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Emerging Contaminants: A Unique Opportunity to Develop Effective Policy based on Sound Science – Will We Take Advantage or Blow It?

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ABSTRACT: Too often, well-intended environmental improvement strategies fail or result in unintended negative consequences because the problem and proposed solutions were not fully and objectively measured and analyzed. Whether due to government agencies with compartmentalized technical disciplines or inadequate consultation with key business and community stakeholders, we find that the problem often fails to get solved or has unintended but negative side effects. In the case of emerging contaminants (ECs), such as trace pharmaceutical and personal care product contaminants in wastewater, government programs are already being implemented and many more are being discussed and proposed – without a scientific basis for expected environmental or human health protection or improvement and without objective evaluation to measure or demonstrate effectiveness.

With scientific research and capabilities related to ECs growing dramatically, as demonstrated by the presentations at this conference, we are in a unique position to steer future policy development in the direction of effective environmental improvement and human health protection. The purpose of this paper is to present the current unique opportunity to link science to effective policy action, and challenge participants in the Special Session on Policy to develop a list of steps for the EC research community to tackle.

By addressing environmental issues with a multi-disciplinary technical approach, we can prevent wasted efforts and unwanted side effects, and provide opportunities to optimize environmental improvements. Absent this approach, our government agencies (and thus citizens in general) may waste millions of dollars implementing pollution control strategies, later found to be ineffective (at best) if not counterproductive (at worst). We will suggest starting the discussion with a proposal to implement a broad-based stakeholder advisory group, including public and private sector researchers; local, state, and federal government representatives; health-care providers; pharmaceutical manufacturers; water suppliers; wastewater treatment utilities; and other relevant representatives. We will propose developing a stakeholder-based program to determine the environmental and human health impacts of emerging contaminants, and what can and should be done to prevent or mitigate the negative impacts.

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INTRODUCTION

The issue of emerging contaminants (ECs) is a rapidly growing field of study as more information is being compiled on a wider array of chemical pollutants and possible adverse environmental effects resulting from their environmental fate. Some initial environmental analyses of wastewater treatment plant discharges have pointed to disruptions in the sexual development and male-to-female ratio patterns in fish and other aquatic life. Some health officials have begun to suggest that environmental contaminants may also have a correlation to human health and demographics, particularly concerning the early onset of puberty in girls and the slowly shifting ratio of males to females born in this country. Underlying these studies and concerns is a great deal of scientific uncertainty that demands further scientific and academic inquiry before an adequate understanding of the issue can be achieved.

In spite this uncertainty, many individuals have begun to call for environmental protection and improvement strategies that address the issue of ECs. Unfortunately, such strategies, no matter how well-intended, when developed and implemented without an adequate scientific understanding of the initial issue, often result in ineffective or wasteful policies and programs, or worse, in producing unintended negative side-effects that exacerbate the problem. In addition, such strategies are even less effective when relevant and key business leaders and community stakeholders are not included in the development of these strategies. This paper is intended as a call to scientists, government agencies, and other stakeholders to come together and develop initial steps that can link sound science to effective public policy.

Over the last several years, researchers in Colorado and around the world have noticed the perceived effects of emerging contaminants in wastewater discharge on local fish populations in streams and rivers where the wastewater is being discharged. We know that ECs occur as pollutants in the environment; quantifying and addressing the environmental and human health impact of these pollutants will require a wide range of activities. The critical first step is to engage the full range of stakeholders, from consumers to product manufacturers, in characterizing the problem and developing sound and effective strategies. The full nature and extent of environmental pollution from toxic contaminants in wastewater is far from fully quantified. While these powerful biochemicals are commonly found in ECs, and are characterized as endocrine disruptors, they can also be found in pesticides and residuals, fire retardants, plasticizers, and other common chemicals and their byproducts. One major unanswered question is how much of each of these potential sources contributes to water quality impairments that may result from the presence of these chemicals.

The scientific evidence for the effects of endocrine disruptors and other toxic pollutants on the environment is in the beginning stages of being quantified. Studies conducted on the lower Potomac River as well as on Boulder Creek have provided evidence of hermaphroditic or inter-sex smallmouth bass and other smaller fish in waters that showed readable levels of endocrine disruptors.[1] Several of these studies were able to duplicate their results in laboratory tests. Studies in Great Britain have shown very similar results.[2] Effects on the wider environment are still unknown. Possible human health effects

[1] Avasthi, Amitabh. "Sex Changing Chemicals Found in Potomac River." *National Geographic News*, January 22, 2007. Accessed at: http://news.nationalgeographic.com/news/2007/01/070122-sex-change.html?source=rss Also, Woodling; John, Norris, Dr. D.; Vajda, Dr. A.; Maldonado, Dr. T.; Lopez, E. PowerPoint Presentation: "Ammonia Them, Estrogen Now: the decimal point differs." From the proceedings of the South Platte Forum, October 25-26, 2007, Longmont, Colorado. Accessed at: www.southplatteforum.org/2006_forum_files/John_Woodling.pdf

[2] Briggs, Helen. "'Gender-Bender' Fish Problem Widens." *BBC News World Edition*, September 6, 2000. Accessed at: http://news.bbc.co.uk/2/hi/in_depth/sci_tech/2000/festival_of_science/913273.stm

of endocrine disruptor pollution are a much more unknown factor. There is very little quantified evidence for the effects of long-term, low-dose exposure to endocrine disruptors on such human health problems as cancer, early onset of puberty, and other medical issues associated with elevated hormone levels.

AMBIGUITIES AND CHALLENGES

While the knowledge base concerning ECs is expanding, there are still large gaps in the overall picture of this type of pollution. The chemicals associated with emerging contaminants and their attendant by-products are found in numerous consumer, industrial, and agricultural products, which number in the dozens. These chemicals often find their way to bodies of water. Advances in trace chemical detection technologies have made the quantification of contamination possible. However, this detection technology does not tell us where these chemicals originated and how they made it into the water. This is an area that requires more research to determine the point and non-point sources of ECs, and equally as important, the relative contribution of each of these chemicals to the pollution in the water.

Trace contamination appears to act on aquatic life as endocrine disrupting compounds, affecting demographic patterns and individual sexual characteristics. What is less clear is which of the trace contaminants is causing these effects. It is unknown whether the effects are caused by a combination of contaminants or if they are cumulative impacts due to long-term, low-level exposure. Even less clear is the impact of emerging contaminants on the wider environment and if the impacts on aquatic life transfer to other ecosystems and wildlife. Any possible effects of ECs on humans at this point appear to be very speculative, although the possibility is beginning to be acknowledged. While the research done to this point is promising, these areas need to be explored more fully to foster a more complete understanding of this emerging issue.

Due to the synthetic nature of many of these emerging contaminants, one strategy for addressing this issue would be to deploy pollution prevention, mitigation, and treatment programs. Unfortunately, there is ambiguity in the approach as well. In the absence of the information that the research areas identified above would produce, pollution prevention programs could be implemented targeting different consumers or businesses, but their efficacy would be questioned, and the potential for waste would be high. Likewise, pollution mitigation strategies would be lacking the necessary information to develop an effective program. While pollution treatment strategies appear to have much promise, this approach has its own set of challenges. New technology and equipment can be prohibitively expensive, and the existing techniques and technologies that can be optimized to remove ECs have not yet been identified. While an argument can be made for relying on praxis to gain the information needed to make these approaches effective, this is rarely the most cost-efficient or scientifically sound method to use when addressing pollution.

PUBLIC POLICY CONSIDERATIONS

Due mainly to the recent attention to emerging contaminants on aquatic life in the media, there is slowly growing pressure on public officials to do something about this issue. However, because of the still incomplete state of science regarding ECs, there is the strong possibility of the enactment of well-intentioned, but misguided, attempts to solve the problem. The pattern of political officials seeking quick and publicly palatable solutions to very complex problems is common. This issue has the potential for 'feel-good' solutions to be implemented that are actually ineffective and end up being a waste of time and resources. Emerging contaminants include a broad range of potential pollutants, and there is a resulting larger number of potential targets for pollution reduction activities. Care needs to be taken to ensure that the most effective proven strategies in terms of actual pollution reduction, rather than convenience, are the first to be implemented when developing any sort of trace contamination reduction policy.

One big unknown relevant to public policy consideration is the relative sources and strengths of each trace contaminant and how they affect aquatic life and ecosystems. Considering that ECs are found in a wide array of products, such as pharmaceuticals, personal care products, plasticizers, fire retardants, and fertilizers, many of these and their associated industries could be adversely affected by misguided pollution abatement policies. Since the goal of addressing this issue is to promote knowledge as well as to ensure a safe and healthy environment, and not to foster unnecessary and counter-productive confrontation with any stakeholder in this issue, bringing sound science into the policy debate and development would help to avoid the alienation of impacted parties.

Major challenges to effective public policy and pollution control strategy development include the following issues.

Nontraditional Non-point Sources

The most "convenient" pollution to control is pollution that is directly traceable to a defined source. ECs are generally not traceable to a specific source. Where we can link EC pollution to a source, it is generally a non-point source, such as the human population. In other arenas, such as air pollution, history shows a clear pattern where major point sources and traceable pollutants were the first to be regulated. Control technology was effectively developed and implemented. When air pollution persisted (and sometimes increased) in spite of point source controls, regulators reluctantly looked to controlling area (dispersed) sources and to developing control and prevention methods to reduce pollution that was not traceable to a single source. ECs will challenge the most innovative of pollution prevention and control strategy developers.

As noted above, not only must the sources be determined, but the relative contributions of the sources must also be determined to then develop scientifically effective mitigation strategies.

Lack of Defined Cause and Effect Relationships

Consistent with non-point sources of environmental contaminants, ECs characterized in streams and wastewater treatment plant (WWTP) discharges present human health and environmental concerns. But the concerns have not been quantified. The link from the presence of ECs to human health and ecosystem threats has not been adequately made. Steadily improving analytical capabilities are making the detection of more trace contaminants possible. Improved analysis is desirable, but it is critically important to clearly identify what increases in EC identification are due to improved chemical analysis and what is due to changes in the environment.

POLICY RESEARCH TO ADDRESS CHALLENGES

As the research into emerging contaminants continues to expand, the effects on the environment are slowly becoming more apparent. Further and more extensive research points to a growing urgency for dealing with ECs. While there are the ambiguities and difficulties as described above, there is no reason that progress cannot still be made in addressing this issue. One way to avoid the pitfalls in policy development described above would be to adopt a multi-disciplinary, technical, and stakeholder-based approach to that policy development.

To this point, many of the pollution control and abatement laws and regulations have been reactive in nature, as environmental agencies, research personnel, and citizen activists perceive a relatively large problem and work to alleviate these pollution-based problems by implementing a top-down regulatory solution. This process has indeed resulted in reductions of pollution overall, yet the inflexibility of such a top-down system has meant that unnecessary adversarial relations have developed between environmental

and public health agencies charged with implementing these plans and the businesses that must comply with them. Furthermore, a 'one-size-fits-all' approach to pollution abatement has resulted in less than efficient pollution control activities. This inflexibility and inefficiency cannot be solely ascribed to the actions of government agencies, as they are also a result of preconceived notions as to the sources of pollution. As alluded to above, this poses a major stumbling block in dealing effectively with emerging contaminants; care needs to be taken to ensure that 'obvious' or deep-pocketed targets of pollution abatement schemes are only targeted if they are actually the major sources of ECs.

Policy Based on Science

An urgent need exists to find, test, and implement sound scientific cost-effective solutions to complex environmental problems. By addressing environmental issues with a multi-disciplinary technical approach, we can prevent waste and unwanted side effects, and provide opportunities to optimize environmental improvements, and reduce energy consumption and greenhouse gas emissions. Too often, well-intended environmental improvement strategies fail or result in unintended negative consequences because the problem and proposed solutions were not fully and objectively measured and analyzed. Whether due to stove-piped government agencies with compartmentalized technical disciplines or inadequate consultation with key business and community stakeholders, we find that the problem is not effectively solved.

Public policy is not often based on sound science. However, public policy to address environmental problems is most effective when it is based on sound, independent, and objective scientific analysis – although this is often not the easiest approach. Emerging contaminants is an environmental problem which needs such analysis.

The analysis to develop effective public policy needs to begin with definition and understanding of the problem. That, of course, is a challenge in this case. But we must define the problem we are addressing before embarking on scientific analysis to address it.

Stakeholder Approach

This is where a stakeholder-based, multi-disciplinary, and technical approach can be very valuable. By having cause-effect research done at the outset of a project, with stakeholder involvement, a wide array of information relating to as many facets of the issue as possible can be complied to use as a baseline for the definition of the problems the issue presents. Compiling a stakeholder base for the issue, beyond those typically associated with pollution abatement identified above and particularly inclusive of relevant business interests and professional groups, provides a foundation for collaborative activities that can result in more specifically defined problems to be addressed and potential solutions to these problems. Taking a stakeholder approach to this problem helps to avoid excessive confrontation and adversarial relationships between equally relevant and important stakeholders or stakeholder groups. People working together tend to avoid duplication and inefficiency. Being as inclusive as possible in engaging stakeholders helps to foster acceptance of potential solutions that need to be investigated further.

The process to bring the community and stakeholders together to identify and reduce exposure to ECs must be multi-faceted. Working with local and regional community members is a way to determine the most effective means to bring groups together for meaningful dialogue.

To work effectively with stakeholders and community groups, one must first understand the factors what motivates the members of these groups. Understanding the issues of importance to each stakeholder allows one to find effective means to engage individuals in joining the collaborative effort to tackle the challenge of emerging contaminants. For example, the motivation for a pharmacist to participate would be

different than the motivation for a local university. Once a relationship is established, stakeholders should have the opportunity to network with each other and potentially find additional benefits from meetings and other avenues of communication. Meetings are just one way that stakeholders have the opportunity to have their opinions and comments heard and to make a difference in their community. Collaborative working groups can be established as needed to work on specific issues and to address the specific needs and priorities of groups of stakeholders.

Educational outreach information developed in collaboration with key stakeholders can help to bring participants to a common level of understanding. Printed and electronic communication tools, as well as presentations and discussions, can provide important technical and environmental information. Comprehensive background research, consultation with regional and national experts, and organization of scientific and regulatory information is needed.

POTENTIAL STRATEGIES TO SUPPORT EFFECTIVE POLICY DEVELOPMENT

Baseline Information

Before possible solutions can be attempted, baseline data need to be assembled to be able to accurately gauge the efficacy of each individual approach. When considering ECs in water and how to compile this information, it may actually be easier to do the initial studies at places high in the watershed to avoid as much anthropogenic pollution as possible. Since the potential sources of emerging contaminants are very diverse, working with as blank of a slate as possible would help to identify which of the varied pollution abatement activities are actually working. In other words, it would make no sense to implement a pharmaceutical take-back program if the greater source of ECs happened to be fertilizers. Much of this baseline data can be compiled by water quality tests being taken at both the water treatment works as well as the WWTP, and then cross-analyzing this data. Indeed, WWTPs may offer great promise in confronting this pollution problem, but without the data to back this up, it is naught but pure speculation.

Accessible Database

An electronic database similar in style to Wikipedia (the free on-line encyclopedia) could offer the stakeholders and the public access to scientific data on EC research, data, and projects. It could allow scholars and outside experts to contribute additional edited definitions, articles, and current information to e-library. The specific concept is to allow the dissemination of information to the general public and sharing of information among stakeholders and researchers while gaining supplemental information from additional sources. Contributors could submit information and articles in a submission page that would be peer-reviewed. Qualified work would then be filed within the database. Stakeholders would be included in all phases of the process. Educational awareness of the database would be provided to the public on how to properly use the database for their benefit. The specific areas that the database would cover could include (but are not limited to):

- Human health risk
- Ecological risk
- Technological advancement in trace pharmaceutical isolation and removal
- Mitigation processes, analytical methods and results

While building on the numerous positive aspects of the public access Wikipedia concept, it is important to note that the proposed technical database would not allow free and unedited access. Rather, it will be “gated” to assure the highest standards of scientific peer review.

The Internet provides amazing new opportunities for access to information. However, thoughtful and organized information on important scientific issues is not readily available. Providing access to reliable and comprehensive information consolidated in one location would be a powerful asset in effectively tackling the challenge of trace pharmaceutical (emerging) contaminants.

Potential outcomes of this database include: increased public awareness of the human health and ecological risks of ECs; centralized access to vast data and information on ECs; regulatory information on what actions are being taken to mitigate the contamination of local waterways from trace pharmaceuticals; and information on what potential methods may be useful in the isolation and elimination of pharmaceutical residual in wastewater.

Pilot Test Programs

It is not practical or realistic to wait until science and technology developments have established firm answers to the questions of the sources, impacts, and mitigation strategies of ECs before developing approaches to the problem. However, it is vital that experimental control and mitigation projects be developed with monitoring and measurements to determine the effectiveness of the effort both in total life cycle costs and in environmental benefits. Independent objective scientific measurements (not modeling) of the programs is essential.

1. Wastewater Treatment Plant Processes to Remove ECs: A potential initial pilot program could tackle existing wastewater treatment processes for removal of trace pharmaceutical contaminants. There are indications that existing treatment methods utilized by WWTPs can remove varying concentrations of trace pharmaceutical contaminants from wastewater.[3] Thus, the important question is how current wastewater treatment methods affect endocrine disruptor pollution levels, if at all, and how effective methods can be optimized. A pilot program could work with smaller local wastewater treatment plants to investigate which aspects of the treatment process are responsible for the removal of the contaminants. It would study whether enhancing current technologies would result in cost-effective removal of more trace pharmaceutical contaminants from wastewater.

It is well known that one of the critical challenges of the EC issue is measuring the contaminants in water. This pilot program would start with tackling the limits of feasible measurements, so that useful analysis can be done within a reasonable budget. A later phase would incorporate broader field testing and implementation and evaluation of treatment methods, if the pilot project points to promising strategies. The pilot could include the following tasks:

- Identify the environmental benefits to having reduced concentrations of trace contaminants entering waterways
- Research existing treatment methods
- Determine if there have been any studies already done regarding current and/or new treatment methods. Identify mitigation strategies that have been used in other projects
- Work with stakeholders to implement the pilot program. Identify and involve stakeholders in the design, testing, and evaluation of treatment methods
- Develop a way to measure the amount of trace contaminants entering and leaving the WWTPs, both before and after enhanced treatment methods are utilized. This program would focus on pollution reduction. Quantifying the results would indicate whether the program was effective or not. A cost-benefit analysis would also be completed once the results are quantified
- Educate other WWTPs and municipalities about the potential benefits of the pilot program.

[3] Interview with Ken Lykens, P.E., Principal Engineer for MWH Group. September 28, 2006.

2. Pharmaceutical Take-Back Program: Some states and communities have implemented programs that aim to reduce the amount of these contaminants entering the environment through implementation of pharmaceutical take-back programs. The actual methods vary and include a mail-in program, the depositing of pharmaceutical and personal care products at previously designated household hazardous waste collection centers, and allowing pharmacies to accept pharmaceuticals at their counters for later disposal. A two-phase collaborative program could evaluate and implement some of the methods for pharmaceutical take-back programs mentioned above. Phase 1 would focus on the research, design, and educational components of a program in collaboration with all concerned stakeholders. Phase 2 would entail broader field testing and implementation by a local agency, and evaluation of the pilot project, in collaboration with local and state agencies and stakeholders.

It is important to recognize that, while a pharmaceutical take-back program may be a visible response to the challenge of trace contaminants in wastewater, it may not provide significant or measurable reductions in wastewater contamination. Thus it is critically important to develop a program that involves cost-effective public education building on efforts in other areas and pursuing parallel efforts to address this complex challenge. Tasks would include:

- Establish a Stakeholder Steering Committee, involving selected participants, such as state regulatory agencies and key stakeholders. Implement the Steering Committee to organize the collaborative effort
- Research existing take-back programs in U.S. states and communities to determine their crucial elements, and if possible, their efficacy. Use this research to formulate a proposed pilot program
- Research existing disposal methods to determine the most effective method for the prevention of the release of trace contamination from disposed-of medications
- Develop a broad-based stakeholder committee to determine the legality of a proposed program, the specific details of a final pilot project, feasibility, environmental testing standards, and the final objective evaluative parameters for the project, among other considerations
- Collaborate with stakeholder committee to develop relevant educational strategies, information, materials, and programs
- In collaboration with Steering Committee members, develop a proposed pilot program to be implemented by a local agency at a pilot site or sites to be determined in consultation with the stakeholder committee.

Pollution Prevention

The diversity of points of discovery of ECs suggests that trace contamination in streams is a pervasive condition. Effective pollutant removal at the point of impact may be cost-prohibitive. Pollution prevention starting with the source (like pharmaceutical take-back) may be the most technically and cost-effective strategy to reduce ECs in the environment. Limited research has been done to investigate and develop pollution prevention strategies.

There are significant challenges to achieving significant reductions of ECs in the environment through pollution prevention. Generations of changes in human behavior, such as we have experienced in the reduction of cigarette smoking, may be required.

However, the fundamental pollution prevention approach has the potential to be the least costly and most effective. Therefore it is extremely important to tackle this approach.

Public Information

The final piece of this new approach concerns the involvement and education of the citizenry. Of course, interested citizens are a valuable part of any stakeholder group. However, their involvement does not end there. Educating the public about the issue of emerging contaminants is a very important part of this process. Quality research and information compiling is needed before an educational campaign can commence, as education offered to the public needs to be properly contextualized and presented in a manner they can readily understand.

Information dissemination and communication may need to address the fact that objective scientific analysis and results may be disappointing. Sound independent research may yield results that contradict popular understanding. The science may point to contaminant sources and impacts that are bad news for businesses, manufacturers, even government agencies. Thorough preparation of and commitment to solid scientific information is essential to overcome such disappointment and potential opposition.

The broad involvement and engagement of the full-range of stakeholders throughout the process is important to promoting the dissemination of objective scientific results.

CONCLUSION

The issue of ECs is vast and multi-faceted, and poses many large and challenging questions that beg to be answered. However, one reality of this new century is that resources for these types of activities are limited. This demands that any actions taken to address the issue of emerging contaminants need to be done right the first time. This can be accomplished by implementation of stakeholder-based approaches to strategy development, and a steady regimen of monitoring and evaluation of any activities pursued. There are many opportunities for being pro-active in addressing the extensive challenges of ECs, and every chance to affect positive and effective change should not be missed.

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