

Solutions Network Formulation Report

NASA's Potential Contributions for Remediation of Retention Ponds Using Solar Ultraviolet Radiation and Photocatalysis

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1. Candidate Solution Constituents

- a. Title: NASA's Potential Contributions for Remediation of Retention Ponds Using Solar Ultraviolet Radiation and Photocatalysis
- b. Authors: Lauren W. Underwood and Robert E. Ryan, Science Systems and Applications, Inc., John C. Stennis Space Center
- c. Identified Partners: EPA (U.S. Environmental Protection Agency) and USGS (U.S. Geological Survey)
- d. Specific DST/DSS: SWMM (Storm Water Management Model) and SLAMM (Source Load and Management Model)
- e. Alignment with National Application: Water Management and Public Health
- f. NASA Research Results – Table 1:

Missions	Sensors/Models	Data Product
Heritage Nimbus 7 and Meteor 3, Earth Probe	TOMS (Total Ozone Mapping Spectrometer)	Aerosol & Ozone
Aura	OMI (Ozone Monitoring Instrument)	Aerosol & Ozone
GSFC	OMI Surface UV (ultraviolet) algorithm	Surface UV Irradiance

- g. Benefit to Society: Increase effectiveness of retention ponds and improve water quality.

2. Abstract

This Candidate Solution uses NASA Earth science research on atmospheric ozone and aerosols data (1) to help improve the prediction capabilities of water runoff models that are used to estimate runoff pollution from retention ponds, and (2) to understand the pollutant removal contribution and potential of photocatalytically coated materials that could be used in these ponds. Models (the EPA's SWMM and the USGS' SLAMM) exist that estimate the release of pollutants into the environment from storm-water-related retention pond runoff. UV irradiance data acquired from the satellite mission Aura and from the OMI Surface UV algorithm will be incorporated into these models to enhance their capabilities, not only by increasing the general understanding of retention pond function (both the efficacy and efficiency) but additionally by adding photocatalytic materials to these retention ponds, augmenting their performance. State and local officials who run pollution protection programs could then develop and implement photocatalytic technologies for water pollution control in retention ponds and use them in conjunction with existing runoff models. More effective decisions about water pollution protection programs could be made, the persistence and toxicity of waste generated could be minimized, and subsequently our natural water resources would be improved. This Candidate Solution is in alignment with the Water Management and Public Health National Applications.

3. Detailed Description of Candidate Solution

a. Purpose/Scope

This report examines use of NASA-derived atmospheric aerosol and ozone data (1) to measure UV dosage levels, (2) to evaluate whether this information would enhance the decision makers' ability to use prediction models such as SWMM and SLAMM, and (3) to understand the efficiency of photocatalysis as an incorporated method for controlling and/or removing pollutants in water retention ponds.

A water retention pond is a large, shallow basin that protects water resources from storm water runoff. One function these ponds serve is to control the release of pollutants from this runoff into the environment. Retention ponds have no outlets or streams; water collects in the ponds and is released through atmospheric phenomenon, such as evaporation or infiltration. This slow, natural process requires sunlight (EPA, 2006). Retention ponds provide pollutant removal through settling and biological uptake (Narayanan, 2007). Ponds remove 30 to 80 percent of certain pollutants from water before they enter nearby streams—pollutants including sediments, bacteria, greases, oils, chemicals, and metals (England, 2001). Retention ponds can be an effective tool for providing protection and pollutant removal in urban streams (Mallin et al., 2002) and also for providing a form of water quality control (EPA, 1999).

Unfortunately, storm water runoff has become one of the most extensive causes of impaired water quality in the United States (Tsihrintzis and Hamid, 1997). Impacts of urbanization, including the effects that buildings, roadways, parking lots, and driveways have had on the environment, are a primary cause of this impairment: water cannot soak into these surfaces during a rainfall. Because these surfaces are impermeable, the water must run off to areas of lower elevation. For example, petroleum products from roadways run off of these impermeable surfaces and find their way into retention ponds. Therefore, during the past decade, to augment city planning and to decrease the negative impacts storm water runoff has had on receiving waters, interest in looking at retention ponds had rapidly increased. These ponds are built to handle a quick influx of water and to release the water slowly back into the ground. Although some retention ponds are very good at catching, removing, and/or breaking down pollutants and at discharging cleaner water, sometimes sediments and contaminants can settle out of the water, become trapped in the retention pond, and accumulate. Then environmental pollutants, such as organics, microbes, pesticides, and other toxic chemicals, can enter bodies of water and end up in streams and rivers. These pollutants can bioaccumulate and have negative effects on the overall water quality, subsequently affecting plant, animal, and human life. To avoid this occurrence, retention ponds must function efficiently and maximally.

Increased public awareness of runoff management has forced the remediation of retention ponds into a challenging position (Public Works Staff, 2006). Safe solutions to pollution problems need to be considered. When reviewing appropriate approaches for remediation technologies, some key environmental, social, and economic criteria should be taken into account, like costs, time, reliability, and long-term maintenance. To ensure that these requirements are met, runoff remediation has been integrated as part of water management programs.

As part of this integration process, water runoff models have been developed to understand the effects that runoff from these ponds has on the environment and on water quality. Most models emphasize and focus on the consequences of very large storms and rains. The EPA's SWMM is a comprehensive, rainfall-runoff simulation model that is used primarily but not exclusively for urban areas and for single-event or long-term (continuous) simulation aspects of the urban hydrologic and quality cycles. SWMM is the first all-inclusive model of its type for urban runoff analysis. The USGS' SLAMM was developed to improve the appreciation of the relationships between sources of urban runoff pollutants and associated runoff water quality, particularly when connected with smaller weather events (Pitt, 1998). SLAMM enables a more accurate prediction of the pollutant source

runoff and flows associated with storm water quality analyses for a broad range of rains, as well as an increased understanding of urban and non-urban characteristics and control practices. Unfortunately, the assumptions and simplifications that are used with runoff models are not always directly appropriate for water quality models. Therefore, to enhance their usefulness, the models have been combined; the EPA's SWMM has integrated SLAMM (Pitt et al., 1999). While this incorporation has improved the function and outcomes of both models, the need to develop more advanced integrative management tools for storm water runoff protection and to provide optimal protection of our water sources still exist.

In environmental engineering, photocatalysis is an area of research whose potential for environmental cleanup is rapidly developing popularity and success (Rajeshwar et al., 2001). Photocatalysis, a natural chemical process, is the acceleration of a photoreaction in the presence of a catalyst (Fujishima et al., 1999). Photocatalytic agents are activated when exposed to near ultraviolet light (320–400 nm) and to water. This technology can break down organic molecules, like pollutants, into smaller molecules and can ultimately degrade the molecules into carbon dioxide and water (Hermann, 1995).

Although retention ponds have been identified as a powerful mechanism to resolve storm water runoff pollution issues associated with urban areas, urbanization has attributed to a reduction in the functionality of this normally natural process. Cultivating measures to enhance a retention pond's breakdown capacity may provide a means to resolve this problem. In this way, retention pond function *and* construction, combined, would serve as a valuable tool to manage runoff pollution.

We propose using titanium dioxide coated materials in retention ponds, as catalysts for water purification, and then evaluating the removal efficiencies of these materials to determine whether they could be used to improve the pond's degradation function. These photocatalysts would be constructed out of light-weight materials that would float on the water and, under UV radiation, would be able to decompose such contaminants as chemical pollutants in the water (Choi, 2006). Photocatalytic materials for a water treatment have been conducted using such materials as coated particles suspended in contaminated water (Li et al., 2003; Kanki et al., 2005). This type of purification process can be labor intensive and costly. For example, processing steps can include pumping water, mixing water and the catalyst, exposing the mixture of water and catalyst to air, irradiating UV to the mixture of water and catalyst, and then sometimes running these materials through a reactor. These methods make it challenging and impractical for the purification of large amounts of contaminated water, like ponds, lakes, and rivers and retention ponds. However, floating materials coated with titanium dioxide could be very useful for the treatment of large bodies of contaminated water. Furthermore, the floating catalysts would require little or no maintenance, and the production cost would be relatively inexpensive.

NASA UV data could be (1) integrated into SLAMM and SWMM to enhance the understanding of how these models function, and then (2) used to predict and evaluate the effectiveness of using floating photocatalytic materials in retention ponds, so that their ability to use solar UV radiation for pollution removal could be improved.

b. Identified Partner(s)

The EPA works with state, local, and federal governments, as well as with industry and environmental groups, to identify requirements necessary to develop water pollution prevention programs. The agency also provides systematic approaches for identifying and reducing the causes of source pollution resulting from urban development activities that can affect water quality.

The EPA's Pollution Prevention Act (1990) defines "source reduction" as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering anywhere into the

environment (before recycling, treatment, or disposal) and that subsequently decreases hazards to public health and the environment that would be associated with the release of such substances.

Today, a leading source of water pollution is associated with polluted runoff. Treatment technologies for removing contaminants from drinking water are expensive and do not eliminate the contaminant source. If water runoff was cleaner, water bodies for all use, including drinking, would be improved. The EPA's Clean Water Act (2002) helps establish national goals to protect and maintain the chemical, physical, and biological integrity of our Nation's waters and works with state, local, and government agencies to develop programs to regulate the control of storm water runoff from urban, industrial, and construction sources.

Since retention ponds are constructed to contain and to treat storm water pollutants, they should also minimize the effects runoff has on the environment. From a functional perspective, retention ponds have several important advantages: low costs, simple operation and maintenance, and high performance. However, their principal disadvantage is that because they are an entirely natural method of pollution treatment, their efficacy is dependent on the amount and availability of UV light. Therefore, if runoff is uncontrolled or inefficiently treated, pollution from these ponds can contaminate the environment. Because of these concerns, individual states are required to develop and implement source water assessment and protection programs that monitor pollutants from water runoff.

The EPA developed the SWMM to assess water runoff quantity and quality for urban and non-urban areas. The SWMM is the most frequently utilized storm water runoff model that is used for urban planning, analysis, and design; this model can estimate the production of pollutant loads associated with this runoff (EPA, 2007). The SLAMM was developed to enhance this assessment process. SLAMM is based on small runoff volume hydrology, and this model increases source pollution prediction accuracy, which in turn helps improve water quality controls upon runoff flow. Recently, the SWMM has been integrated with SLAMM to produce a more useful tool. The combination of the two models helps increase evaluation and condition flexibility.

By partnering with NASA, historical and real-time UV data could be incorporated into the SWMM and the SLAMM to improve their prediction capability, and in this way, provide additional useful support to state and local decision makers to help reduce potential water pollution. Furthermore, introducing photocatalytic materials as a part of retention pond function could provide a means for enhancing a pond's overall remediation performance. Together, this would enable cost-effective practices that could help establish a comprehensive integrative runoff modeling tool to assess water runoff pollution; this would include complementary remediation capabilities (photocatalysis) that could prevent, protect, and restore receiving water bodies from pollution.

c. NASA Earth-science Research Results

Heritage data from the TOMS on the Nimbus 7, Meteor 3, and Earth Probe Missions, all specializing in ozone retrieval, could be used to develop long-term UV irradiance averages. This sensor provided daily global coverage of erythral UV exposure, total column ozone, aerosol index, and reflectivity (GSFC, 2006). The latest TOMS is currently out of commission. Ozone and aerosol data is currently being provided by the OMI on the Aura satellite that was launched July 2004 into a near-polar, sun-synchronous orbit with a period of approximately 100 minutes. Aura repeats its ground track every 16 days to provide atmospheric measurements over virtually every point on the Earth in a repeatable pattern, permitting assessment of atmospheric phenomena changes in the same geographic locations throughout the life of the mission. The mission is designed for a 6-year lifetime. OMI observes Earth's solar backscatter radiation in the visible and UV with a wide-field telescope feeding two hyperspectral imaging systems. This sensor will add to the TOMS record of total ozone and other atmospheric parameters related to ozone chemistry and climate.

d. NASA Earth-Science Models

NASA-funded radiative transfer codes, such as the as the OMI Surface UV algorithm (Stammes, 2002), are used to estimate UV irradiance on the ground (Tanskanen et al., 2006a; 2006b) from satellite observations. These algorithms are relatively accurate for unobstructed surfaces.

e. Proposed Configuration's Measurements and Models

NASA historical and current UV, ozone, and aerosols datasets, along with radiative transfer models and biological activity functions, would be used for evaluating the impact photocatalysis has on the breakdown of biological and chemical pollutants in retention ponds. This would include the use of UV maps with standard and activity response information to help understand and assess UV effects on photocatalytic performance.

By partnering with the EPA and with the USGS, NASA could provide historic and real-time UV data for integration into existing storm runoff models, to help understand their functional competency. Additionally, NASA data could help determine whether the inclusion of photocatalytically coated materials in retention ponds could significantly reduce water pollution in environments at both local and regional scales.

Further research is necessary, such as studying the interaction between TiO₂ and other materials and understanding the effects of varying UV dosing. Additionally, time-dependent measurements require consideration. Because this type of ozone and aerosol data will have product continuity, life cycle issues will probably need to address product changes such as resolution and format. Such issues will result in some software changes and additional update of legacy systems.

The main objective is to achieve a certain level of pollutant removal, which then may be included as a specific objective in the design standards of water retention ponds.

4. Programmatic and Societal Benefits

By partnering with the EPA and with the USGS to collaborate on the design and maintenance of retention ponds with photocatalytic materials, NASA UV data could improve the pollution prediction efficacy of the SLAMM and of the SWMM and ultimately, by including photocatalytic technologies, could improve water quality on larger scale. Incorporation of photocatalytic materials could potentially increase the degradation capability of these water retention ponds. These approaches could shift the fundamental basis/dogmas associated with water pollution control on a nationwide level.

By improving the function of water retention ponds, NASA UV data, combined with photocatalytically coated materials, would apply to Water Quality and Public Health National Applications.

A test application designed as a future Rapid Prototyping Capability experiment would demonstrate whether photocatalytic materials would improve the efficiency and effectiveness of these ponds and whether the inclusion of additional UV data would enhance the applicability of this photocatalytic process.

5. References

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