Research on environmental impact of water-based fire extinguishing agents

Shuai WANG
Tianjin Fire Research Institute, Tianjin, China
wangshuai@tfri.com.cn

Abstract. This paper offers current status of application of water-based fire extinguishing agents, the environmental and research considerations of the need for the study of toxicity research. This paper also offers systematic review of test methods of toxicity and environmental impact of water-based fire extinguishing agents currently available, illustrate the main requirements and relevant test methods, and offer some research findings for future research considerations. The paper also offers limitations of current study.

1. Introduction and need for the study

1.1. Environmental aspects
Fire extinguishing agents are used extensively around world for suppression and control of fires. Each year, fire control agencies utilize millions of mixtures on a wide array of ecosystems. On the other side, the application may contain endangered, threatened significantly on plant and animal species. Historically, little information was available on the toxicity of these chemicals to aquatic and terrestrial life; less information was available concerning impacts at the community and ecosystem level.

The extensively used ammonium compounds-essentially dry or liquid fertilizer formulations - have long been considered to have minimal toxicological or ecological impact.

1.2. Research considerations
Water has been recognized as a fire extinguishing agent in ancient times. This is because of the characteristics of strong heat absorption and cooling ability of ambient environment. At the same time, water could be transformed to large amount of steam after being vaporized, and the steam could prevent air from entering into the burning area, cut down the entering of combustion accelerator, and thus cut down the burning process. But it is also noted that water has some deficiencies in being applied as fire extinguishing agent. Water has high degree of fluidity, hard to stay on the surface of the burning item, and thus it cannot linger on the combusting item for a longer time and cannot cooling down the temperature and will probably lead to vapor explosion if more vapor accumulated within an enclosed space. In that case, certain additives have been added in water to change the physical and chemical performances of water and to elevate fire performance with lower application of the amount of water.

More awareness have been aroused that water additives in fire agents have harmful effect to human beings, living creatures and environment. China’s government has signed Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention or Convention for short) on May 23, 2001. The
tenth session of the standing committee of the National People’s Congress has approved *Convention* on June 25, 2004. *Convention* has become effective in China on Nov. 11, 2004 and is applicable in HKSAR and MacauSAR. According to the requirement No.7, China compiled and submitted *China national implementation plan for Stockholm Convention on Persistent Organic Pollutants* to contracting party. China promises to undertake every obligation in Convention, and to involve the obligation to China’s relevant national plan, to make and improve relevant management policies, and to make and implement regarding policies and necessary measures, with a view to achieve the control objective. In addition, toxicity and environmental effect of liquid agents have also been increasingly realised. International organizations and some national institutes have offered toxicity test methods, such as toxicity from bacteria, aquatic life, mammals and soil.

1.3. Research plan
By analysing OECD test methods, OPPTS test methods and tracing ISO standard projects on Class A foams with the test methods on toxicity specifically, the paper tries to combine different methods together, and try to find pros and cons to accumulate academic experiences for future standard development.

2. Research analysis

2.1. Available standards
Based on current materials compilation, toxicity and environmental effects are regulated under the following standards materials.

| No. | Standards | Name of standards |
|-----|-----------|-------------------|
| 1   | GB17835-2008 | Water based extinguishing agent |
| 2   | NFPA18-2017 | Standard on Wetting Agents |
| 3   | NFPA 18A-2017 | Standard on Water Additives for Fire Control and Vapor Mitigation |
| 4   | WD ISO 7203-4 | Fire extinguishing media—Foam concentrates—Part4: Specification for Class A Foam Concentrates |

2.2. Research analysis
OECD (Organization for Economic Co-operation and Development) is an intergovernmental economic organisation with 35 member countries, founded in 1960 to stimulate economic progress and world trade. It is a forum of countries describing themselves as committed to democracy and the market economy, providing a platform to compare policy experiences, seeking answers to common problems, identify good practices and coordinate domestic and international policies of its members. Most OECD members are high-income economies with a very high Human Development Index (HDI) and are regarded as developed countries. OECD is an official United Nations Observer.

As for the development of globalization, trade volume of chemical products, pesticides, pharmacies and cosmetics have increasing grown. More tough safety problems of chemical products aroused. It has become common knowledge to evaluate and monitor the safety and impact to environment, human-beings and living creatures of chemical products. The OECD Council therefore adopted a Council Decision in 1981 – on Mutual Acceptance of Data (MAD) - stating that test data generated in any member country in accordance with OECD Test Guidelines and Principles of Good Laboratory Practice (GLP) shall be accepted in other member countries for assessment purposes and other uses relating to the protection of human health and the environment.

It has recently been reported that China is in discussions with the Organization for Economic Cooperation and Development (OECD) to become a provisional adherent to the Mutual
Acceptance of Data (MAD) system. This would require China to accept data from safety testing of chemicals from participating countries generated under the MAD conditions and to establish a Good Laboratory Practice (GLP) compliance monitoring program. If China were to become a provisional adherent to the MAD system, this decision could conflict with its requirement that certain environmental and aquatic toxicity studies be conducted in China. The timeframe for the discussions was not provided.

| Parameter       | ISO draft about Class A foam | China's GB standard | NFPA18&18A | China's standard on water-based extinguishing agent |
|-----------------|------------------------------|---------------------|------------|---------------------------------------------------|
| Bacteria        | EN ISO 11348/2                |                     |            |                                                   |
| Aquatic life    |                              |                     |            |                                                   |
| Fish            | OECD-203                     | GB/T27861-2011      | OPPTS850.1075 | GB17835-2008                                    |
| Daphnia         | OECD-202                     | GB/T21830-2008      |            |                                                   |
| Algae           | OECD-201                     | GB/T 21805-2008     |            |                                                   |
| Degradation     | OECD-301f                    | GB/T 21801-2008     | OPPTS835.3110 |                                                   |
| Mammals         |                              |                     |            |                                                   |
| acute toxicity, oral, rats | OECD 420                  | GB/T 21804-2008    | OPPTS 870.1100 |                                                   |
| Skin Irritation and Corrosion | OECD 404                | GB/T 21604-2008    | OPPTS 870.1200 | OPPTS 870.2500                                  |
| irritation eye  | OECD 405                     | GB/T 21609-2008     | OPPTS 870.2400 |                                                   |
| Soil            |                              |                     |            |                                                   |
| Earthworm, Acute Tox. Test | OECD 207                  | GB/T 21809-2008    |            |                                                   |
| Terrestrial Plant Test | OECD 208                  | GB/T 27851-2011    |            |                                                   |

2.3. Parameters analysis

As for degradation, China has conducted relevant research on foam extinguishing agents. Zhang (2014) investigates the biodegradability of the component and typical foam extinguishing agents by carbon dioxide evolution test and manometric respiration test. The results show that 28 day biodegradation rate of reference compound sodium dodecyl sulphate is 89.4% and 85.1%. These two methods are equivalent in the evaluation of the biodegradation of foam extinguishing agents. According to the criteria, the foam extinguishing agents tested in the paper are easy for biodegradation. Zhang also explains the reasons for their easy biodegradation from the prospect of the composition of the foam extinguishing agents.

Regarding to toxicity parameters, Barry Poulton (1997) has offered several toxicity findings. All five chemicals were of comparatively low order of toxicity to terrestrial species. For all test species, the LD50 exceeded the limit criteria for significant acute toxicity suggesting that no mortality should result from direct chemical application or from dietary exposure to fire chemicals. However, results from avian tests suggest that dietary exposure to Silv-Ex may result in temporary lethargy and loss of equilibrium in birds. Tests with aquatic organisms indicated the two foam suppressants (Silv-Ex and Phos-Chek WD-881) were similar in toxicity and were significantly more toxic than were the three non-foam chemicals. Water quality did not modify toxicity in a consistent manner for all species. The egg life stage of fish species was more tolerant of chemical exposure than other life stages; swim-up (larval) stage was most sensitive. These results imply that accidental introduction of these chemicals into an aquatic system during the salmonid swim-up period could cause significant mortality and be catastrophic to a local population, especially if that population were threatened or endangered. Degradation of all five chemicals was more rapid in soils with high organic content that in soils with low organic content. The overall rapid degradation of both foam and nonfoam chemicals that was documented during these studies suggests that long term effects from the chemicals tested would be
unlikely.

3. Conclusion and limitation of the study
This paper offers test methods of toxicity currently available and finds the interrelationship in different standards. The paper also offers current research findings in the relevant fields which offered solid theoretical knowledge for China's standard development and maintenance on foam and water-based fire extinguishing agents. In addition, more attention should also be focused that due to the limitation of research funds and efforts, the paper did not offer any practical experiments nor any pilot study research on China's liquid agents.

References
[1] Antea Group Project No. 45618 del04, Perfluorocarbon(PFC) – Containing Firefighting foams and their use in Minnesota: Survey and Sampling Activities, State Fiscal Year 2011
[2] International Organization of Standardization. ISO 7203-1: 1995 Fire extinguishing media — Foam concentrates — Part 1: Specification for low-expansion foam concentrates for top application to water-immiscible liquids
[3] International Organization of Standardization. ISO 7203-2: 1995 Fire extinguishing media — Foam concentrates — Part 2: Specification for medium- and high- expansion foam concentrates for top application to water-immiscible liquids
[4] International Organization of Standardization. ISO 7203-3: 1999 Fire extinguishing media — Foam concentrates — Part 3: Specification for low-expansion foam concentrates for top application to water-miscible liquids
[5] International Organization of Standardization. ISO 7203-1: 2011 Fire extinguishing media — Foam concentrates — Part 1: Specification for low-expansion foam concentrates for top application to water-immiscible liquids
[6] International Organization of Standardization. ISO 7203-2: 2011 Fire extinguishing media — Foam concentrates — Part 2: Specification for medium- and high- expansion foam concentrates for top application to water-immiscible liquids
[7] International Organization of Standardization. ISO 7203-3: 2011 Fire extinguishing media — Foam concentrates — Part 3: Specification for low-expansion foam concentrates for top application to water-miscible liquids
[8] OCSP 850.1075 Freshwater and Saltwater Fish Acute Toxicity Test, United States Environmental Protection Agency
[9] OPPTS 835.3100 Aerobic Aquatic Biodegradation [EPA712–C–98–075] United States Environmental Protection Agency
[10] OPPTS 870.1100 Acute Oral Toxicity [EPA 712–C–02–190]United States Environmental Protection Agency
[11] OPPTS 870.1200 Acute Dermal Toxicity [EPA 712–C–98–192] Environmental Protection Agency
[12] OPPTS 870.2400 Acute Eye Irritation [EPA 712–C–98–195], Environmental Protection Agency
[13] OPPTS 870.2500 Acute Dermal Irritation [EPA 712–C–98–196], Environmental Protection Agency
[14] Robert E. Tapscott, Halon substitutes - An overview. Center for Global Environmental Technologies, New Mexico Engineering Research Institute, University of New Mexico, Albuquerque, NM 87131-1376, USA
[15] Roger A. Klein, MA, PhD, MB, BChir, CSci, CChem, FRSC, MIFireE, Cambridge, UK, Firefighting foam and the environment, Environment SUMMER 2008-09
[16] Susan Finger, Toxicity of fire retardant and foam suppressant chemicals to plant and animal communities, Final report prepared for Interagency Fire Coordination Committee Boise, Idaho
[17] ZHANG Xian-zhong al., Study on assessment methods of ready biodegradability of foam extinguishing agent, Safety and Environmental Engineering, Vol.21, pp 68-72.