COMMENTARY

On Applied Toxicology

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Abstract: Analytical chemistry allows an accurate quantification of the total concentrations of a range of chemicals in different media of the ecosystems and contaminated sites, but the numerical values do not have direct relevance to the toxicity of them because the measured concentrations do not represent the active fraction that imposes toxic effects on organisms. It is apparent that an assessment of pollutant concentrations in ecosystems shall be made with new innovation to obtain the organism exposed concentrations so that the subsequent toxicological effects based on these data can provide reliable estimate on toxicity for management decision accordingly. Applied Toxicology, e.g., Ecotoxicology, and Environmental Toxicology, therefore shall have a different scientific framework to adopt the use of a new concentration term for pollutants to establish a close relationship between the effective concentration in the ecosystem and the toxicity to the organisms to make a meaningful understanding of the ecotoxicology and environmental toxicity. In addition, the choice of the organisms as indicators for chemical toxicity assays is another critical issue and the organism shall be selected with an international consensus to establish a solid baseline for comparable results from different laboratories around the world. Doing this way, the Applied Toxicology can make great advancement and contributes to the society better on a more competitive level based on exact science similar to physical sciences today. A greater opportunity is ahead and effective action needs to be taken collectively and immediately to advance the new knowledge of this research subject.
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Our society is facing a great pressure from population increase and the associated environmental deterioration from greenhouse gas emission, wastewater discharge, agricultural chemical contamination, oil and chemical spills to industrial pollution. Environmental pollutants including both metals and metalloids, and organics are toxic and have their negative impact on microorganisms, flora and fauna, upon exposure at high concentration or over a long period of time. Toxicity testing conducted under the current laboratory conditions generally involves the introducing of a high concentration of the selective chemical to a selective organism and then monitor the terminal end-points, mortality, biochemical, physiological and genetics (molecular) to derive the LD_{50}/LC_{50} as an end-point value for comparison and assessment of safety from toxicity threshold values (Bitton and Dutka, 1986; Dutka and Bitton, 1986; Cairns, 1983; Alexander, 1999; Schwarzenbach et al., 2006). This approach was and has been used very successfully in medical science, particularly pharmacology, but is generally misused in the ecological and environmental science areas, resulting in huge variability and non-reproducible data. The simple reason for the current situation is that pollutants interact constantly with the physical environment, and the analytical concentrations of pollutants in samples cannot serve as a reliable numerical value for toxicity estimation because they do not have a high correlation with the fraction of the total concentration that the organism experiences. Then, the toxicity is derived from pure chemicals currently for predicting those in the ecosystems without considering the association with matrices or ageing over time (Alexander, 1999; Gu, 2018; Stotzky, 1986). On these bases, concentration analysis by chemical approach is one of the most important issues and an accurate evaluation of the toxicity of pollutants in ecosystems dependent upon the meaningful concentration of the pollutants. The inability to derive an accurate biological based concentration by accepted method causes the high variability of the current toxicity assays. An fundamental improvement of the current situation will need innovation of the analytical methods and adoption of organisms readily available at low cost to provide a solid foundation for applied toxicology.

1 The Meaning of Concentration

Pollutant concentrations in ecosystems can be measured analytically, but they are highly variable due to the physical, chemical and biological entities involved of the specific ecosystem. In addition, time is another factor that affects the availability and also concentration of pollutants to the affect organisms. For metals and metalloids, sequential extraction procedures illustrate this very well to a very large extent (Tessier et al., 1979), but unfortunately there is no similar conceptual framework established for the organic pollutants. This deserves some very serious soul searching to move forward. In the sequential extraction procedures, different fractions, including water soluble, sorbed, carbonate, Fe/Mn oxides, organic matter, and the mineral structural components, are experimentally obtained for a meaningful understanding of chemical states and the bioavailability from the total analytical concentration. This allows a better assessment of the chemical (bonding) state for more accurate bioavailability evaluation or prediction from the overall total concentration, including toxicity to be derived from these data. This laboratory based and well-defined method can be applied for a good understanding of the inorganic pollutants in sediments and agricultural soils experiencing sequestration and decreasing of toxicity even though the chemical concentrations may remain without much changes (Alexander, 1999; Stotzky, 1986; Stumm and Morgan, 1996). Since toxicity of chemicals is assessed with pure chemicals under laboratory conditions, there is a great deviation in toxicity between the pure chemical and the chemical in the environmental matrices, especially at the same analytical concentration for both. This happens without considering ageing of chemical in ecosystem over time, e.g., herbicides and pesticides (Alexander, 1999; Gu, 2016, 2018, 2019). It is a common practice to obtain sediment/soil samples and then carry out analysis of the target chemicals for a prediction of their toxicity based on toxicity mainly derived from pure chemical assays under laboratory condition. This way of conducting science and then environmental management is not science-based by introducing huge error because of the misunderstanding of the chemical pollutants in the matrix of environmental samples. Without a better approach to address this critical issue, the current literature and the additional new ones on applied toxicology is of very little value for decision-making.

Concentrations used with toxicology data are highly variable in their meaning. When conducting a toxicological assay, a common practice widely used is to spiking a range of concentrations into the testing system and then monitor the exposed organisms for end-point analysis (Cairns, 1983). In this approach, the concentration term is an assume one, not determined through analytical or other means. In addition, the real concentration in the testing systems, no matter water or sediment/soils, is not or rarely measured (Yu and Gu, 2008; Yu et al., 2007; Yu and Feng, 2016), so the relationship, or cause-and-effect, later on reported, is not based on the actually determined concentrations or to the corresponding responses by the selective organisms. The scientific basis becomes shaky and the data are therefore not reliable. When dealing with high toxic chemicals, polyaromatic hydrocarbons (PAHs) and agricultural chemicals (DDT), they do not dissolve in water well due to hydrophobicity (Schwarzenbach et al., 2006). Though in practice solvent is used to allow such chemical to be delivered to the test vessels at the predicted concentrations, the actual concentration in water or other media will be reduced greatly depending on the size of the vessels used and also the matrix compositions, e.g., sediment. Such fundamentally important factors, that affect the concentration so greatly, have not been given an adequate or enough attention to address such urgent matter to establish a meaningful concentration, effective concentration (activity) in scientific research. When dealing with so large inventory of chemicals, testing their toxicity is almost an impossible task to achieve. Since the toxicity evaluation and assessment are being conducted in such ambiguous way, the available data have weak scientific basis and less reliable meaning for any extrapolation.

2 Toxicity Testing

Applied toxicology is mostly about the pollutants in natural or contaminated environments, and then assessment of their toxic effects. There is no agreed common organism to be used for a comparative toxicology research currently. The choice of testing animals is a big issue in the field of applied toxicology even though some organisms are proposed for adoption, e.g., blue mussels, zebra fish and microorganisms (Gu, 2018). The major issues here for a careful consideration are the availability of such organisms with a well-documented genetic background, readily access and inexpensive, and also physiological state for calibration. Without a solid ground on the calibration and reproducibility, the toxicological results derived from them worldwide are less meaningful or meaningless due to the high variability. This important issue has not been addressed seriously, but new data are continuously generated, making this ambiguous situation without any clear solution, but accumulating more and more data. Since both the concentration and the organisms are at the fundamental basis for generating reliable and reproducible results, toxicological tests are undermined. With these issues, future advancement and development of this research field are seriously compromised to become a more competitive research subject area. If toxicological testing data are used for management, the research conducted now is no more than service simply to provide some reference data on each separate case. This is an uncomfortable situation for young people because of their future career may be directed to this field without a clear understanding on the current status and issue.

Pessimism expressed here is not to discourage anyone, but to encourage and support those working on this subject area to recognize the shortfalls and then make a genuine effort with a common goal to promote and advance this subject area to the next level with the current available information and technology to be a better research field with identity and public reputation (Gu, 2018). A new way to derive the environmental concentration of pollutants shall be advanced to provide new insights to the new concentration that are meaningful for the organisms and then toxicology assessment. At the same time, the selection of organisms for toxicology analysis shall form a set of standard protocols or practices to implement international calibration of tests to safeguard the data generated and reported. Without such ground level for everyone, data are not useful and financial resources are wasted without producing any useful results for management and assessment. This is a serious dilemma we are facing currently.

3 Ecotoxicity Inference

Applied toxicology is a useful subject to protect people and serve the society. The gap between toxicology and applied toxicology, including ecotoxicology and environmental toxicology, is huge and the deviation between them results in many uncertainties in our understanding of applied toxicology and management action. To bridge this gap, genuine efforts are needed from physical sciences, especially analytical chemistry and physical chemistry to incorporate understanding of the physical world into the derivation of chemical concentrations of biological meaning. This research field can be further strengthened more when the scientific contents of the research practice can be focused on both a better understanding of the concentration relevant to organism exposure and also the choice of a set of easily accessible organisms readily for international adoption and use. Without a common agreement on these two key issues, future development and reputation will be compromised for this research subject. The required action is a timely one because the science of the testing and the animals used must be of the caliber of scientific research and for the scientific scrutiny, similar to physical sciences. Chemical concentrations shall be more close to the biologically meaningful and chemically obtained, available concentration to the testing organisms. This requires toxicological researchers to be knowledgeable about the physical sciences, e.g., clay mineralogy, applied chemistry, and physical chemistry to be equipped with the available basics to conduct their experiments accordingly.

Environmental management can become a science only when the available data are strongly based on scientific knowledge and derived through scientific methods. Applied toxicology has its own unique characteristics and role to today's society by protecting people and also the ecosystems, but its success will be highly dependent upon the contributions from basic sciences. Choice of the acceptable organism is a much more difficult challenge than a better technical approach to obtain the concentrations due to the available data and also the on-going research and testing internationally. On this issue, a proactive approach is needed before going too far in to counter-productive direction.

4 Future Perspectives

DNA technology and bioinformatics provide new momentum and a solid basis for many old and new subject areas to modify and improve, applied toxicology shall embrace this new development effectively and productive to advance the subject area. These new techniques will enhance the fundamental information and knowledge on the organisms and also the specific changes taking place during exposure to the enzymes, genes, and nucleotide sequences to be more specific (Gu, 2018; Alexander, 1999; Schwarzenbach et al., 2006). With such accuracy, toxicology has a great opportunity to flourish into a more competitive research subject to be aligned with new emerging technology. Through gene editing, more innovative research can be conducted to test the specific genes involved for the morphological or phenotypic changes observed at a much fast pace.

In conclusion, applied toxicology faces a serious issue in deriving a meaningful concentration of the pollutants in environmental matrices for a meaningful assessment of toxicity to organisms. This issue requires a similar approach to sequential extractions procedures for metals and metalloids in sediments and soils to be developed for the organics soon. With a meaningful understanding of concentration, toxicity shall be assessed with reference organisms of international wide adoption implemented to advance the fundamental science on this subject. With these basics established on a solid ground, toxicity of pollutants in the environments can be evaluated meaningfully and reliably to provide useful information for management decision.

Conflict of Interest

Author declares that there is no conflict of interest in this research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by the author involved.

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