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Effect of water treatment additives on lime softening residual trace chemical composition – Implications for disposal and reuse

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A B S T R A C T

Drinking water treatment residues (WTR) offer potential benefits when recycled through land application. The current guidance in Florida, US allows for unrestricted land application of lime softening WTR; alum and ferric WTR require additional evaluation of total and leachable concentrations of select trace metals prior to land application. In some cases a mixed WTR is produced when lime softening is accompanied by the addition of a coagulant or other treatment chemical; applicability of the current guidance is unclear. The objective of this research was to characterize the total and leachable chemical content of WTR from Florida facilities that utilize multiple treatment chemicals. Lime and mixed lime WTR samples were collected from 18 water treatment facilities in Florida. Total and leachable concentrations of the WTR were measured. To assess the potential for disposal of mixed WTR as clean fill below the water table, leaching tests were conducted at multiple liquid to solid ratios and under reducing conditions. The results were compared to risk-based soil and groundwater contamination thresholds. Total metal concentrations of WTR were found to be below Florida soil contaminant thresholds with Fe found in the highest abundance at a concentration of 3600 mg/kg-dry. Aluminum was the only element that exceeded the Florida groundwater contaminant thresholds using SPLP (95% UCL = 0.23 mg/L; risk threshold = 0.2 mg/L). Tests under reducing conditions showed elevated concentrations of Fe and Mn, ranging from 1 to 3 orders of magnitude higher than SPLP leachates. Mixed lime WTR concentrations (total and leachable) were lower than the ferric and alum WTR concentrations, supporting that mixed WTR are appropriately represented as lime WTR. Testing of WTR under reducing conditions demonstrated the potential for release of certain trace metals (Fe, Al, Mn) above applicable regulatory thresholds; additional evaluation is needed to assess management options where reducing conditions may develop.

1. Introduction

Water utilities employ a number of different treatment chemicals and processes to produce potable water for human use and consumption. Coagulants such as ferric chloride, ferric sulfate, and aluminum sulfate are frequently employed for surface water treatment with a goal of removing, among other things, the organic chemicals responsible for color (Ippolito et al., 2011; Matilainen et al., 2010). Water softening using lime is common for groundwater sources high in hardness. All of these processes result in a high-solids residual (sludge) that must be appropriately managed. Depending on factors such as applicable waste management regulations, available markets for beneficial use, and economics, water treatment residuals (WTR) are most commonly beneficially recycled (e.g., agricultural land application, ingredient in other products or processes) or disposed of in a landfill (Elliott et al., 1990; Heil and Barbarick, 1989; Lucas et al., 1994). Land applied WTR have been demonstrated to have a number of beneficial properties, including a reduction of bioavailable phosphorous in soils and runoff (Ippolito et al., 2011; Oladeji et al., 2008; Oliver et al., 2011).

In the early 2000s in the state of Florida, US, questions regarding the appropriate management of WTR motivated research on the chemical characteristics of various WTR types and whether the presence of trace chemicals should limit their beneficial use through land application (Townsend et al., 2001). Samples of lime softening, ferric coagulation, and alum coagulation WTR from throughout Florida were characterized for their total (mg/kg-dry) and leachable (mg/L) concentrations of a suite of organic and inorganic trace chemicals (Jain et al., 2005), and the results were subsequently used by the Florida Department of Environmental

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Table 1
Additive dosing rates and characteristics of WTR samples.

Facility	Lime (lb/day/MGD)	Iron (lb/day/MGD)	Alum (lb/day/MGD)	Other	pH	MC (%)
A	1168	N/A	N/A	N/A	9.6	41
B	240	N/A	N/A	0.26 (Polymer) 10 (Phosphate)	9.4	30
C	661	23	N/A	1.75 (Polymer)	10.1	44
D	480	2	N/A	0.08 (Chem-Floc)	9.6	27
E	3156	N/A	N/A	1.6 (Polymer)	9.7	26
F	550	N/A	N/A	0.5 (Polymer)	9.6	13
G	2100	N/A	240	N/A	9.9	13
H	380	N/A	N/A	2.3 (Polymer)	9.4	25
I	1001	N/A	N/A	Polymer	12.1	15
J	708	N/A	N/A	N/A	9.3	29
K	1364	N/A	N/A	30.3 (Silicate) 6.6 (Polymer)	8.9	21
L	914	40	N/A	N/A	9.3	24
M	1466	120	N/A	N/A	9.3	4.5
N	676	63	N/A	N/A	11.6	19
O	186	N/A	N/A	N/A	9.1	15
P	636	23	N/A	N/A	9.0	37
Q	1147	N/A	N/A	1.2 (Polymer) 8.3 (Phosphate) 2.4 (Starch)	10.2	28
R	222	N/A	N/A	9.6 (Silicate)	11.0	53

Protection (FDEP) to set policy for the land application of WTR (FDEP, 2006).

The FDEP guidance allows unrestricted land application of lime softening WTR for beneficial uses, but places some restrictions on the land application of ferric and alum WTR. Proposed beneficial uses of ferric and alum WTR require evaluation on a case-by-case basis; samples require characterization for total (mg/kg-dry) and leachable (mg/L) concentrations of several elements (e.g., aluminum, arsenic, barium, copper, iron, lead and manganese) with these results compared to risk-based thresholds established by the state of Florida. More recently, questions have been raised by Florida's regulatory community regarding the appropriate management of WTR produced when lime softening is accompanied by the addition of a coagulant or other treatment chemical. In many parts of South Florida, groundwater sources are highly connected to surface water bodies, and in addition to hardness removal, other treatment additives are frequently used to remove color, and other contaminants more typical of surface water. It has been reported that WTR can increase phosphorus stability in water body sediments under both aerobic and anaerobic conditions, a proposed application for WTR (Oliver et al., 2011; C. Wang et al., 2013). Some utility operators have questioned whether these WTR might be appropriate for clean fill below the water table, a technique practiced for some other wastes (e.g., concrete) (NJEPA, 2013). Previous demonstration that ferric WTR preferentially remove arsenic (Makris et al., 2006; Nagar et al., 2010), and that the soluble arsenic can be released from these residuals under reducing conditions (Makris et al., 2006; Meng et al., 2001; Ghosh et al., 2004, 2006), additionally motivated the need for characterization data on mixed WTR.

Research is presented here on the total and leachable trace chemical components of lime softening WTR in Florida, including an evaluation of WTR from facilities which only utilize lime, and those employing both lime and other treatment chemicals. While some data are available regarding the trace chemical occurrence and leachability from lime softening, alum treatment, and ferric treatment WTR (Elliott et al., 1990; Schmitt and Hall, 1975; Townsend et al., 2006; Uwimana et al., 2010) data on mixed WTR have not been reported. The objective of this research was to characterize the total and leachable chemical content of WTR from Florida facilities that utilize multiple treatment chemicals; samples from eighteen water treatment utilities were included in the study and management implications were assessed by comparing these results to risk-based regulatory thresholds. To evaluate the applicability of the current land disposal guidelines to mixed WTR, the characterization data are compared to the values of lime, ferric, and alum WTR in the previous Florida study (Townsend et al., 2001). Assessment of the potential for the release of trace metals under submerged conditions was conducted using leaching tests with the addition of a chemical reducing agent. The chemical dosing rates from the treatment facilities are provided so these results can be used to evaluate potential WTR from facilities outside of the region presented here. While the data presented are specific to one geographic region, they provide insight to those dealing with similar concerns elsewhere in the world.

2. Methods

2.1. Facilities description and sample collection

WTR samples were collected from 18 water treatment facilities within the state of Florida. Due to varying storage and disposal methods, as well as operational differences among facilities, samples were obtained from the point that represented the most recently produced WTR available for sampling at each facility. Composite WTR samples from sludge lagoons and drying piles were collected by removing the top 8 cm of the WTR at the sampling location and collecting subsamples from 6 to 10 points encompassing the entire sampling area. Collection from belt filter presses or other mechanical drying equipment was performed over a 20-min period to form a composite sample. All samples were collected using acid-washed plastic scoops and stored in sealed, acid-washed, 19-L HDPE buckets. Trip blanks, field blanks, equipment blanks, and duplicate samples were carried or collected during sampling trip. Information on chemical additives, dosing rates, pH and average moisture content of WTR were provided by the treatment facility operators and are shown in Table 1.

Following collection, WTR samples were allowed to settle for a period of 48 h; any WTR containing free water was first decanted then allowed to dry for a period of three days. Samples were stored in sealed, acid-washed 19-L buckets and homogenized through repeated mixing. Moisture content was measured in triplicate