. However, if a comment addresses a portion of the MND that I do not specifically mention, it should still be applied to that section. Many of my comments address this finding and accompanying discussion in addition to any other section to which they may apply:

3. *Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?*

Discussion: "In the evaluation of environmental impacts in this Initial Study, the potential for adverse direct or indirect impacts to human beings were considered in the response to specific questions in Section III (A through Q). As a result of this evaluation, there were determined to be potentially significant effects to human beings related to the following: Aesthetics and Visual Resources, Cultural Resources, and Noise. However, mitigation has been included that clearly reduces these effects to a level below significance. As a result of this evaluation, there is no substantial evidence that, after mitigation, there are adverse effects to human beings associated with this project. Therefore, this project has been determined not to meet this Mandatory Finding of Significance."

The above discussion is incomplete. Important information relevant to this proposal that should be disclosed to the public has been left out of the MND, including well-documented data possessed by Davenport Sanitation District about continuing sewage flows from the Cemex site to the Davenport treatment lagoon. In my review of data provided by the Davenport Sanitation District I found varying flows from the Cemex site into the treatment lagoon (discussed below). I found no data reporting chemical constituents of either the inflow from the Cemex site or the Davenport treatment plant wastewater effluent that would reassure the public about precisely what is flowing into the wastewater lagoon from the Cemex site, crucial information needed to determine whether the treated wastewater effluent is safe for its current use, much less the proposed uses of food crop irrigation, playing field irrigation, trucking of the water out of the district, etc. proposed in the various options.
It's difficult to understand why this MND was put out for public comment prior to completion of the final Davenport Recycled Water Study that serves as the feasibility study for the project. How a determination of no significant environmental impact can be made without analysis of a significant industrial inflow to the wastewater treatment plant such as the one from the Cemex site is unclear, but the omission of complete public information about industrial and commercial sewage components of the wastewater that is the subject of this proposal sidesteps key intentions of the CEQA process. The expedient nature of California wastewater regulations and wastewater project development in light of drought conditions should not exclude wastewater recycling from the appropriate CEQA or other applicable environmental or public health reviews.

The following statement is made in the draft Davenport Recycled Water Study, which I believe was provided as background information for least one grant application to a state agency for this proposed project:

Section 4.5
Sources of Industrial or Other Constituents of Concern and Control Measures
"Now that the cement plant is decommissioned there are no known sources of industrial or other constituents of concern entering the collection system."

In the very same report, this language follows: **"Even though the Cemex plant is no longer operating, the District is still receiving about 30,000 gallons per month of wastewater flow from the Cemex sewer main. The district is investigating the source of this flow...."**

I found no mention of industrial inflows to the treatment plant in the main body of the MND. The 30,000 gallon/month figure is not an accurate representation of the flow of sewage from the Cemex site to the treatment lagoon according to reports obtained from the Davenport Sanitary District. The actual amount of sewage flow from the Cemex site is variable – in 2014 it ranged from 22,000 gallons/month (January) to 68,000 gallons/month (March) and in 2013 the flow range was greater, 26,000 gallons/month (July/Aug) to 103,000 gallons/month (April). More detailed flow data are available in the Davenport Sanitation District's public record.

Why is contradictory information about industrial sewage inflows presented in the draft Davenport Recycled Water Study? Why is there no discussion of the Cemex sewage flows presented in the Mitigated Negative Declaration provided for public review and comment? When was the last time the treated Davenport effluent was tested for all contaminants listed in table 1 of the current operating permit, Central Coast RWQCB order 95-27? Has the treated effluent been tested for hexavalent chromium? There are large cement kiln dust (CKD) waste areas and other hazardous materials sites located on the Cemex site, as documented in the Phase One and Limited Phase Two Environmental Site Assessment, and the residents of Davenport have already experienced exposure to airborne hexavalent chromium and mercury during plant operations; they deserve an abundance of care from the county and regulators in the perceived and actual oversight and monitoring of wastes on the Cemex site, and of any flows from there, intentional or otherwise, into the wastewater treatment facility.

Is there any runoff or other surface flow from the Cemex site into the treatment lagoon? What means would be used to ensure that all runoff from the Cemex property is sucessfully diverted to the NPDES permitted discharge location? How is it determined whether contaminated water flows from the former coal pile, iron ore pile and/or other contaminated areas of the Cemex site (as described in the Phase One and Limited Phase Two Environmental Site Assessment, Cemex Property, Attachment 5, MND) during storm events into the treatment lagoon, e.g. during heavy downpours or prolonged rain events?What about sewer-line infiltration on the Cemex property – has this been evaluated?

Regarding the current level of treatment, the MND states: "The facility treats about 28 acre-feet of water annually to Title 22 disinfected tertiary level and the treated water is spray irrigated onto un-mowed turf adjacent to the treatment plant." However, it is not even clear that the current level of treatment is "Title 22 disinfected tertiary," as opposed to secondary-23. According to the draft Davenport Recycled Water Study the current effluent meets secondary-23 standard as defined under the California Code of Regulations, Title 22, Division 4, Chapter 3, Water Recycling (Title 22). The district agreed to provide this level of treated recycled wastewater to the cement plant. It appears that one of the purposes of the proposed plant upgrades is to achieve Title 22 tertiary 2.2 status.

However it is not clear that the proposed changes to the treatment plant will improve wastewater quality significantly over the long term; that remains to be determined. There will still be only one treatment basin, for example, and the upgrades described in the MND don't suggest that suspended solids will be eliminated, nor that variable water quality conditions such as nitrate and pH fluctuations observed periodically in the effluent would be significantly reduced. The high chlorine level routinely required is concerning, and alternatives should be explored since this treatment cannot ensure complete pathogen neutralization.

Even with the high chlorination level described in the proposal (5 mg/L, 90 min) incomplete disinfection can occur, and the presence of variable suspended solids at times can contribute to incomplete disinfection, particularly in resistant pathogens, including *toxoplasma gondii*, *cryptosporidium parvum* and others, a problem that can't be observed by the routine monitoring of indicator bacteria that Title 22 requires (total coliform and/or fecal coliform). (Reference: Centers For Disease Control, Effect of Chlorination on Inactivating Selected Pathogen http://www.cdc.gov/safewater/effectiveness-on-pathogens.htm) Serious, even fatal health impacts can result from incomplete disinfection of recycled wastewater.

The documented presence of suspended solids in the effluent is also clear evidence that nanoparticles (from personal care and other commonly used products) are making it through the treatment train. Engineered nanoparticles, made of metals such as silver and zinc and other materials, are not regulated, and their impacts on soils, crops and humans have not been evaluated. (Please see the attached statement by Jude Todd for supporting information on engineered nanoparticles.) Other types of manufactured particles found in everyday products such as plastic microbeads, which can carry organic chemical contaminants, are also a concern when suspended solids are not completely removed from wastewater. How will the impacts of nanoparticles and microparticles be evaluated and mitigated?

Will there be any monitoring for pathogen regrowth in the proposed agricultural storage ponds for treated effluent? What monitoring will be done and what measures would be taken if test results are positive? What are the potential impacts of these measures?

What methods of insect and algae control, including pesticides and herbicides if any, will be used if needed in the proposed recycled wastewater storage ponds? What are the potential impacts? Will use of pesticides/herbicides in the storage ponds impact use of the recycled water for organic crops?

Environmental Resources and Constraints:
Page 9:

Indicates that the project is not in a water supply watershed, however there are currently proposals to use groundwater from this area to supplement the Santa Cruz drinking water supply before the city's WSAC. Groundwater wells are also currently used to supply water for crop irrigation (and likely also for potable purposes) in the project area. Has any groundwater quality monitoring been done in the proposed project area? Why are baseline water quality data for groundwater and a discussion of potential impacts from this recycled wastewater project not included in the Mitigated Negative Declaration for public review?

Air Quality
Page 26
4. Will the project "*Expose sensitive receptors to substantial pollutant concentrations?*"
("less than significant" box is checked.)
Discussion: "The proposed recycled water project would not generate substantial pollutant concentrations. Emissions from construction activities represent temporary impacts that are typically short in duration. Impacts to sensitive receptors would be less than significant."

Comment: The project alternatives have not been sufficiently evaluated according to the MND with regard to this question. Has soil testing been done in the project area for hexavalent chromium, mercury, lead, or other contaminants that may be present as a result of deposition from 100 years of cement plant operation? Has there ever been a soil study for hazardous waste dumping in the proposed project locations? Mitigations that may be appropriate for particulates are not necessarily sufficient when a carcinogen or other chemical contaminant is present.

HYDROLOGY, WATER SUPPLY, AND WATER QUALITY
page 59:
6. "Otherwise substantially degrade water quality?"
("less than significant" box is checked)
Comment: There is no evaluation in the MND of impacts of proposed recycled wastewater use on groundwater, streams or the sensitive coastal ocean environment. Baseline groundwater quality data is not provided and it is not clear whether it has been collected.

Page71/72: CEQA-Plus Evaluation
Environmental Justice: Does the project involve an activity that is likely to be of particular interest to or have particular impact upon minority, low-income, or indigenous populations, or tribes?

Comment: The project is likely to impact the health of field workers due to inadequate health regulation of recycled wastewater for agriculture. (Please see attached statement by Jude Todd.)
Following chlorination of the wastewater effluent, what level of de-chlorination is considered to be successful? Will de-chlorination be monitored, and if so how closely? Sufficient contact time with de-chlorination chemicals is necessary for effective de-chlorination. The high chlorination level stipulated in this proposal (5 mg/L, 90 minutes contact time) is likely to produce significant levels of disinfection byproducts such as halomethanes, haloacetic acids, halonitromethanes and chloramines at times. Some toxic disinfection byproducts are volatile and could present a health hazard to workers routinely exposed to recycled irrigation water. Current state regulations do not regulate disinfection byproducts, including carcinogenic compounds known to be present in some recycled wastewater used for agriculture. Also, as pointed out previously in this public comment, incomplete disinfection and/or pathogen regrowth during storage could lead to pathogen contamination, which in turn could lead to illness in those who come in contact with the recycled wastewater. These impacts to fieldworkers have not been considered in the MND.

Water quality impacts to farmlands:
There is no discussion in the MND of the potential short-term and long-term impacts of the change in water quality on valuable North Coast farmland if recycled wastewater from Davenport Sanitation District is

introduced, including potential impacts to soil and crops from variations in pH, chlorides, nitrates, miscellaneous residual chemicals that have not been evaluated, engineered nanoparticles, etc. including impacts to soil microbiology and crops. For example, according to recent operational data (the past 4 years) there appears to be the potential for unpredictable variations in total nitrogen, reported ammonia concentrations of 23-24 mg/L (Aug-Sept 2014; very little other ammonia data provided); ; pH varied between 9.1 and 7.3 in one quarter (April-June 2014). I also found very significant and obvious errors in reported high nitrate concentrations that, while demonstrated to be erroneous by supporting lab data leads to concerns about sufficient regulatory oversight of routine data reports.

Truck filling station:
How would inappropriate, unsafe uses of recycled wastewater outside the district be prevented? Was the greater Santa Cruz County area that would be impacted by recycled wastewater from this source area notified of the opportunity to comment on this MND?

Lagoon Dredging:
How will dredged solids from the lagoon be stored and disposed of? Are there data characterizing the solids for toxic chemical constituents, asbestos (e.g. from aging sewer system pipes), other hazardous particles, etc.? Clearly there is urgent need to dredge the treatment lagoon, but it must be done with due care and attention to hazardous wastes.

Based on the discussions above, more comprehensive public information on the current Davenport Sanitation District effluent quality and other information should be provided prior to further advancement of any alternatives in this proposal. The fact that the Cemex site may change hands, and the long process of site cleanup ahead certainly do not assure the public that sewage flows from the Cemex site will stop at any specific time in the near future. The lack of attention to the post-closure Cemex sewage flows from regulators inspires low public confidence that public health will be assured in a scenario of wastewater recycling by the district for food crops and landscapes where children play.

A list of all commercial and industrial wastewater accounts in the Davenport Sanitation District should be made available to the public, and any pre-treatment reports or activities are public information and should be made available as well.

Finally, when the final Davenport Recycled Water Study (feasibility report) is complete it should be made available to the public. Additional public comments should then be invited (since the feasibility study was not included in the MND), and a public hearing should take place before a decision is made on how to proceed with this project. I wish to be notified when this study and any additional reports supporting this project become available, and when a public hearing is scheduled.

Thank you for taking the time to consider my comments.

Submitted by,
Debra Wirkman

Attachment: Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz

cc:
Santa Cruz County Board of Supervisors
Sheila McDaniel

References

Centers For Disease Control Website: Effect of Chlorination on Inactivating Selected Pathogen, http://www.cdc.gov/safewater/effectiveness-on-pathogens.htm

Phase One and Limited Phase Two Environmental Site Assessment of Cemex Property (2/29/2012) Attachment 5, Notice of Intent to Adopt a Mitigated Negative Declaration, Davenport Recycled Water Project, Santa Cruz County, CA

Process Monitoring Data from Davenport Sanitation District 2011-2014, Santa Cruz County, public information obtained from public works staff

Todd, Jude. (2015) Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz. Unpublished ms.

Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz

I. INTRODUCTION

A. Purpose

Recycled wastewater use is growing rapidly in California and other western states, largely in response to drought-inspired worries about water supply security. Growing concerns about the impacts of wastewater pollution on receiving waters also factor into the water-reuse equation in many communities. This is true in Santa Cruz as we explore ways to fortify our water supply. But important questions need to be carefully considered and satisfactorily answered before adopting any uses of recycled municipal wastewater water here in Santa Cruz, including:

-- What else besides water do the various types of recycled wastewater contain?

-- What are the possible human and environmental health impacts of proposals to use recycled municipal wastewater that are being considered by the Water Supply Advisory Committee (WSAC)?

-- How should we go about discerning between safe, beneficial uses of recycled municipal wastewater and those that pose more risks than benefits to environmental and public health?

This statement, endorsed by People Against Unsafe Wastewater Reuse and other community members, aims to provide information for policymakers regarding these challenging questions. After discussing problems posed by "contaminants of emerging concern" (CECs) in recycled municipal wastewater, it reviews California State regulations and policy regarding recycled wastewater and examines the two categories of uses that seem particularly problematic (food-crop irrigation and potable reuse). It then briefly explores two more general categories (landscape irrigation and commercial/industrial uses) as including promising candidates for safe, appropriate application of recycled municipal wastewater.

B. Scope of Discussion

Recycled municipal wastewater refers to water that is treated and recycled from the sewer system -- not to greywater or other decentralized wastewater recycling systems. Santa Cruz municipal wastewater comes from sinks, tubs, floor drains, showers, and toilets in homes, business and industrial establishments, hospitals (both human and veterinary), and other institutions such as research laboratories, schools (including college and university science labs), assisted-living communities, long-term care facilities, and the county jail. The Santa Cruz wastewater treatment plant processes this sewer water from "the City of Santa Cruz and the Santa Cruz County Sanitation District (includes Live Oak, Capitola, Soquel and Aptos)" (City of Santa Cruz 2015).

Recycled municipal wastewater use is divided into four categories:

-- potable reuse (including both indirect potable reuse (IPR) and direct potable reuse (DPR))

-- agricultural irrigation

-- landscape irrigation (e.g., irrigation of parks, playgrounds, golf courses, cemeteries, and other landscapes)

-- commercial and industrial purposes (e.g., flushing commercial toilets, controlling dust on roads or streets, mixing concrete, and many other possible uses).

C. The Precautionary Principle

In all cases, our assessments are guided by the Precautionary Principle. While there are many versions of the Precautionary Principle, it has three commonly accepted components:

(1) Where there is reliable scientific evidence that a product or practice <u>may</u> cause serious harm to either humans or the environment, the product or practice should not be used unless or until there is proof of its safety.

(2) Those who advocate adopting the product or practice bear the burden of proof to demonstrate that it is safe <u>before</u> it is put on the market or adopted for use. This second component is important because so many products, including those made with endocrine-disrupting chemicals or engineered nanoparticles, have been unleashed into the environment without adequate safety testing, leaving it up to those who are concerned about public and environmental welfare to spend years appealing to the EPA, FDA, or other agencies to appropriately regulate the product.

(3) The Precautionary Principle also requires democratic public participation as well as full transparency on the part of governing agencies regarding scientific evidence that informs a policy decision.

II. CONTAMINANTS OF EMERGING CONCERN (CECs) IN RECYCLED MUNICIPAL WASTEWATER

Use of the Precautionary Principle is important because of increasing scientific evidence of contaminants heretofore unidentified in recycled wastewater that pose health concerns. These "contaminants of emerging concern" (CECs) in recycled municipal wastewater include personal care products, pharmaceuticals, industrial and agricultural chemicals, pathogenic agents, nanomaterials, and byproducts of any of the above that are not regulated but that are now known or strongly suspected to cause harm to either humans or wildlife. So, for example, DDT is not a contaminant of emerging concern because we already know that it is toxic. An itemized list of substances that scientific evidence indicates might be harmful in recycled wastewater would be too long to assemble, but characteristics of some types of CECs, including those that can disrupt endocrine systems, are summarized below to provide a brief documentation of the nature of that concern.

A. Number of Synthetic Chemicals

Over 100,000 synthetic chemicals have been registered in the U.S. including "more than 84,000 industrial chemicals, 9,000 food additives, 3,000 cosmetic ingredients, 1,000 pesticide active ingredients, and 3,000 pharmaceutical drugs" (Regional Monitoring 2013:49).

B. Trace Amounts of CECs Remain in Treated Municipal Wastewater

Currently, there is no wastewater treatment train, even those using reverse osmosis, that can remove all contaminants of emerging concern; **trace levels – i.e., amounts in the parts per billion or parts per trillion levels** -- of many CECs, including endocrine disruptors and an array of disinfection byproducts, **remain in the effluent** (Asano et al. 2007:113; see also WEF and AWWA 2008:1-6; Raghav et al. 2013:4,7; Schnoor 2014:12A).

C. Health Impacts of Endocrine Disruptors (EDs)

Our dependence on synthetic chemicals is problematic because, as endocrinologists and other independent scientists have shown, many such chemicals -- especially those that disrupt the endocrine systems of humans and other animals – are implicated in the etiology of diseases that now plague people all over the planet. As the term suggests, endocrine disruptors (EDs) can impact all the complex and delicate endocrine systems, including the pituitary gland, hypothalamus, thyroid, cardiovascular system, mammary glands, pancreas, ovaries, uterus, prostate, and testes, as well as the brain and adipose (fat) tissue (Diamanti-Kandarakis et al. 2009:4). EDs can impact an organism by either mimicking or antagonizing (or sometimes both) the animal's innate hormones, thus binding with hormone receptors. So, e.g., an ED that mimics estrogen can interfere with the functioning of both male and female reproductive organs; an ED that mimics insulin can throw off the delicate balance maintained by the pancreas; an ED that mimics or antagonizes thyroxin can unbalance the thyroid.

But mimicking or antagonizing endogenous hormones[1] is not the only mode of action for EDs; as Linda Birnbaum, the toxicologist who heads up both the National Toxicology Program and the National Institute of Environmental Health Services, explained in a recent interview, **an ED is "anything that affects the synthesis of a hormone, the breakdown of a hormone or how the hormone functions.** We

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[1] "Endogenous hormones" are those produced within an organism. Exogenous hormones are those produced outside the organism itself.

used to think it had to bind with a hormone receptor but endocrine disruptors can perturb hormone action at other stages in the process" (qtd. in Borrell 2012, emphasis added). Such perturbations in hormone function can have wide-ranging impacts on our bodies. As the Environmental Working Group, an independent health research organization, explains:

> There is no end to the tricks that endocrine disruptors can play on our bodies: increasing production of certain hormones; decreasing production of others; imitating hormones; turning one hormone into another; interfering with hormone signaling; telling cells to die prematurely; competing with essential nutrients; binding to essential hormones; accumulating in organs that produce hormones. (Environmental Working Group 2013)

Given this list of ways that EDs can stymie our normal bodily functions, we can begin to see how they can precipitate childhood leukemia and other cancers, allergies, asthma and other respiratory problems, genital malformations in baby boys, early puberty in girls, ADHD, lowered IQ, autism, obesity, diabetes, cardio-pulmonary diseases, immune-system dysfunction, and Parkinsonism; evidence is mounting that endocrine disruptors may also play a role in development of Alzheimer's disease and other mental illnesses (Alonso-Magdalena 2006; Grandjean et al. 2007; Diamanti-Kandarakis et al. 2009; Birnbaum 2010; Burkardt-Holm 2010; Landrigan 2010; Soto and Sonnenschein 2010; Karoutsou and Polymeris 2012; Sargis et al. 2012; Weiss 2012; Zoeller et al. 2012; Birnbaum 2013; Carpenter 2013; Welshons 2013; Blaszczak-Boxe 2014; Grandjean and Landrigan 2014; Hamblin 2014; Richardson et al. 2014; Schiffer et al. 2014; Bellanger et al. 2015; Konkel 2014a,b, 2015; Genuis and Kelln 2015; Grossman 2015; Scutti 2015; Trasande et al. 2015).

D. Trace Quantities of Endocrine Disruptors and the Developmental Basis of Disease

Endocrine disruptors in only trace amounts -- the same amounts present in recycled sewer water -- are especially dangerous for fetuses, infants, and small children. As American Water Resources Association researchers David Norris and Alan Vajda write in their article "Endocrine Active Chemicals (EACs) in Wastewater: Effects on Health of Wildlife and Humans," **"...ample evidence of endocrine disruption of reproduction related to nano-quantities (parts per billion and parts per trillion) of human-based xenoestrogens in wastewater effluents appeared in the late 1980s and early 1990s"** (Norris and Vajda 2007:15, emphasis added).[2] Since that time, evidence of the impacts of EDs on health of both wildlife and humans has grown substantially.

Those health impacts are more likely when the organism is exposed to the ED during the early stages of development. Illnesses triggered by chemicals during those vulnerable formative years are often irreversible (Zoeller et al. 2012:4101). When present in the body of a pregnant woman, endocrine disruptors can be passed on via the placenta to the fetus and via breast milk to the infant. Maternal transmission of EDs is particularly important because, as explained in the Endocrine Society's comprehensive review and analysis, *Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement,* the age at which one is exposed to these chemicals can make the health impacts more or less significant, and fetal and early postnatal-infant stages are developmental periods when mammals are most vulnerable (Diamanti-Kandarakis et al. 2009). The brain and nervous system, immune system, reproductive system, heart, lungs, and all other crucial organs are being developed at those times; **illnesses due to malfunction of those systems and organs that are precipitated during those early months and years may not become apparent until years or even decades later** (Diamanti-Kandarakis et al. 2009:3; see also Colborn, vom Saal, and Soto 1993; Colborn 1997, 2004a; Shapley 2009; Burkhardt-Holm 2010; Landrigan and Goldman 2011; Zoeller et al. 2012; Braun 2014; Williams 2013/2014; Grandjean and Landrigan 2014; Whyatt et al. 2014).

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[2] The analogy commonly used to illustrate one "part per trillion," or one nanogram per liter, is that it is like one drop of water diluted into 20 Olympic-sized swimming pools. "Xenoestrogens" are chemical compounds, such as those in some pesticides, drugs, and industrial products like plasticizers, that mimic estrogen and can thus disrupt the endocrine system.

Among the many scientific articles demonstrating greater susceptibility to endocrine disruptors by fetuses and children is Philip J. Landrigan and Lynn R. Goldman's (2011) study, "Children's Vulnerability to Toxic Chemicals: A Challenge and Opportunity to Strengthen Health and Environmental Policy." Landrigan, a pediatrician and epidemiologist, is dean of global health and a professor of preventive medicine and pediatrics at the Mount Sinai School of Medicine; Goldman is dean of the School of Public Health and professor of environmental and occupational health at George Washington University. Their review article on this topic explains that children are more susceptible than adults to health impairments from chemical exposure for four reasons:

> First, children have greater exposures to toxic chemicals for their body weight than adults. **A six-month-old infant drinks seven times more water per pound than an adult**....Children's hand-to-mouth behavior and play on the ground further magnify their exposures.
>
> Second, children's metabolic pathways are immature, and a child's ability to metabolize toxic chemicals is different from an adult's.... **[Children] lack the enzymes needed to break down and remove toxic chemicals from the body.**
>
> Third, children's early developmental processes are easily disrupted. Rapid, complex, and highly choreographed development takes place in prenatal life and in the first years after birth... In the brain, for example, billions of cells must form, move to their assigned positions, and establish trillions of precise interconnections....[3] **[Exposures to chemicals during crucial "windows of vulnerability"] can disrupt organ formation and cause lifelong functional impairments....**
>
> Fourth, children have more time than adults to develop chronic diseases. **Many diseases triggered by toxic chemicals, such as cancer and neurodegenerative diseases [including dyslexia, mental retardation, attention deficit hyperactivity disorder [ADHD], and autism],...evolve through multistage, multiyear processes that may be initiated by exposures in infancy [or in utero].** (Landrigan and Goldman 2011:843, emphasis added)

Chemical-induced diseases set in motion during gestation or infancy often do not show up until years or even decades after exposure. **This "long delay between the time point of exposure and measurable effects" makes tracing causative factors for particular instances of cancer, Parkinsonism, Alzheimer's Disease, or other diseases that appear in later years very challenging** (Burkhardt-Holm 2010, emphasis added).

E. Transgenerational Epigenetic Inheritance of Disease

The long delay between exposure to harmful chemicals and their health consequences is turning out to be even longer than once thought. **Research in the last couple of decades has indicated that in some instances harms inflicted by endocrine disruptors and some other chemicals may be passed on to subsequent generations via a process known as transgenerational epigenetic inheritance** (Edwards and Myers 2007; Grandjean et al. 2007; Diamanti-Kandarakis et al. 2009:4,7-8; Burkhardt-Holm 2010:484-487; Birnbaum 2010; Daughton 2010:54-55; Birnbaum and Jung 2011; Francis 2011; Guerrero-Bosagna and Skinner 2012; Martin 2013; Head 2014; Tollefsbol 2014).

The concept of transgenerational epigenetic inheritance can seem puzzling at first, but it is not as strange as it might initially seem. We are familiar with the "nature vs. nurture" debate, which most scientists readily resolve by saying that health is a result of both nature (our genes) and nurture (factors in

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[3] As Lauren K. Wolff (2014), writing for the *Chemical and Engineering News*, explains, "**Nerve cells** grow and connect, sometimes **forming 40,000 new junctures [synapses] per second, until a baby reaches about two years of age**" (Wolff 2014, emphasis added).

our environment). Most people would likely agree that environmental influences (e.g., diet, exercise, exposure to toxic substances) interact with genetics to influence health.[4] The term "epigenetics" refers to those environmental factors – factors outside the genome itself -- that influence gene expression without causing a genetic mutation. Sometimes those environmental factors, particularly exposure to chemicals such as endocrine disruptors, can result in "methylation" of one or more genes, and that, in turn, influences gene expression. Methylation is a chemical reaction in which a carbon atom and three hydrogen atoms, known in organic chemistry as a methyl group, attach to a molecule. Gene methylation is one of several epigenetic mechanisms by which exposure to endocrine disruptors and other chemicals can alter genetic expression, sometimes resulting in disease or diminished capacity.

"Transgenerational epigenetics" – the newer and more surprising concept -- refers to heritable changes in gene expression that are not due to a mutation. As Jessica Head, with the University of Michigan School of Natural Resources and Environment in Ann Arbor, explains:

> Epigenetics is not a newly discovered phenomenon; we have known about the role of DNA methylation in regulating gene expression for over 35 years.... What is new is our developing epigenetic perspective on how early life experiences can have lasting impacts on health that may even be inherited by future generations.... **With epigenetic modes of action, level of exposure to contaminants, intermediary sub-clinical responses, and the overt toxic response may be temporarily separated throughout an individual's lifetime, or even between generations, a possibility that most risk assessment does not take into account.** (Head 2014:83-84, emphasis added)

Linda Birnbaum, Director of the National Institute of Environmental Health Sciences (NIEHS) and National Toxicology Program, shares Head's concern about the shortfall of risk assessment and outdated toxicological methods in evaluating the ways that endocrine disruptors and other synthetic chemicals can impact health (Birnbaum 2010). Birnbaum and her colleague Paul Jung, chief of staff at NIEHS, explain transgenerational epigenetics as follows:

> ...we're born with our genes, but epigenetic changes occur because of environmental influences during development and throughout life. Epigenetics thus provides a measurable "imprint" on DNA expression that may be useful as a biomarker for disease susceptibility. And these imprints can be carried and expressed across generations. (Birnbaum and Jung 2011:818)

It would thus seem advisable for people considering the possible health impacts of trace amounts of drugs and other chemicals in recycled wastewater to attend to epigenetics, but the topic is rarely addressed in the water-reuse literature.

One exception is the comprehensive review study by C. G. Daughton (2010), "Pharmaceutical Ingredients in Drinking Water: Overview of Occurrence and Significance of Human Exposure." Daughton, who is the U.S. EPA Chief of the Environmental Chemistry Branch at the National Exposure Research Laboratory, explains epigenetics as follows:

> Unlike the genome, the epigenome is plastic, dynamic, extraordinarily complex, and varies across tissues and individuals.... **[E]pigenetic alterations can accumulate, resulting in delayed-onset outcomes that can persist long after exposure has ceased – even across several generations**. (Daughton 2010:54, emphasis added)

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[4] Stephen Rappaport and Martyn Smith, with the UC Berkeley School of Public Health, sum up the relative proportion of chronic disease attributable to genes vs. environment as follows: "Although the risks of developing chronic diseases are attributed to both genetic and environmental factors, 70 to 90% of disease risks are probably due to differences in environments" (Rappoprt and Smith 2012:460).

Daughton also comments on the dearth of attention to the health implications of epigenetics when considering drugs as drinking-water contaminants:

> Given the thousands of publications devoted to APIs [active pharmaceutical ingredients] as environmental pollutants, few address the possible role of epigenetics in human (or even aquatic) health. Epigenetics has been mentioned only in passing in perhaps a dozen or so of the thousands of published works; most of these have been published since 2006. (Daughton 2010:54)

Transgenerational epigenetic effects of trace pharmaceuticals and other chemicals of emerging concern in recycled municipal wastewater should be receiving – but, to date, have not received – serious attention from both the water-reuse industry and its regulators.

F. Nonmonotonicity and Lack of a Threshold Dose

While most synthetic chemicals remaining in the effluent of state-of-the art treatment plants may be present only in "trace" amounts (parts per billion or parts per trillion), such low doses do not protect people or other animals who drink or bathe in it. As we've seen, chemicals that can disrupt endocrine systems are bioactive in the parts per billion or parts per trillion levels, and in some cases even less (Norris and Vajda 2007:15; Myers and Hessler 2007:3; Vandenberg et al. 2012; Welshons 2013). As surprising as this may seem, there is abundant scientific evidence demonstrating that endocrine disruptors can be even more harmful in miniscule amounts than in slightly larger amounts, depending on the target organism and age at time of contact with the chemical; this phenomenon, known as nonmonotonicity, is evidenced by the chemical's nonmonotonic dosage-response curve (Sheehan 2006; Myers and Hessler 2007; Diamanti-Kandarakis et al. 2009:4; Fagin 2012; Schettler et al. 2012; Vandenberg et al. 2012; Welshons 2013; Birnbaum and Jung 2014:816-818; Vandenberg 2014).

Nonmonotonicity seems counter-intuitive. Traditional toxicologists and the regulators whom they advise tend to operate according to the more "common sense" maxim, coined by Paracelsus, the 16th-century Father of Toxicology, that "The dose makes the poison." However, endocrinologists and other independent scientists in the 20th and 21st centuries have shown that this "common sense" maxim does not always hold true. In their article, "Does 'The Dose Make the Poison?' Extensive Results Challenge a Core Assumption in Toxicology," Myers and Hessler (2007) explain that some chemicals, including endocrine disruptors,

> ...cause different effects at different levels, including impacts at low levels that do not occur at high doses.... **Because all regulatory testing has been designed assuming that 'the dose makes the poison,' it is highly likely to have missed low dose effects, and led to *health standards that are too weak*.** (Myers and Hessler 2007:1, emphasis added)

In fact, there may be no "threshold dose" (an amount below which the chemical causes no harm) for some chemicals, especially for fetuses, infants, and children, as explained in the preceding section (Sheehan 2006; Grandjean et al. 2007; Vandenberg, Zoeller, and Myers 2012; Zoeller 2012; Birnbaum and Jung 2014:817-818).

Laura Vandenberg, PhD, molecular and developmental biologist with the Center for Regenerative and Developmental Biology, Tufts University, and eleven other independent scientists whose research has demonstrated nonmonotonicity conclude their review of the topic with the following assessment:

> We understand that [our findings of nonmonotonic dosage-response curves for endocrine-disrupting chemicals] challenge risk assessment dogma, but **society's tendency to maintain the *status quo* is insufficient as an argument to rebut scientific data**.... [T]here is...much evidence within the field of endocrinology to support the interpretation that low doses exert adverse effects

> on the human population. **Data must trump theories, hypotheses, models and assumptions, and not the reverse.** (Vandenberg et al. 2012:16, emphasis added)

In other words, ideologies or other cherished beliefs -- whether that belief is that "the dose makes the poison" or that "only genetic information can be passed on to future generations" -- should be trumped by scientific evidence produced by independent researchers, particularly when public health is at stake.

G. Mixture Effects

Chemicals that mix together in sewer water can interact with one another unpredictably; the **effects of mixing several chemicals** that have a similar physiological effect (e.g., estrogenic) can be **additive, antagonistic,** or **synergistic** (Rajapaske, Silva, and Kortenkamp 2002). Andreas Kortenkamp, with the School of Pharmacy at the University of London, has been studying the problem of mixture effects, particularly in estrogenic chemicals, for many years. He explains that, "In toxicology, 'additivity' describes the case in which chemicals 'act together' to produce effects without enhancing or diminishing each other's action..." (Kortenkamp 2007:98). "Synergism" refers to effects greater than additive, while antagonistic effects are those that are less than additive (Kortenkamp 2007:99).

The numbers of chemicals in sewer water at any given time that can potentially interact with each other (out of the possible tens of thousands) are incalculable. What happens when the innumerable drugs and other chemicals discharged from hospitals, industries, residences, veterinary clinics, long-term-care facilities, or chem labs bump up against each other in sewers? What are the physiological effects on humans and wildlife of these chemical mixtures? Insufficient research has been done to address such vexing questions, but the research that has been done demonstrates that chemicals – even those that pose little or no threat individually – can be more hazardous when mixed with other chemicals (Yang 1994; Biello 2006; Sheehan 2006; Kortenkamp 2007, 2008; Backhaus, Sumpter, and Blanck 2008; Diamanti-Kandarakis et al. 2009; Payne-Sturges et al. 2009; Birnbaum and Jung 2011).

Traditional toxicological methods used to develop "maximum contaminant levels" (MCLs) for regulatory purposes **ignore these mixture effects, relying instead on animal tests of one chemical at a time.** Studying antibiotics in wastewater treatment plants, Sungpyo Kim and Diana S. Aga, chemists at the State University of New York at Buffalo, note:

> Although a few environmental risk assessment studies suggest that the levels of pharmaceuticals in the environment, including antibiotics, are not a major threat to human health...,**the chronic effects of mixtures of these microcontaminants remain unknown. Typical health risk calculations are based on a single drug exposure in a lifetime. The synergistic and antagonistic effects of pharmaceutical mixtures on human[s] and ecology cannot be ruled out, and need to be addressed in risk assessment.** For instance, it was demonstrated that a mixture of ibuprofen, prozac, and ciprofloxacin produced 10- to 200-fold higher toxicity in plankton, aquatic plants, and fish .... These results imply that a more sophisticated approach for the risk assessment of antibiotics... might be necessary to obtain a more accurate assessment of health and ecological risks associated with antibiotics in the environment. (Kim and Aga 2007:568-570, emphasis added)

Research done by endocrinologists, chemists, and many other independent scientists who have considered this issue indicates the need for "a more sophisticated approach for the risk assessment" not only for drugs but also for personal care products, pesticides, and industrial chemicals that find their way into sewer water, small amounts of which can remain in treatment plants' effluent.

H. Drug Metabolites and Transformation Byproducts

Some consumed drugs may pass through our bodies into sewers largely unchanged. For example, "Most antibiotics are poorly metabolized after administration.... Thus, relatively high fractions of the drug are excreted" (Jjemba 2008:172). However, many other drugs create ***metabolic byproducts*** after consumption, further complicating risk assessment of chemicals – and chemical mixtures – in recycled municipal wastewater. For example, the anticonvulsant drug carbamazepine is often found in wastewater treatment effluents, though its several metabolites are usually not included in assessments of wastewater plant efficacy. One exception is the study by Miao et al. (2005), which examined wastewater samples for caffeine, carbamazepine, and five of its known 33 metabolites, at least one of which "has been shown to possess similar anti-epileptic properties [to carbamazepine], and it may cause neurotoxic effects" (Miao et al. 2005:7470; see also La Farre et al. 2008). The authors found the treatment process to be effective in removing caffeine but not in removing the carbamazepine metabolites (Miao et al. 2005:7474). This result is significant because **if a treatment plant's efficacy is assessed looking only for the original drug and not its metabolites, then the analysis could overestimate the plant's treatment efficacy.**

Complicating matters further, "some excreted metabolites can also be transformed back into the parent compound" (Jjemba 2008:172; see also Escher and Fenner 2011). A recent study by Qu et al. (2013) on metabolites of the steroid trenbolone indicates that some drugs are transformed into other compounds by light but then revert to the parent drug in darkness. That study, "Product-to-Parent Reversion of Trenbolone: Unrecognized Risks for Endocrine Disruption," found that, while light breaks down trenbolone (TBA) metabolites, the **phototransformation products re-convert to the parent compounds in dark conditions;** this process "results in the enhanced persistence of TBA metabolites via a dynamic exposure regime that defies current fate models and ecotoxicology study designs" (Qu et al. 2013:350). The authors explain the implications:

> This product-to-parent reversion mechanism results in diurnal cycling and substantial regeneration of TBA metabolites at rates that are strongly temperature- and pH-dependent. Photoproducts can also react to produce structural analogs of TBA metabolites. **These reactions also occur in structurally similar steroids, including human pharmaceuticals, which suggests that predictive fate models and regulatory risk assessment paradigms must account for transformation products of high-risk environmental contaminants such as endocrine-disrupting steroids.** (Qu et al. 2013:347, emphasis added)

The ability of some endocrine disruptors' transformation products to revert to the original chemical in darkness has implications for proposals to inject treated wastewater into aquifers. If testing for these revertible chemicals were done only under light conditions, that could lead to erroneous conclusions about the amount of drugs being introduced into aquifers, which are pretty dark places.

Similar studies need to be undertaken for a wide range of pharmaceuticals that may remain even in trace amounts in recycled municipal wastewater, which contains every type of drug taken by people in the community: statins, beta blockers, antidepressants, radiotherapeutic agents, sedatives, bronchodilators, antibiotics, diuretics, cytotoxic cancer drugs, anti-psychotics, analgesics, narcotics, drugs to facilitate gender changes, drugs to address erectile dysfunction, "recreational" drugs, etc. Some research has been done on transformation byproducts of X-ray contrast media (Schulz et al. 2008; Kormos, Schultz, and Ternes 2011). Chemotherapeutic cancer drugs have also received some attention (Kosjek and Heath 2011; Zhang et al. 2013).

Other chemicals besides drugs also undergo changes during wastewater treatment (Cwiertny et al. 2014; Ortiz de Garcia et al. 2014). While not much is known about the fate of chemical transformation byproducts in wastewater treatment plants, enough is known to conclude that this phenomenon contributes in important ways to the problem of mixture effects discussed in Section G above. But this area of metabolites and transformation byproducts needs more research – and much more attention from the water-reuse industry and the agencies that regulate it.

I. Engineered Nanoparticles

Unimaginable numbers of engineered nanoparticles, particles with at least one dimension smaller than 100 nanometers, are present in our sewer water. Without regulation by the EPA or any other regulatory agency, the use of nanoparticles – especially the antibiotic nanosilver -- has spread widely and rapidly. Engineered nanoparticles are now used in some personal care products (e.g., toothpaste, sunscreens, baby wipes), clothing (e.g., socks, shoe insoles, underwear), kitchen utensils (e.g., knives, cutting boards, ceramic-coated pots and pans), and other products. When those products are washed, nanoparticles can get flushed down drains into sewers. Nanoparticles are also used in drugs and even in diet drinks, allowing them to be excreted into sewers (Reed et al. 2014).

Furthermore, some washing machines use nanosilver to eliminate mold. One such washer, made by Samsung, releases 100 quadrillion silver nanoparticles (that's 100,000,000,000,000,000 of them) into sewers with each wash (Feder 2007).

Engineered nanoparticles, another contaminant of emerging concern, pose a problem for potable reuse of sewer water because they are potentially harmful to humans (Gwinn and Vallyathan 2006; Birnbaum and Jung 2011; Abbott Chalew and Schwab 2013), and their presence in the effluent of wastewater treatment plants has **not been adequately studied.** Consequently, we do not know the extent to which various treatment trains remove nanoparticles. As R. Rhodes Trussell et al. (2013) write in *Potable Reuse: State of the Science Report and Equivalency Criteria for Treatment Trains*, "only a limited number of studies have been performed in this research area, but the preliminary data indicate that this may be an important issue to consider in potable reuse applications" (39). Trussell and colleagues express concern about the type of washing machine discussed above, as well as other sources of nanoparticles in sewer water, and they acknowledge the "potential for nanoparticles to persist through [advanced wastewater treatment] trains" (39). They conclude that "There is currently little evidence to determine whether nanoparticles pose a significant public health threat in potable reuse applications. The reuse community would be wise to keep a watchful eye on this issue in the future" (Trussell et al. (2013:39).

Bottom line: Given the inadequate study of the health effects of drinking and bathing with recycled municipal wastewater that may contain unknown numbers of nanoparticles, EDs, and other CECs; studies that suggest harmful effects of many CECs on human health; and the absence of evidence that any wastewater treatment train can effectively remove these contaminants to levels that are safe for fetuses, infants, and children,[5] the Precautionary Principle requires that we in Santa Cruz not use recycled municipal wastewater for drinking or bathing.

III. STATE REGULATIONS AND POLICY REGARDING RECYCLED WASTEWATER

Given the known presence of trace amounts of chemical contaminants in even the most advanced municipal wastewater treatment systems as discussed above and the scientific evidence of potentially serious health impacts, how is it possible that the State permits potable reuse of such water? And how is it possible that less thoroughly treated sewer water can be used to irrigate food crops, including organic produce? As briefly explained below, the State overlooked sound scientific evidence when they wrote

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[5] This caution also applies regarding members of other "sensitive populations" not addressed here, including the elderly, people who are chemically sensitive, girls going through puberty, and people in ill health.

Title 22 regulations for non-potable reuse and again when they formulated the 2013 *Recycled Water Policy*, which addresses indirect potable reuse (IPR) via aquifer recharge. This section also explains why Governor Brown's efforts to fast-track regulations for direct potable reuse (DPR) appear likely to repeat the State's history of ignoring important scientific evidence regarding the potential health effects of emerging contaminants in recycled municipal wastewater.

A. Title 22 Regulation of Recycled Wastewater for Food-Crop Irrigation

There are no federal regulations of recycled municipal wastewater. That task is left up to the states. Here, non-potable uses of recycled sewer water are governed by "Title 22: California Recycling Criteria." Title 22 governs irrigation for all agricultural purposes, including ornamental plants, pasture for milk animals, fodder and fiber crops for animals, etc. This paper focuses on the portions of Title 22 that regulate food-crop irrigation.

Title 22 permits irrigating food crops, including organic crops, with either secondary- or tertiary-treated recycled wastewater, depending upon the type of crop and the method of irrigation. The Precautionary Principle rules out irrigating food crops with recycled sewer water for the following reasons:

1. Uptake of Chemicals

Both secondary- and tertiary-treated wastewater contain small amounts of synthetic chemicals, including endocrine disruptors. It is well known that plants can and do take various synthetic chemicals up into their roots, stems, leaves, and fruits (Schneider 2008; Calderon-Preciado, Matamoros, and Bayona 2011; Malchi et al. 2014). When children and adults, including pregnant women, eat the plants, they would also ingest small amounts of these potentially harmful chemicals. As noted above, endocrine disruptors are especially hazardous for fetuses, infants, and small children. Such risk of serious harm to future generations is unacceptable; instead, farmers could use drip irrigation and employ other conservation methods, including considering crop choices that make sense in a drought-prone region.

2. Engineered Nanoparticles

Both secondary- and tertiary-treated wastewater would also likely contain high quantities of engineered nanoparticles, including antimicrobials such as nanosilver, which is known to harm soil organisms and suspected of causing health problems for higher animals, including humans (Navarro et al. 2008; Gajjar et al. 2009; Birnbaum and Jung 2011; Abbot Chalew and Schwab 2013).

3. Antibiotic Resistance Genes

It is well known that antibiotic-resistant bacteria (ARB), such as methicillin-resistant *Staphylococcus aureus* (MRSA) -- which alone kills about 19,000 people in the U.S. annually – are on the rise and pose a serious health threat, particularly in hospitals (Krasner et al. 2006). Such dangerous bacteria are killed by disinfectants, including those used in hospitals and homes as well as chlorine and all other types of wastewater disinfection. Disinfection of recycled sewer water is, of course, essential. However, researchers have now demonstrated that killing the ARB permits the bacteria's antibiotic-resistance genes (ARGs) to be released into the wastewater. By a process known as ***horizontal gene transfer***, these ARGs can be taken up by other living bacteria, causing those bacteria to become antibiotic resistant (Jjemba 2008:171-179; Dodd 2012; McKinney and Pruden 2012; Fahrenfeld et al. 2013; Fatta-Kasinos and Michael 2013; Pruden et al. 2013; Hong et al. 2014; Mole 2014). Consequently, wastewater disinfection, which leads to production of "approximately 600-700" chemical byproducts (Krasner et al. 2006), also contributes to the spread of antibiotic resistance. As medical geo-hydrologist Edo McGowan, M.D., explains, "Pathogens that in nature might never get together for gene exchange are thrust into each other in a sewer plant" (McGowan, posted in Olena 2013).

In his December 2010 comments to the SWRCB regarding CEC monitoring for recycled wastewater, McGowan explains at length how horizontal transfer of ARGs into the human intestine can result in development of antibiotic resistance, why this is dangerous, and why the source of the problem would be untraceable (California State Water Recourses Control Board 2011).

4. Title 22 Regulations of Non-Potable Reuse Ignore Important Scientific Evidence

How is it possible that food-crop irrigation is this fraught with problems? One might assume that California regulations would be sufficiently protective. However, those regulations do not take into account scientific evidence available at the time.

In the year 2000, when the Title 22 regulations of recycled wastewater were put in place, synthetic chemicals were disregarded, even though prior to that year, there was already reliable scientific evidence that endocrine disruptors (EDs) can harm wildlife and can lead to an array of serious illnesses in humans, including infertility, genital abnormalities, breast cancer, and other health problems, as discussed earlier (Colborn, vom Saal, and Soto 1993; Jobling 1996; Sharpe et al. 1996; Kelce and Wilson 1997; Daugton and Ternes 1999).

As noted earlier, Norris and Vajda (2007) have pointed out that there was already "ample evidence of endocrine disruption of reproduction related to nano-quantities (parts per billion and parts per trillion) of human-based xenoextrogens in wastewater effluents... in the late 1980s and early 1990s" (Norris and Vajda 2007:15, emphasis added). A study by Bitman and Cecil (1970) on polychlorinated biphenols and chemicals like DDT demonstrated estrogenic activity even three decades prior to enactment of Title 22's regulations of recycled wastewater.

Although Title 22 permits use of recycled wastewater on food crops, prior to enactment of the recycled wastewater regulation, it was already known that plants can take synthetic chemicals up into their roots, stems, leaves, and fruits (Briggs, Bromilow, and Evans 1982; Ryan et al. 1988; Hsu, Marxmiller, and Yang 1990; Paterson et al. 1990; Simonich and Hites 1995; Sicbaldi et al. 1997; Burken and Schnoor 1998; Wilson 1998).

The fact that chemical mixtures can have additive, antagonistic, or synergistic effects, as discussed earlier, was also known prior to enactment of recycled wastewater regulations in Title 22 -- even as early as 1939 (Bliss 1939; Calabrese 1991; Yang 1994).

Even the fact that some endocrine disruptors have nonmonotonic dosage-response curves was also recognized prior to enactment of the Title 22 regulations of recycled wastewater (Mehendale 1994; Svendsgaard and Hertzbert 1994; vom Sal and Sheehan 1998; Nawaz et al. 1999).

Bottom line: California Title 22 regulations for non-potable reuse of recycled wastewater are inadequate to protect the health of both humans and other organisms because regulators ignored sound science that warned about health impacts of endocrine disruptors and other contaminants of emerging concern. The potential for irrigation with treated wastewater to spread antibiotic resistance has come to light more recently, as have problems with nanoparticles, adding to the concerns about this practice, especially in irrigation of food crops.

B. Recycled Municipal Wastewater for Potable Reuse

Potable reuse of wastewater is divided into two types: indirect and direct. While exact definitions vary, currently in California, **indirect potable reuse (IPR)** refers to treated municipal wastewater that is sent to an aquifer, either by direct injection or by surface spreading.[6] The recycled wastewater gradually mixes with the rest of the water in the aquifer; it is subsequently drawn out and processed in the drinking-water treatment plant before being sent to people's taps. **Direct potable reuse (DPR)**, which is not yet permitted in California, refers to treated wastewater that is sent from an advanced wastewater treatment facility directly to either the municipal water treatment plant (where it undergoes the usual treatment for drinking water) or directly into the distribution system that supplies tap water. In either scenario, DPR differs from IPR in that there is no intermediate step where the treated water is first put into an aquifer.

There are no federal regulations of recycled municipal wastewater for potable reuse. However, drinking water is federally regulated via the Safe Drinking Water Act. The State of California has somewhat stricter drinking-water standards than the federal government requires. The combined Federal and State regulation of potable reuse are inadequate to protect public health. The number of synthetic chemicals regulated under the Federal Safe Drinking Water Act plus those added to the list by the California EPA add up to just 60, plus an additional 11 disinfection byproducts (California Department of Health 2014). That still leaves about 100,000 other man-made chemicals unregulated, and thus largely untested, in drinking-water treatment plants.[7] **When recycled wastewater advocates assert that a treatment plant's effluent "meets or exceeds" all Federal and State drinking-water requirements, the claim may sound reassuring, but it is hollow.**

C. State Policy Regarding Indirect Potable Reuse

Thirteen years after the Title 22 regulations of non-potable reuse were enacted, the State Water Resources Control Board (SWRCB) published its ***Policy for Water Quality Control for Recycled Water (Recycled Water Policy), 2013***. This policy, intended to "streamline" the permitting process for non-potable uses as well as for indirect potable reuse (IPR), purports to address the chemical contamination of recycled wastewater. However, this 2013 policy, like the Title 22 regulations before it, fails to adequately protect environmental and public health.

In spite of scientific evidence of potential harms to humans and other organisms posed by CECs, the 2013 *Recycled Water Policy* permits recycled wastewater for indirect potable reuse with minimal monitoring of CECs to indicate treatment-plant efficacy. That policy requires monitoring **only eight chemicals out of the tens of thousands** of the drugs, personal care products, food additives, pesticides, industrial chemicals, disinfection byproducts, and household chemicals that may be present in tertiary-treated wastewater used to replenish aquifers by surface spreading. For advance-treated wastewater using reverse osmosis, **only six** of those chemicals must be monitored for direct injection into aquifers.

Like the Title 22 regulations described earlier, this 2013 policy still relies on **traditional approaches to toxicology:** test one chemical at a time on lab animals, looking for acute toxic reactions, then reduce the dosage downward with each round of testing to the point where the "no observable adverse effect level" (NOAEL) is found; then extrapolate from those animal studies, using "uncertainty factors," to determine the "safe" dosage for humans.

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[6] At this time, the State has no regulations for IPR involving a reservoir rather than an aquifer, although the City of San Diego was permitted by the CDPH to test this alternative in a demonstration plant using microfiltration, RO, UV, and hydrogen peroxide (Gerrity et al. 2013:332). Regulations for reservoir augmentation with treated municipal wastewater may be developed pending the 2016 recommendations of an expert panel (California State Water Resources Control Board 2014).

[7] EPA and other government agencies have some programs for occasional additional testing of drinking water and sources for some other contaminants such as EPA's Contaminant Candidate List Program http://www2.epa.gov/ccl/basic-information-ccl-and-regulatory-determination and the USDA Pesticide Data Program, which studied the Santa Cruz municipal water system in 2012-2013.

-- This **traditional toxicological** approach:

-- **ignores additive, antagonistic, and synergistic mixture effects;**

-- **ignores epigenetic transgenerational inheritance**;

-- **ignores nonmonotonic dose-response curves;**

-- **ignores** the corollary **that there often is no threshold dose for EDs and some other chemicals**;

-- **ignores scientists' warnings that ingesting trace amounts (parts per trillion or even less) of EDs and other CECs can have serious health consequences, especially for fetuses, infants, and children**.

This neglect of substantial bodies of scientific evidence regarding the characteristics and potential health impacts of endocrine disruptors and other CECs raises the question: Why would the State set aside scientific evidence in formulating the 2013 *Recycled Water Policy*?

One answer is that the State Water Resources Control Board gave too much credence to the report of six "blue ribbon" panelists who were appointed in 2009 by the Southern California Coastal Water Research Project to advise the SWRCB on how to address CECs in recycled wastewater (Anderson et al. 2010). The only expert in human toxicology on that panel, Paul Anderson, a traditional toxicologist, had co-authored at least three industry-funded, industry-informed studies concluding that there are no health concerns from pharmaceuticals in drinking water (Schwab et al. 2005; Hannah et al. 2009; Caldwell et al. 2010). At the time of his appointment to the "blue ribbon" panel, Anderson was also employed by ARCADIS U.S., a southern-California company that sells water-reuse services and technologies (ARCADIS U.S. 2014). This apparent **conflict of interest** was overlooked by the SWRCB.

The "blue ribbon" panel's guidelines recommend monitoring just eight indicator chemicals for tertiary-treated recycled wastewater that would be surface-spread to replenish aquifers. Those eight indicators for monitoring chemicals in wastewater used in surface application for groundwater recharge are N-nitrosodimethylalamine (NDMA, a disinfection byproduct), 17beta-estradiol, caffeine, triclosan, DEET, gemfibrozil, iopromide, and sucralose (Anderson et al. 2010:66). For advance-treated wastewater directly injected into aquifers, the two pharmaceuticals, gemfibrozil and iopromide, were removed from the list of indicator chemicals, leaving only six indicators for subsurface injection of treated sewer water into aquifers.

Prior to the State's acceptance of the expert panel's recommendations, the list of indicators was questioned by Dr. Andrew Eaton, Technical Director of MWH Laboratories in Monrovia, California, which specializes in testing for CECs in water (Eaton 2010). In his comments for the public hearing on the topic held December 15, 2010, Eaton notes that caffeine "is detected in only about 50% of effluent samples ... and is subject to extensive biodegradation," so it is "potentially a poor indicator" (Eaton 2010). Similarly, because gemfibrozil only turns up in about 40% of the effluents, "using this compound as an indicator of treatment performance would run the risk of measuring a compound that was frequently not present at all..." (Eaton 2010). Eaton also lists iopromide as a poor indicator because "it is not commonly used as an X-ray contrast medium. Instead iohexol ... occurs much more frequently and at higher concentrations" (Eaton 2010). In each instance, **using the indicator chemicals recommended by Anderson et al. (2010) could lead to false-negative conclusions about the existence of CECs in a treatment plant's effluent.** Given that Eaton's lab is "the largest in the U.S. that is focused solely on water analysis, specifically CECs in water" (Eaton 2010), his comments regarding the panel's choice of indicators suggest that their research into that topic may not have been sufficiently careful.[8]

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[8] See also Eaton's more recent co-authored studies, "The List of Lists – Are We Measuring the Best PPCPs for Detecting Wastewater Impact on a Receiving Water?" (Eaton and Haghani 2012) and "How Reliable Is the Recycled Water Monitoring List?" (Eaton and Wilson 2013). Those publications

The SWRCB set aside Eaton's comments on the choice of indicator chemicals, McGowan's warnings about antibiotic resistance genes, and other letters raising scientifically grounded concerns with the "blue ribbon" panel's recommendations. The SWRCB adopted the panel's recommendations into the 2013 *Recycled Water Policy.*

D. The Next Wave: Direct Potable Reuse (DPR)

Governor Brown's intent to use ever more recycled wastewater prompted a provision in SB 322 to form another expert panel to advise the CA Department of Public Health (CDPH)[9] on developing guidelines for both indirect and direct potable reuse (DPR). The charge to this new expert panel was described on the SWRCB website, as of February 23, 2015, as follows:

1. Assess what, if any, additional areas of research are needed to be able to establish uniform water recycling criteria for direct potable reuse;
2. Advise on public health issues and scientific and technical matters regarding development of uniform water recycling criteria for indirect potable reuse through surface water augmentation; and
3. Advise on public health issues and scientific and technical matters regarding the feasibility of developing uniform water recycling criteria for direct potable reuse. (California State Water Resources Control Board 2015)

Given that two of the three tasks include offering advice regarding "public health issues," one might expect the panel to include several experts in public health, such as people with advanced degrees in that field, endocrinologists, and others who understand the potential health impacts of contact with the EDs and other CECs remaining in trace levels in potable-reuse wastewater. Such is not the case. About half of the panelists are engineers. There is only one epidemiologist (Tim Wade). While another panelist, Joan Rose, has much-needed expertise in water pathogens, she is not an expert in chemical contaminants. **Absent from the panel are endocrinologists and other independent scientists with expertise in the public-health implications of EDs' nonmonotonic dose-response curves, likely absence of a threshold dose, or the transgenerational epigenetic consequences of early-life exposure to phthalates, cosmetics, pesticides, pharmaceuticals, and other chemical contaminants.**

On the contrary, the panel includes Richard Bull, of MoBull Consulting, who, with James Crook (fellow panelist) and two others, wrote an extensive defense of using "therapeutic dose" as the point of departure for determining safe levels of drugs in drinking water (Bull et al. 2010). Bull and Crook argue that risk assessors should use the dose of a drug intended for a patient who needs that drug as the basis for calculating the amount of that drug that would be safe for members of the public to consume in drinking water.[10] Subsequently, Bull, Crook, and the same colleagues authored *Health Effects Concerns of Water Reuse with Research Recommendations,* published by the WateReuse Foundation (Cotruvo et al. 2012). In both publications, they write: "it is difficult to articulate a [human]-health-based concern that would even require municipal wastewater to be treated to remove drugs" (Bull et al. 2010:16; Cotruvo et al.

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recommend that a very different and much longer list of indicators be used instead of those few identified in the SWRCB's *Recycled Water Policy.*

[9] On July 1, 2014, the Drinking Water Program transferred from CDPH to the State Water Resources Control Board (http://www.waterboards.ca.gov/drinking_water/programs/DW_PreJuly2014.shtml Accessed January 15, 2015). The wording of the expert panel's charge was edited to reflect that change.

[10] Using therapeutic dose as the point of departure for determining safe daily consumption levels for people who do not need those drugs flies in the face of all the evidence regarding characteristics of EDs discussed in this paper. For a critique of the many questionable assumptions inherent in this practice, see C. G. Daughton (2010:49-51).

2012:xx). Crook and Bull's statement might baffle endocrinologists and other independent scientists familiar with the ways EDs impact health. But endocrinologists and other scientists with expertise to challenge Crook and Bull's views are not on the State's panel charged with evaluating potable reuse.

In their more recent monograph, Crook, Bull, and colleagues describe "the very low concentrations of" pharmaceuticals and personal care products (PPCPs) in recycled municipal wastewater as follows:

> These chemicals do not necessarily pose a significant health hazard at concentrations found in [recycled] drinking water, but they serve as reminders of where the water comes from.... [Therefore] the issue **may not be a need for health research, but a need for the regulatory agency to make a formal judgment** on whether the levels even approach those at which adverse health effects would be expected with an adequate margin of safety. (Cotruvo et al. 2012:7, emphasis added)

Crook and Bull's statement implies that a regulatory agency simply needs to *write* that the water "is safe," and it shall be so. Bizarre as that idea sounds, that same approach – determine that a recycled-wastewater process "is safe" by fiat rather than by unbiased scientific investigation – would not be new, since it was used for the State's Title 22 regulations of non-potable recycled wastewater and for the 2013 *Recycled Water Policy*.

Since **both Crook and Bull are on the panel that will recommend the new (2016) State policy regarding both IPR and DPR** – in fact, **Crook is now the panel's co-chair** -- it appears that wastewater-reuse regulators may again ignore the warnings of many members of the Endocrine Society and other prominent scientists whose work demonstrates that even trace amounts – the amounts of some CECs found in advance-treated municipal wastewater -- of drugs, cosmetics, pesticides, plasicizers, and other EDs can have serious, long-term health effects, especially for fetuses, infants, and children.

Bottom line: Unless and until there is much more rigorous, science-based regulation of contaminants of emerging concern in recycled wastewater destined for potable reuse, whether as IPR or DPR, we cannot rely on either Federal or State regulations to protect people who would be drinking and bathing in it.

IV. OTHER USES FOR RECYCLED MUNICIPAL WASTEWATER

Although reliable scientific evidence indicates that using recycled municipal wastewater for food-crop irrigation or for drinking is not worth the health risks, there are other possible uses of this water that may not pose undue risk to humans or other organisms. This section looks very briefly at some examples of reuse in landscape irrigation and for commercial or industrial purposes.

A. Landscape Irrigation

Each proposal for using recycled sewer water for landscape irrigation should be carefully studied in light of the Precautionary Principle. In each case, possible impacts on the health of humans, other animals, plants, insects, and soil microorganisms should be considered, along with any pertinent issues relating to run-off or penetration of the effluent into aquifers. **In light of the heightened vulnerability of fetuses, infants, and children to endocrine disruptors and other contaminants of emerging concern, particular attention should be given to potential exposure of children and pregnant women to recycled municipal wastewater.** Accordingly, although specific conclusions about the advisability of any particular application would depend on information about the treatment train, the effluent quality, the irrigation site, and other parameters of application, it seems likely that irrigation of freeway landscaping might be a more appropriate use of recycled wastewater than would irrigation of children's playgrounds.

Applying the Precautionary Principle and studying specific features of each proposal on a case-by-case basis is a sensible way to proceed.

B. Commercial and Industrial Uses

Other possible uses for recycled sewer water include flushing commercial toilets, mixing concrete, fire-fighting, settling road dust, etc. To briefly explore a few examples: Assuming proper protection of workers and others who might potentially contact the recycled wastewater were put in place, it seems that using recycled wastewater to flush sanitary sewers would be a good application, and using it to flush commercial toilets and mix concrete might also be promising candidates for using recycled sewer water. However, using it to settle dust on roads or streets might be more problematic (depending on the setting) due to contaminant accumulation and potential runoff into a sensitive stream or other habitat. Particularly in populated areas, the nanoparticles, antibiotic resistance genes, and some chemical contaminants could also become a future airborne health threat if the dust were not adequately controlled. However, these hypothetical scenarios are just general sketches, and decisions would need to be made in light of the Precautionary Principle and factors specific to each proposal.

V. CONCLUSION

To summarize: Given that current wastewater treatment technology leaves trace amounts of endocrine disruptors and other contaminants of emerging concern in the effluent; that some of those trace contaminants can be especially harmful for fetuses, infants, and children; that existing regulations fail to adequately protect public health from such contaminants; and that using recycled municipal wastewater for either food-crop irrigation or for drinking is not aligned with the Precautionary Principle, both of those ways of using recycled sewer water should be avoided. For all other purposes, including landscape irrigation and commercial/industrial uses, policymakers should apply the Precautionary Principle to each proposal on a case-by-case basis, taking into account the specific parameters of the proposed application.

There are alternatives: The Water Supply Advisory Committee, City Council, County Board of Supervisors, and other policymaking bodies have an obligation to the community to fully and fairly explore the many viable alternatives to potable reuse and irrigating food-crops with recycled wastewater. There are several promising proposals currently before the Santa Cruz WSAC that should be considered thoroughly and objectively before pursuing recycled municipal wastewater for drinking or other contact uses. For example, Desal Alternatives has submitted nine strategies to WSAC for making the City's water system more reliable and resilient. They include water conservation methods (conservation pricing; water-neutral growth; building-code revisions; measures to reduce landscape irrigation); aquifer restoration through inter-district collaboration; watershed restoration; and infrastructure that would enable better use of existing resources (e.g. a second pipeline from Felton to Loch Lomond). Other groups and individuals have also submitted strategies, such as using abandoned quarries for aquifer recharge and storage, and engineer Jerry Paul's Lochquifer and Spill-Over plans, among others. All of these strategies to make better use of rainfall are also lower in energy intensity and cost than potable reuse of sewer water.

The big picture: Toxic chemicals are ubiquitous in contemporary environments. Drinking clean water is one of the few ways our bodies have to eliminate such chemicals once ingested, so increasing both the *numbers* of different chemicals and the *quantities* of them in our diets by daily consumption of recycled wastewater is a step in the wrong direction. Instead, we should be working to reduce both the numbers and amounts of man-made chemicals in our diets and in the environment.

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COUNTY OF SANTA CRUZ | Planning Department

MEMORANDUM

Date: April 16, 2015

To: Sheila McDaniel

From: Todd Sexauer

Re: Responses to Debra Wirkman's Comments on the Draft IS/MND for the Davenport Recycled Water Project

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Effluent from the Non-operational Cemex Site

The Davenport Wastewater Treatment Plan is continuing to receive sewage from the non-operational Cemex property but cannot verify specifically where it is coming from. According to District records, Cemex is passing as little as 19,000 (633 gpd) and as much as 114,000 (3,800 gpd) gallons per month through to the treatment plant. It is possible that they are passing the water in the lined pond they have through their system and then to the wastewater treatment plant. The County does not have permission to access the Cemex property to determine the source of the water, and Cemex has not disclosed this information to the County. It is not within the scope of this project to determine how much water is flowing from the non-operational Cemex plant. As a result, it was not discussed in the Initial Study.

Tertiary treated water can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations. The State Water Resources Control Board (SWRCB) Recycled Water Policy adopted on February 3, 2009 (modified January 2013), finds that "...the use of recycled water in accordance with this Policy, that is, which supports the sustainable use of groundwater and/or surface water, which is sufficiently treated so as not to adversely impact public health or the environment and which ideally substitutes for use of potable water, is presumed to have a beneficial impact." The tertiary treated recycled water would be treated to a high level that meets Title 22 requirements.

The Davenport County Sanitation District is required to meet the California Regional Water Quality Control Board Waste Discharge Requirements and Water Discharge Requirements as per Order 95-27. The reclaimed water flowing out of the treatment plant is required to meet the following specifications outlined in Section 20(C), Reclaimed Water Specifications (see attached). Specific limits for effluent must be met.

Implementing the project would require preparation of an Engineering Report for review and approval by the Executive Officer of the Regional Water Quality Control Board. The Engineering Report would need to demonstrate that the wastewater treatment plant can consistently produce disinfected tertiary quality water and that safeguards are in place to prevent non-compliant water from being discharged illegally. The District's Waste Discharge Requirements would also need to be updated to reflect changes in operations and water reuse anticipated with the implementation of the project and this would also require review and approval by the Executive Officer.

Nanoparticles

Please see Responses to Jude Todd's Comments on the Draft IS/MND for the Davenport Recycled Water Project. These are not currently regulated by the state.

Pathogen Regrowth

No monitoring would occur for pathogen regrowth in the storage pond. However, there would be a small chlorine residual in the water leaving the plant to control such regrowth. The state only requires disinfection and the specified contact time with the chlorine.

Groundwater Quality Monitoring

No groundwater quality monitoring is being proposed. Impacts to groundwater are not expected. Irrigation water is currently treated to secondary levels and sprayed onto an adjacent vegetated spray field. The project proposes to treat the water to disinfected tertiary levels. Also see discussion under Water Quality Impacts to Farmlands below.

Algae and Insect Control in the Storage Pond

The small chlorine residual in the water would assist in algae control. Some algae is expected to grow in the pond. No chemicals would be used for algae or insect control. Mosquito fish would be used in the pond to control their larvae.

Air Quality

The project is proposing an upgrade to the Davenport Wastewater Treatment Plant to disinfected tertiary treatment. The District is responsible for meeting their Waste Discharge Requirements established by the Regional Water Quality Control Board regarding heavy metals (see discussion below under Hydrology, Water Supply, and Water Quality). There is no requirement for testing surrounding farmlands for hexavalent chromium or other heavy metals.

Hydrology, Water Supply, and Water Quality

See discussion below under Water Quality Impacts to Farmlands. The General Waste Discharge Requirements for Recycled Water Use adopted on June 3, 2014, regulate recycled water use and how it is applied for irrigation as follows:

1. The treatment, storage, distribution, or use of recycled water shall not cause or contribute to a condition of pollution as defined in Water Code section 13050(l) or nuisance as defined in Water Code section 13050(m).
2. No recycled water shall be applied to irrigation areas during periods when soils are saturated.
3. Recycled water shall not be allowed to escape from the use area(s) as surface flow that would either pond and/or enter surface waters, unless authorized by WDRs, waivers of WDRs, or conditional prohibitions regulating agricultural discharges from irrigated lands.
4. Spray or runoff shall not enter a dwelling or food handling facility, and shall not contact any drinking water fountain, unless specifically protected with a shielding device. If the recycled water is undisinfected or secondary-23 quality then spray or runoff shall not enter any place where public access is not restricted during irrigation.
5. The incidental runoff of recycled water shall not result in water quality less than that prescribed in water quality control plans or policies unless authorized through time schedule provisions in WDRs, waivers of WDRs, or conditional prohibitions regulating agricultural discharges from irrigated lands.
6. No recycled water shall be discharged from treatment facilities, irrigation holding tanks, storage ponds, or other containment, other than for permitted use in accordance with this General Order, Regional Water Board issued WDRs, NPDES permits, or a contingency plan in an approved Water Recycling Use Permit.
7. There shall be no cross connection between potable water supply and piping containing recycled water. All Users of recycled water shall provide for appropriate backflow protection for potable water supplies as specified in title 17, section 7604 or as specified by the CDPH.
8. This General Order authorizes certain beneficial recycled water uses consistent with title 22. The following activities are not authorized by this General Order:
    a. Activities designed to replenish groundwater resources. Groundwater replenishment activities may include surface spreading basins, percolation ponds, or direct injection.
    b. Disposal of treated wastewater by means of percolation ponds, excessive hydraulic loading of application areas, etc. where the primary purpose of the activity is the disposal of treated wastewater.

Environmental Justice

The proposed project would be upgrading the treatment plant to produce disinfected tertiary treated water. Tertiary treated water produced by the plant and transported by water truck can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations. The California Department of Public Health does not recognize the use of disinfected tertiary treated water as a health issue for field workers.

Water Quality Impacts to Farmlands

Section 26 of the State Water Resources Control Board Order WQ 2014-0090-DWQ General Waste Discharge Requirements for Recycled Water Use, Adopted on June 3, 2014, states the following regarding common constituents associated with recycled water:

26. Constituents associated with recycled water that have the potential to degrade groundwater include salinity, nutrients, pathogens (represented by coliform bacteria), and disinfection by-products (DBPs). If the discharge is not consistent with Basin Plan requirements, the applicant may elect to improve treatment to enroll under this General Order, or to apply for a site-specific order from the Regional Water Board. The State Water Board finds that the use of recycled water permitted under this General Order will not unreasonably affect beneficial uses or result in water quality that is less than that prescribed in applicable policies because of the following characteristics and requirements associated with each of the recycled water constituents of concern. Each of the recycled water constituents are discussed below:

    a. Salinity is measured in water through various measurements, including but not limited to, total dissolved solids (TDS) and electrical conductivity. Excessive salinity can impair the beneficial uses of water. Salinity levels in the receiving water can be affected by the use of recycled water if the recycled water has elevated concentrations of salinity. However, it is anticipated that in most cases, the use of recycled water for irrigation will consist of a portion of the total applied irrigation water. Other sources of irrigation water are likely to be potable water, imported water, agricultural water supply wells, irrigation districts (surface water supplies), and precipitation. The blending of sources of irrigation water will generally reduce concentrations of, and/or loading rates of salinity constituents. As a result, salinity increases are unlikely to impair an existing and/or potential beneficial use of groundwater.

    b. Nitrogen is a nutrient that may be present in recycled water at a concentration that can degrade groundwater quality. This General Order requires application of recycled water to take into consideration nutrient levels in recycled water and nutrient demand by plants. Application of recycled water at an agronomic rate and considering soil, climate, and plant demand minimizes the movement of nutrients below the plants' root zone. When applied to cropped (or landscaped) land, some of the nitrogen in recycled water will be taken up by the plants, lost to the atmosphere through volatilization of ammonia or denitrification, or stored in the soil matrix. As a result, nitrogen increases are unlikely to impair an existing and/or potential beneficial use of groundwater.

    c. Pathogens and other microorganisms may be present in recycled water based on the disinfection status. Coliform bacteria are used as a surrogate (indicator) because they are present in untreated wastewater, survive in the environment similar to pathogenic bacteria, and are easy to detect and quantify. Pathogens are generally limited in their mobility when applied to land. Setbacks from recycled water use areas are required in title 22 as a means of reducing pathogenic risks by coupling pathogen inactivation rates with groundwater travel time to a well or other potential exposure route (e.g. water contact activities). In general, a substantial unsaturated zone reduces pathogen survival compared to saturated soil conditions. Fine grained soil particles (silt or clay) reduce the rate of groundwater transport and therefore are generally less likely to transport pathogens. Setbacks also provide attenuation of other recycled water constituents through physical, chemical, and biological processes. When needed, disinfection can be performed in a number of ways. Title 22 contains water recycling criteria, which lists disinfection requirements for specifically listed activities.

    d. Disinfection by-products consist of organic and inorganic substances produced by the interaction of chemical disinfectants with naturally occurring substances in the water source. Common disinfection by-products include trihalomethanes, haloacetic acids, bromate, and chlorite. DBPs present in recycled water receive additional treatment when applied to land. Biodegradation, adsorption, volatilization, and other attenuative processes that occur naturally in soil will reduce the concentrations and retard migration of DBPs in the subsurface.

Truck Filling Station

This recycled water project is exempt from LAFCO review under Government Code Section 56133 by which LAFCOs regulate the expansion of city and special district service areas outside their agency boundaries. Subsection (e) of the Government Code Section 56133 clearly states that LAFCO review "does not apply to contracts or agreements for the transfer of nonpotable or nontreated water." Tertiary recycled water is nonpotable. Therefore, recycled water obtained from the truck filling station could be used according to the requirements under Title 22 within or outside of the Davenport County Sanitation District boundaries.

Outside of the wastewater treatment plant and approved spray field location, all potential users (e.g., truck fill station, farmers, ranchers, contractors, etc.) would need to meet the requirements of Title 22 including signage, backflow prevention, buffer zones, and approved reuse application based on the recycled water quality provided to the customer. Customers would first need to obtain a Recycled Water Use Permit from the District which would require education and training on proper use of recycled water.

Tertiary treated water produced by the plant and transported by water truck can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations.

Lagoon Dredging

A mobile (truck mounted) belt filter press would be used to remove water from the accumulated solids removed from the treatment lagoon to produce a non-liquid material for disposal in an authorized landfill. The water removed from the accumulated solids would be returned to the treatment lagoon. Belt filter presses can be used to dewater most biosolids generated at municipal wastewater treatment plants and are a common type of mechanical dewatering equipment. Samples of the biosolids would be tested for levels of contamination to determine how to dispose of them. The results of the testing would then be sent off to various certified landfills to determine who will accept the spoils.

The final Davenport Recycled Water System Feasibility Study will be made available to the public when it is completed.

From:	Celia Scott [twinks2@cruzio.com]
Sent:	Monday, March 23, 2015 3:58 PM
To:	Todd Sexauer
Cc:	Sheila McDaniel; Moroney, Ryan@Coastal
Subject:	Davenport Recycled Water Project/Mitigated Negative Declaration

To: Todd Sexauer, Environmental Coordinator
Santa Cruz County Planning Department
701 Ocean St.,
Santa Cruz, CA 95060

Please accept the following comments on the proposed Mitigated Negative Declaration for the Davenport Recycled Water Project APP#: 151029

Given the unusual length of this Negative Declaration, my comments will be limited to a few areas that have not received adequate analysis for this major public works project, in my opinion. I am also writing in support of the comments submitted by Jude Todd, Debra Wirkman, and Ryan Moroney (Coastal Commission staff) and will not duplicate their remarks to any extent

1. Alternatives Analysis. Although four alternatives for this project were apparently considered by the County there is no comparative analysis of their potential environmental impacts in this document. The only reference to the four alternatives is found in the Biological Assessment (pp. 106-7) with no comment on their possible differential impacts.

2. Project Description. The project description, and subsequent discussion, is incomplete with respect to the proposed truck filling station for taking recycled water from the project elsewhere outside the Davenport Sanitation District.

It would appear also that no conditions are proposed for the sale and distribution of the recycled water. How and where would it be used? What would be the requirements for customers of the recycled water? Would there be any limits to the distribution of the recycled water...anywhere in Santa Cruz County? Within the incorporated cities of the County? Outside the County? Could it go to schools and playgrounds and public parks? And for what purposes?

3. Traffic and Transportation. There is no analysis of post-construction traffic impacts on Highway 1 or other roadways from truck traffic accessing the truck filling station. Given that the exits from Cement Plant Road have limited visibility (depending on the direction of the exiting vehicle), this analysis should be included. Of course, answers to the questions raised in Item 2 above, will be necessary to make such an analysis.

4. Deferred Impact Analysis. With regard to the protection of Wetlands and Waters, it is proposed in the Mitigated Neg Dec to postpone required delineation of wetlands and waters potentially

impacted by the project until after final project design is completed. (See pp. 18-9, and p. 48, Bio-20). In order to allow public comment and review of the delineation and possible impacts on wetlands and waters in the project vicinity, this delineation should be undertaken <u>prior</u> to completion of the project design. Excluding public comment on this important potential impact is not compatible with one of the basic purposes of the environmental review process.

A similar procedure is proposed (p. 61) for the required erosion control plan to protect waterways from adverse environmental impacts due to grading for the project .

5. <u>Conversion of Prime Farmland.</u> The alternative selected for this project places the storage pond, pump and truck filling station, and the staging area for construction of the project all on Coast Dairies Agricultural Parcel 2, for a total of 4.5 acres on land zoned for agricultural. (p.21, p.51 and p. 67).The fact that the land is fallow now is irrelevant. Although an argument is presented in the Neg Dec that more recycled water will equal more agricultural land in production, and therefore is justified, there is no reference to the Conservation Easement on the Coast Dairies Agricultural parcels, available at the Santa Cruz County Recorders Office. It is also obvious that the selection of Alternative 3 maximizes the direct impact on prime farmland, and is an additional reason why the Mitigated Nec.Dec should include a full and adequate analysis of the alternatives to the project as proposed.

6. <u>Extend the Review Process.</u> The final date of March 24 for written comments on the proposed MND is prior to the availability of the final feasibility study and the final project design, both of which will contain information relevant to the environmental review process. I would request that the environmental review process be extended to allow public review of those two documents. In addition, it is clearly necessary for a public hearing to be held at the local level, and I would request that such a hearing be scheduled after the final feasibility study and the final project design are available to the public.

Please acknowledge receipt of this communication.

Celia Scott
1520 Escalona Drive
Santa Cruz, CA 95060

COUNTY OF SANTA CRUZ | **Planning Department**

MEMORANDUM

Date: April 15, 2015

To: Sheila McDaniel

From: Todd Sexauer

Re: Responses to Celia Scott's Comments on the Draft IS/MND for the Davenport Recycled Water Project

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Comment 1: *Alternatives Analysis. Although four alternatives for this project were apparently considered by the County there is no comparative analysis of their potential environmental impacts in this document. The only reference to the four alternatives is found in the Biological Assessment (pp. 106-7) with no comment on their possible differential impacts.*

Response: An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). An alternatives analysis is required when preparing an Environmental Impact Report (CEQA §15126.6). The contents of a Negative Declaration circulated for public review includes: a) A brief description of the project, including a commonly used name for the project, if any; b) The location of the project, preferably shown on a map, and the name of the project proponent; c) A proposed finding that the project will not have a significant effect on the environment; d) An attached copy of the Initial Study documenting reasons to support the finding; and e) Mitigation measures, if any, included in the project to avoid potentially significant effects. As stated in the Initial Study Project Description, "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

Comment 2: *Project Description. The project description, and subsequent discussion, is incomplete with respect to the proposed truck filling station for taking recycled water from the project elsewhere outside the Davenport Sanitation District.*

It would appear also that no conditions are proposed for the sale and distribution of the recycled water. How and where would it be used? What would be the requirements for customers of the recycled water? Would there be any limits to the distribution of the recycled water...anywhere in Santa Cruz County? Within the incorporated cities of the County? Outside the County? Could it go to schools and playgrounds and public parks? And for what purposes?

Response: This recycled water project is exempt from LAFCO review under Government Code Section 56133 by which LAFCOs regulate the expansion of city and special district service areas outside their agency boundaries. Subsection (e) of the Government Code Section 56133 clearly states that LAFCO review "does not apply to contracts or agreements for the transfer of nonpotable or nontreated water." Tertiary recycled water is nonpotable. Therefore, recycled water obtained from the truck filling station could be used according to the requirements under Title 22 within or outside of the Davenport County Sanitation District boundaries.

Outside of the wastewater treatment plant and approved spray field location, all potential users (e.g., truck fill station, farmers, ranchers, contractors, etc.) would need to meet the requirements of Title 22 including signage, backflow prevention, buffer zones, and approved reuse application based on the recycled water quality provided to the customer. Customers would first need to obtain a Recycled Water Use Permit from the District which would require education and training on proper use of recycled water.

Tertiary treated water can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations. The State Water Resources Control Board (SWRCB) Recycled Water Policy adopted on February 3, 2009 (modified January 2013), finds that "...the use of recycled water in accordance with this Policy, that is, which supports the sustainable use of groundwater and/or surface water, which is sufficiently treated so as not to adversely impact public health or the environment and which ideally substitutes for use of potable water, is presumed to have a beneficial impact." The tertiary treated recycled water would be treated to a high level that meets Title 22 requirements.

Comment 3: *<u>Traffic and Transportation</u>. There is no analysis of post-construction traffic impacts on Highway 1 or other roadways from truck traffic accessing the truck filling station. Given that the exits from Cement Plant Road have limited visibility (depending on the direction of the exiting vehicle), this analysis should be included. Of course, answers to the questions raised in Item 2 above, will be necessary to make such an analysis.*

It is estimated that approximately 0.2 acre feet (65,000 gallons) of recycled water would be dispensed annually through the truck fill station. This equates to approximately one new truck trip per week using a 3,000 gallon water truck during the summer months when the water is in demand. Traffic trips on Cement Plant Road are minimal, and no current traffic counts are available for Cement Plant Road. With the closure of the Cement Plant, very little traffic trips are generated on the roadway. The addition of one trip per week would not result in an adverse impact to traffic.

Comment 4: *<u>Deferred Impact Analysis</u>. With regard to the protection of Wetlands and Waters, it is proposed in the Mitigated Neg Dec to postpone required delineation of wetlands and waters potentially impacted by the project until after final project design is completed. (See pp. 18-9, and p. 48, Bio-20). In order to allow public comment and review of the delineation and possible impacts on wetlands and waters in the project vicinity, this delineation should be undertaken prior to completion of the project design. Excluding public comment on this important potential impact is not compatible with one of the basic purposes of the environmental review process.*

A similar procedure is proposed (p. 61) for the required erosion control plan to protect waterways from adverse environmental impacts due to grading for the project.

Response: Page 43 of the Initial Study states, "To ensure that no wetlands or riparian areas would be impacted, a formal delineation of wetlands and waters of the U.S., waters of the state, and coastal wetlands would be conducted prior to final project design. Mitigation Measure BIO-20 shall be implemented prior to final design to ensure avoidance. Impacts would be considered less than significance with the implementation of mitigation.

BIO-20 A formal jurisdictional delineation of wetlands and waters of the U.S. shall be conducted within project area stream crossings and ditches prior to implementation of the project. The project will be designed to avoid impacts to all jurisdictional areas. The proposed project will comply with the Santa Cruz County General Plan Chapter 5 Objective 5.2 and Section 16.30 of the County Code which covers Riparian Corridors and Wetlands.

CEQA Section 15126.4(a)(1)(B) states, "Where several measures are available to mitigate an impact, each should be discussed and the basis for selecting a particular measure should be identified. Formulation of mitigation measures should not be deferred until some future time. However, measures may specify performance standards which would mitigate the significant effect of the project and which may be accomplished in more than one specified way."

The performance standard included in Mitigation Measure BIO-20 is that the project will be designed to avoid impacts to all jurisdictional areas. Mitigation is not being deferred until a later time. The project is consistent with CEQA.

Page 58 of the Initial Study states, "An erosion control plan would also be required per Section 16.22.060 of the County Code." This is required under Section 16.22.060 the County Code and will become a condition of approval. The requirement is not a mitigation measure. This is not considered a deferral of mitigation. The project is consistent with CEQA.

Comment 5: *<u>Conversion of Prime Farmland</u>. The alternative selected for this project places the storage pond, pump and truck filling station, and the staging area for construction of the project all on Coast Dairies Agricultural Parcel 2, for a total of 4.5 acres on land zoned for agricultural. (p.21, p.51 and p. 67).The fact that the land is fallow now is irrelevant. Although an argument is presented in the Neg Dec that more recycled water will equal more agricultural land in production, and therefore is justified, there is no reference to the Conservation Easement on the Coast Dairies Agricultural parcels, available at the Santa Cruz County Recorders Office. It is also obvious that the selection of Alternative 3 maximizes the direct impact on prime farmland, and is an additional reason why the Mitigated Neg. Dec should include a full and adequate analysis of the alternatives to the project as proposed.*

Response: See response to Comment 1. Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation

District to reach an agreement with Cemex to do so. Therefore, the proposed project does not include placing the storage pond on Cemex property.

Exhibit B (3) of the Conservation Easement between Coast Dairies Land Company and the County of Santa Cruz regarding Permitted Uses and Practices states, "Developing and maintaining water resources on the Property, including but not limited to wastewater storage and use, necessary or convenient for ranching, agricultural, irrigation, and farmer and farmworker residential uses on the Property or Grantor's adjacent property in a manner consistent with the conservation purpose of this Easement."

Page 18 of the Initial Study states, "The proposed project is designed to provide recycled water to farmlands on the north coast in an effort to increase their productivity. Approximately 2 acres of Prime Farmland would be developed into a water storage facility. However, the proposed use would be considered an agricultural use and no conversion of Prime Farmland would occur." Section 13.10.312 of the County of Santa Cruz Code under Agricultural Support and Related Facilities states, "Recycled municipal wastewater (i.e, tertiary treatment) facilities for the production of recycled water solely for agricultural irrigation use, subject to the provisions of SCCC 13.10.635.

Section 13.10.635 of the County of Santa Cruz Code, (D) states, "The facility shall minimize reduction of acreage of agricultural lands and shall prevent a reduction in land available for agricultural production by offsetting the loss of agricultural land associated with facility construction. Mitigation measures that may be used to offset the loss of agricultural land resulting from project construction include, but are not limited to:

(1) Enabling fallow agricultural land to be put back into production;

(2) Protecting or restoring agricultural operations on lands where nonagricultural development has been permitted, among other ways by acquiring the land or obtaining an affirmative agricultural easement;

(3) Improving the productivity of degraded or marginal agricultural land by transporting the topsoil from the development site to such land; and

(4) Any combination of the above, or similar measures.

The mitigation measures used to offset the loss of agricultural land associated with facility construction shall enhance agricultural productivity within the project service area to an extent that is equal or better than the productivity of the agricultural land lost from project construction, and shall be implemented in a manner that is consistent with the coastal resource protection provisions of the General Plan/LCP, such as those protecting environmentally sensitive habitat areas, riparian corridors, wetlands, and coastal water quality."

As stated on page 18 of the Initial Study, the project would provide recycled water to farmlands on the north coast in an effort to increase their productivity. This would enable fallow agricultural land to be put back into production as stated in (1) above. No conversion of prime farmland would occur.

Comment 6: *<u>Extend the Review Process</u>. The final date of March 24 for written comments on the proposed MND is prior to the availability of the final feasibility study and the final project design, both of which will contain information relevant to the environmental review process. I would request that the environmental review process be extended to allow public review of those two documents. In addition, it is clearly necessary for a public hearing to be held at the local level, and I would request that such a hearing be scheduled after the final feasibility study and the final project design are available to the public.*

Response: The proposed project described in the Detailed Project Description on page 14 of the Initial Study adequately addresses the project proposal. Substantial changes are not anticipated between the draft and final feasibility study. The Initial Study was circulated through the State Clearinghouse for a period of 30 days as required under Section 15073(a) of the State CEQA Guidelines. No extension is necessary.

March 23, 2015

1425 Seabright Ave.

Santa Cruz, CA 95062

Todd Sexauer

Santa Cruz County Planning Department

701 Ocean Street, 4th Floor

Santa Cruz, CA 95060

Subject: Davenport Recycled Water Project

March 23, 2015

Comments on Draft Initial Study/Proposed MND

Dear Mr. Sexauer:

Thank you for the opportunity to respond to the Mitigated Negative Declaration regarding the Davenport Recycled Water Project.

I am a member of People Against Unsafe Wastewater Reuse (PAUWR), a group that formed as we became aware that the state of California had not done a thorough job in the writing of Title 22 regarding recycled water use. The authors of those regulations did not take into account the body of scientific evidence from endocrinologists, public health experts, and other independent scientists and thus avoided serious issues with recycled municipal wastewater. I am writing as an individual, not for the group, but offer our name to alert you to my background interest in this project. I am also a local consumer of organic produce grown by the Rodoni family, who lease the agricultural land across Hwy 1 from the treatment plant site. Incredibly, Title 22 allows irrigation of "organic" farms with tertiary treated wastewater.

Organic produce sells at a premium and is a great product to have grown and sold in our area, but we need to protect the land more than the State has under Title 22 and more than the State Water Resource Control Board is doing at present. North Coast organic farmers know their customers and that we do not want tainted water used on our produce.

The "**Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz** " by, Jude Todd, submitted with her comments to the Mitigated Negative Declaration, should be read by all involved in the decisions about this project.

Specific comments, #1

Quoting Ryan Moroney's MND comment number 3, "While the proposed facilities are intended ultimately [to] allow for the use of recycled wastewater for agricultural use, the main driver behind the proposed Project appears to be Title 22 water quality violations identified by the May 25, 2011 staff inspection by the Central Coast Region Water Quality Control Board, including: '1) the discharge of thousands of gallons of treated wastewater to the Pacific Ocean by runoff from disposal fields, 2) less than the required two feet of freeboard level in the treatment pond; 3) failure to post signage in areas of water reclamation use, etc,; and 4) failure to investigate and submit a spill response report within five days of the discovered spill.' Thus, in at least some respects, the Project can be seen as an industrial wastewater treatment plant upgrade, inconsistent with the current CA zoning and LCP requirements for that zoning."

Since Mr. Moroney is a professional in the field, I expect that his comments will be attended to.

As a practical person, however, I wonder whether the same personnel will be operating the upgraded treatment plant, with or without the addition of alarm bells and extra chemical safeguards.

I would propose, instead, that overflowing sewage can be most effectively and cheaply resolved by adding a second holding lagoon for the sewage and alternating use of these lagoons to allow for regular removal of the sediments. Eight feet of sediment is a lot of wasted space in the lagoon. I would also hope for proper attention to the removal of potentially toxin containing sediment. Aside from this, adding some height to the existing berm/walls or removing weir boards from the lagoon/dam should deliver the required freeboard height.

Comment #2

Page 11 of the MND shows the **Existing and Proposed Wastewater Treatment Plant Schematic.** Currently the product water of the tertiary treatment is sprayed on un-mowed fields. An arrow points off from the new proposed product water storage lagoon and says: "to customers". Previously Cemex used all the product water and was not picky about the quality of that product. The current project included a survey of the 110 parcel owners and the lessee of the agricultural acreage. Sixteen responses were received and no interest shown in the product water. Rodoni Farms are transitioning to all organic production, and, though Title 22 allows for organic growers to use tertiary treated recycled water, man organic-food customers will not want to buy produce irrigated with recycled wastewater. Other north coast organic farmers have expressed vigorous opposition to the use of recycled water. My point is that there is a dearth of customers for the product water.

At page 15 the MND says: "Title 3, Water Service District would be amended to allow for the sale and distribution of recycled water to customers located outside of the Davenport County Sanitation District service area." This would likely mean impermissible additional greenhouse gas (GHG) emissions. On page 51, item G addresses GHGs as negative. Yet trucking water is anticipated beyond the construction phase. Water is heavy and the area hilly. Local road watering during the construction phase is the only actual customer for this use mentioned. As Ryan Moroney's comments indicate, the truck fill station could be eliminated from the project.

It seems implausible that Davenport residents would hire a trucker to bring water for their gardens.

Comment #3

On page 9 the MND asserts that no hazardous wastes are at issue. What is in the solids? Thirty thousand gallons of waste continues to arrive monthly from Cemex for some mysterious source as yet undetermined, which could also be hazardous.

Apparently since the County took over operation of the plant, no dredging of the solids produced has been done. No testing of this material appears to have been done and its disposal is not addressed in the MND. How can the proponents say there is no hazardous material present when no testing of the sediment has been done?

The sediment should also be analyzed for other hazardous material that may well arrive in domestic sewage. Approximately seventy percent of adult U.S. residents use pharmaceuticals daily.

The Cemex property has not been completely remediated or even thoroughly studied for the hazardous substances that were used in the past and may still be present in the coal, diesel, shop, and cement kiln dust piles.

As suggested earlier, a second holding/treatment lagoon would obviate the need for this project as now described and reduce the use of extra treatment chemicals now proposed. Violations of Title 22 regarding management of the influent are the source of the project in the first place.

Page 59 claims that no additional pollution will result to runoff in the area. However, considering the use of tertiary-treated wastewater to irrigate fields that have been transitioning to organic agriculture for 10 years, the use of this wastewater that contains pollutants unrecognized as such by Title 22 will result in additional pollution. CECs, including antibiotic resistant bacteria, may be sprayed on fields; they, along with endocrine disruptors, can be taken up by food crops. Our ignorance and arrogance on this issue is vast, and precaution should be the order of the day, recognizing that prenatal, postnatal, and young children are extremely vulnerable to minute amounts of contaminants. (Please see the "**Statement Regarding Use of Recycled Municipal Wastewater in Santa Cruz** " by, Jude Todd, submitted with her comments to the Mitigated Negative Declaration, which should be read by all involved in the decisions about this project.)

Even women who may not buy organic produce for themselves often become intent on doing so when they become pregnant. They should be allowed to choose unpolluted produce to protect their fetuses, infants, and children.

Throughout the MND, the authors act as though the water does not ultimately flow into the Monterey Bay Marine Sanctuary, but it does, and all protection possible to avoid adding biological hazards should be taken. The proposed project may create a greater pollution problem than it was designed to fix!

Comment #4

On page 64, the MND alleges that care has been taken to minimize reduction of acreage of agricultural lands, but as Mr. Moroney of the CCC notes in his Comment #1 this is not true. He calls it Incomplete Alternative Analysis.

Comment #5

On page 77, regarding degrading the environment generally as to all the special species involved and plants, again citing Mr. Moroney's Comments to the MND, no focused surveys have been done for these species. See his comment #4, third paragraph.

The existing irrigation ponds, presumably filled from rain and or wells, and now safe for migratory birds to rest on, may be rendered unsafe by this product water and result in diminished water quality for these passers-by or local special species nesting close at hand. Endocrine disruptors do survive tertiary treatment, and storage in open waters invites contact with red legged frogs and other wildlife needing protection.

Many pharmaceuticals survive the treatment process as shown by citations in Dr. Todd's document. What will beta blockers do to the frogs?

Even if some birds are currently attracted to the existing watering site with un-mowed grass as well as to the existing irrigation ponds on the southern side of Hwy 1, not spreading potential pollutants further seems to be the least harmful approach.

Sincerely,

Christy Kirven 1425 Seabrgiht Ave. CA 95062

COUNTY OF SANTA CRUZ | **Planning Department**

MEMORANDUM

Date: April 17, 2015

To: Sheila McDaniel

From: Todd Sexauer

Re: Responses to the Davenport Recycled Water Project Christy Kirven Comments on the Draft IS/MND

Comment 1:

See Coastal Commission Response to Comments memo dated March 26, 2015. Comments noted.

Comment 2

Page 11 Comments noted.

Approximately 3,000 gallons of water per week during the summer is expected to be trucked from the site. This equates to one truck trip per week using a 3,000 gallon water truck. Impacts to greenhouse gas emissions would not be significant.

Comment 3

The Davenport Wastewater Treatment Plan is continuing to receive sewage from the non-operational Cemex property but cannot verify specifically where it is coming from. According to District records, Cemex is passing as little as 19,000 (633 gpd) and as much as 114,000 (3,800 gpd) gallons per month through to the treatment plant. It is possible that they are passing the water in the lined pond they have through their system and then to the wastewater treatment plant. The County does not have permission to access the Cemex property to determine the source of the water, and Cemex has not disclosed this information to the County. It is not within the scope of this project to determine how much water is flowing from the non-operational Cemex plant or what other potential contamination may occur on the Cement Plant site. As a result, it was not discussed in the Initial Study.

A mobile (truck mounted) belt filter press would be used to remove water from the accumulated solids removed from the treatment lagoon to produce a non-liquid material for disposal in an authorized landfill. The water removed from the accumulated solids would be returned to the treatment lagoon. Belt filter presses can be used to dewater most biosolids generated at municipal wastewater treatment plants and are a common type of mechanical dewatering equipment. Samples of the biosolids would be tested for levels of contamination to determine how to dispose of them. The results of the testing would then be sent off to various certified landfills to determine who will accept the spoils.

Tertiary treated water can be used for irrigation of food crops including all edible root crops where the recycled water comes into contact with the edible portion of the crop; parks and playgrounds, school yards, residential landscaping, unrestricted access golf courses, ornamental nursery stock, etc. according to Title 22 §60304(a) of the California Code of Regulations. The State Water Resources Control Board (SWRCB) Recycled Water Policy adopted on February 3, 2009 (modified January 2013), finds that "...the use of recycled water in accordance with this Policy, that is, which supports the sustainable use of groundwater and/or surface water, which is sufficiently treated so as not to adversely impact public health or the environment and which ideally substitutes for use of potable water, is presumed to have a beneficial impact." The tertiary treated recycled water would be treated to a high level that meets Title 22 requirements.

The Davenport County Sanitation District is required to meet the California Regional Water Quality Control Board Waste Discharge Requirements and Water Discharge Requirements as per Order 95-27. The reclaimed water flowing out of the treatment plant is required to meet the following specifications outlined in Section 20(C), Reclaimed Water Specifications (see attached). Specific limits for effluent must be met.

Implementing the project would require preparation of an Engineering Report for review and approval by the Executive Officer of the Regional Water Quality Control Board. The Engineering Report would need to demonstrate that the wastewater treatment plant can consistently produce disinfected tertiary quality water and that safeguards are in place to prevent non-compliant water from being discharged illegally. The District's Waste Discharge Requirements would also need to be updated to reflect changes in operations and water reuse anticipated with the implementation of the project and this would also require review and approval by the Executive Officer.

Please see Responses to Jude Todd's Comments on the Draft IS/MND for the Davenport Recycled Water Project for responses to concerns regarding CECs.

The General Waste Discharge Requirements for Recycled Water Use adopted on June 3, 2014, regulate recycled water use and how it is applied for irrigation as follows:

1. The treatment, storage, distribution, or use of recycled water shall not cause or contribute to a condition of pollution as defined in Water Code section 13050(l) or nuisance as defined in Water Code section 13050(m).
2. No recycled water shall be applied to irrigation areas during periods when soils are saturated.
3. Recycled water shall not be allowed to escape from the use area(s) as surface flow that would either pond and/or enter surface waters, unless authorized by WDRs, waivers of WDRs, or conditional prohibitions regulating agricultural discharges from irrigated lands.
4. Spray or runoff shall not enter a dwelling or food handling facility, and shall not contact any drinking water fountain, unless specifically protected with a shielding device. If the recycled water is undisinfected or secondary-23 quality then spray or runoff shall not enter any place where public access is not restricted during irrigation.
5. The incidental runoff of recycled water shall not result in water quality less than that prescribed in water quality control plans or policies unless authorized through time schedule provisions in WDRs, waivers of WDRs, or conditional prohibitions regulating agricultural discharges from irrigated lands.
6. No recycled water shall be discharged from treatment facilities, irrigation holding tanks, storage ponds, or other containment, other than for permitted use in accordance with this General Order, Regional Water Board issued WDRs, NPDES permits, or a contingency plan in an approved Water Recycling Use Permit.
7. There shall be no cross connection between potable water supply and piping containing recycled water. All Users of recycled water shall provide for appropriate backflow protection for potable water supplies as specified in title 17, section 7604 or as specified by the CDPH.
8. This General Order authorizes certain beneficial recycled water uses consistent with title 22. The following activities are not authorized by this General Order:
    a. Activities designed to replenish groundwater resources. Groundwater replenishment activities may include surface spreading basins, percolation ponds, or direct injection.
    b. Disposal of treated wastewater by means of percolation ponds, excessive hydraulic loading of application areas, etc. where the primary purpose of the activity is the disposal of treated wastewater.

Significant water quality impacts would not occur to Monterey Bay Marine Sanctuary.

Comment 4

An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). An alternatives analysis is required when preparing an Environmental Impact Report (CEQA §15126.6). The contents of a Negative Declaration circulated for public review includes: a) A brief description of the project, including a commonly used name for the project, if any; b) The location of the project, preferably shown on a map, and the name of the project proponent; c) A proposed finding that the project will not have a significant effect on the environment; d) An attached copy of the Initial Study documenting reasons to support the finding; and e) Mitigation measures, if any, included in the project to avoid potentially significant effects. As stated in the Initial Study Project Description, "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

Comment 5

Alternatives Analysis: An alternatives analysis is not required for an Initial Study/Mitigated Negative Declaration (CEQA §15071). "The new storage pond location is being proposed on the Coast Dairies Agricultural Parcel Two (058-022-11)." Although analyzed in various technical studies, the proposed storage pond is not proposed to be located on the Cemex parcel (APN 058-071-04) due to the inability of the Davenport Sanitation District to reach an agreement with Cemex to do so.

No Focused Surveys: A literature search and focused surveys of the proposed project site were conducted as follows:

Literature Search: Information on special-status plant species was compiled through a review of the literature and database search. Database searches for known occurrences of special-status species focused on the Davenport and Santa Cruz U.S. Geologic Service 7.5-minute topographic quadrangles, which provided a 4.8 km (3 mi) radius around the proposed project area. The following sources were reviewed to determine which special-status plant and wildlife species have been documented in the vicinity of the project site:

- U.S. Fish and Wildlife Service (USFWS) quadrangle species lists (USFWS 2014)
- USFWS list of special-status animals for Sonoma County (USFWS 2014)
- California Natural Diversity Database records (CNDDB) (CNDDB 2014)
- California Department of Fish and Wildlife's (CDFW) Special Animals List (CDFW 2014),
- State and Federally Listed Endangered and Threatened Animals of California (CDFW 2014)
- California Native Plant Society (CNPS) Electronic Inventory records (CNPS 2014)
- Santa Cruz County General Plan Update 1994)
- CDFG publication "California's Wildlife, Volumes I-III" (Zeiner et al., 1990)

The U.S. Fish and Wildlife Service (USFWS) electronic list of Endangered and Threatened Species was queried electronically (www.fws.gov/sacramento/es_spp_lists-overview.htm). We also reviewed the CalFish IMAPS Viewer (www.calfish.org/DataandMaps/CalFishGeographicData), developed by CDFW Biogeographic Branch for analysis of fisheries.

The CDFW BIOS website and the California Essential Habitat Connectivity Project: A strategy for conserving a connected California (Spencer, et al., 2010) were reviewed for wildlife movement information. The CDFW BIOS website and the CNDDB were review for documented nursery sites.

Other sources of information regarding reported occurrences include locations previously reported to the U.C Berkeley Museum of Vertebrate Zoology and the California Academy of Sciences.

Personnel and Survey Dates: Trish Tatarian, wildlife biologist of Wildlife Research Associates, and Jane Valerius, botanist and wetland specialist of Jane Valerius Environmental Consulting, conducted an initial daytime survey of the project site on March 18, 2014, from 1030 to 1345 and on October 22, 2014 from 1130 to1315. Trish analyzed the on-site habitats for suitability for California red-legged frog (CRLF). No access to the Cemex Plant was allowed at the time of the survey. As a result, the water treatment plant, and the proposed disposal area were not surveyed or evaluated for this report.

Analysis of aerial photographs was conducted of adjacent habitat that could provide terrestrial habitat for CRLF, and ponds and water bodies that could provide potential breeding habitat for CRLF but from which have not been reported in the CNDDB. Habitats within 1.6 km were evaluated for their potential to provide connectivity between sites for CRLF. Jane evaluated the onsite vegetation communities for their potential to support special status plants and/or wetland communities.

Wetland habitat on Agricultural Parcel Two:

As stated in the Biological Resources Assessment, trenching for the pipelines that goes from the proposed storage pond south along Cement Plant Road to the treatment pond could potentially impact wetland ditches located both along the eastern edge of the Coast Dairy property and the willow wetland area on the west side of Cement Plant Road across from the Coastal Dairy property. These wetlands could be avoided if the trench was constructed within the roadway. As stated on page 15 of the Initial Study project description, "Pipe installed along Cement Plant Road would be constructed in trenches within the concrete road to avoid potential sensitive resources."

Page 42 of the Initial Study/MND under Wetland s and Waters states, "Trenching for the distribution pipelines connecting the treatment pond on the Cemex property with the proposed storage pond on the Coast Dairies property could potentially impact agricultural wetland ditches located both along the eastern edge of the Coast Dairy property and the willow shrubland located on the west side of Cement Plant Road across from the Coast Dairies property. However, these wetlands would be avoided by trenching for the distribution pipeline within Cement Plant Road. Agricultural wetland ditches located on the western side of Highway 1 could be avoided by trenching within the existing compacted agricultural road."

Page 45 of the Initial Study/MND requires the following mitigation measure to reduce potentially significant impacts to a less than significant level.

BIO-20 A formal jurisdictional delineation of wetlands and waters of the U.S. shall be conducted within project area stream crossings and ditches prior to implementation of the project. The project will be designed to avoid impacts to all jurisdictional areas. The proposed project will comply with the Santa Cruz County General Plan Chapter 5 Objective 5.2 and Section 16.30 of the County Code which covers Riparian Corridors and Wetlands.

Potential wetland and riparian impacts would be avoided.

Please see Responses to Jude Todd's Comments on the Draft IS/MND for the Davenport Recycled Water Project for responses to concerns regarding CECs.