ACS-Gii 2017 White Paper

CONTAMINANTS OF EMERGING CONCERN (CECs):

MOVING FROM AWARENESS TO ACTION

Version 3: 20 March 2018

About the ACS-Gii White Paper

Malaysia, through the American Chemical Society (ACS) Malaysia Chapter, hosted the ACS Global innovation imperatives (ACS-Gii) meeting on 20 and 21 November 2017.

The event was held at Johor Bahru. Universiti Teknologi Malaysia (UTM) played host to the first day of the event (20 November 2017), while Newcastle University Medicine Malaysia (NUMed) hosted Day 2 (21 November 2017) of the event.

The theme selected for ACS-Gii 2017 is "Contaminants of Emerging Concern" (CECs).

Throughout the two-day gathering, scientists and policy makers across Malaysia and beyond gathered for case study presentations, discussions and networking. A site visit was also organised on the second day, allowing participants to understand first-hand community perception on the theme of the meeting.

A white paper is produced as a result of the ACS-Gii 2017. The paper, entitled "Contaminants of Emerging Concern (CECs): Moving from awareness to action", intends to document insights obtained during the event for various stakeholders, and highlight the urgency of the theme to policy makers and practitioners in the field.

The objective of this white paper is as follows:

- To provide a general overview on CECs,
- To summarise key discussions throughout the ACS-Gii 2017, and
- To put forward recommendations concerning CECs and its impact on the community.

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Contaminants of emerging concern (CECs): Moving from awareness to action

1.0 What are CECs?

Contaminants of emerging concern (CECs) refer to pollutants that are present in water supply and wastewater discharges, and have yet to be regulated through law or public reporting.

It is also referred to as emerging pollutants, chemicals of emerging concern, constituents of emerging concern, microconstituents, trace organic organic pollutants, new emerging pollutants, and other similar terminologies.

2.0 The known CECs

CECs encompass a broad category of pollutants, among those include toxic heavy metals such as lead and cadmium, petroleum hydrocarbons, polyaromatic hydrocarbons, certain pesticides and asbestos. It also includes pharmaceuticals and personal care products (PPCPs). Another class of CECs that is commonly researched is endocrine disrupting compounds (EDCs), which comprising an extensive and expanding spectrum of medical compounds.

Many CECs are detected when the scientific community, non-government organisations (NGOs), and other stakeholders conduct research on the subject. The concentration of CECs detected in the environment is small, in the range of parts per billion (ppb) or parts per trillion (ppt). The CECs are detected due to advancements in analytical technologies at wastewater treatment plants and laboratories. Examples of past research on CECs are as follows:

- Barnes et al (2004) detected a total of 76 CECs in five samples of water collected near a landfill in the U.S.

- Mak et al (2009) detected the highest concentration of perfluorinated compounds (PFC) in tap water samples taken from Shanghai, among samples of tap water taken from different countries.

- Birch et al (2015) detected eight types of pharmaceutical compounds (codeine, paracetamol, tramadol, venlafaxine, propranolol, fluoxetine, iopromide and carbamazepine), and seven types of pesticide compounds (2,4-dichlorophenoxyacetic acid (2,4-D), 3,4-dichloroaniline, carbaryl, diuron, 2-methyl-4-chlorophenoxyacetic acid (abbreviated MCPA), mecoprop and simazine) in a Sydney estuary.

- Bayen et al (2016) detected bisphenol A (BPA), atrazine and a number of selected pharmaceutically active compounds (abbreviated PhACs) in mangrove habitats in Singapore.

Among the various categories of CECs, PPCPs and EDCs are considered as major threats of concern. Examples of PPCPs include acetaminophen, caffeine, carbamazepine, diclofenac, and ibuprofen, while examples of EDCs include hormone pills, antibiotics, anti-inflammatory pills, and other prescription medications. EDCs alter the normal functions of hormones, resulting in a variety of health effects. In aquatic lifeforms, the effects of EDCs may only be observed during adulthood. These compounds are intrinsically and biologically active as molecules, with considerable toxicological concerns. They are

also persistent and difficult to remove from the water supply.

3.0 Why are CECs an emerging focus today?

Human activities significantly contribute to the release of CECs into water supply and wastewater discharges. CECs enter the environment through agricultural and mining activities. They also enter the environment through human and animal excretion, flushing of unused medications, household uses, or bathing. The CECs are neither metabolised by the body, nor treated at wastewater treatment plants.

Of great concern is the presence of CECs in surface water sources, such as rivers. This is because surface water sources are the major source of water for daily consumption. Chronic exposure to CECs, even at low concentrations, will severely impact human health.

There is an increased awareness on CECs among the public. This is because CECs are toxic for microorganisms and humankind. Perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), and arsenic, for example, were not included as pollutants until recently, when their health risks to organisms were ascertained through analysis. Many of the CECs only came to light when there is a major prevalence of medical cases reported to the authorities, such as localised miscarriages.

CECs lead to antimicrobial resistance (AMR) in microorganisms. AMR occurs when microorganisms such as bacteria, fungi, viruses, and parasites, are exposed to antimicrobial drugs. Drugs that are categorised as antimicrobial drugs include antibiotics, antifungals, antivirals, antimalarials, and anthelmintics. The microorganisms develop resistance towards the drugs, undergo genetic changes, and consequently becoming superbugs, or microorganisms that are drug-resistant. An individual who is infected by AMR microorganisms requires a stronger dose of medicine, as well as longer period of time to get better from his/her ailment.

AMR microorganisms can be found in people, animals, food, and the environment. They spread between one contact point to another. It is exacerbated by poor infection control, inadequate sanitary conditions and inappropriate food handling processes. Moreover, health practices such as the overuse and misuse of antibiotics to cure viral infections like colds and flu, as well as the use of growth promoters in animals also contribute to the growth of AMR microorganisms in the environment.

To date, regulation on CECs is relatively nascent. There is lack of enforcement on good practices across industries, such as proper disposal of medicine in the health industry, or discharge of agricultural waste into the environment. Additionally, it is difficult to track and keep a comprehensive listing of CECs. Existing laws cannot catch up with the speed at which industries invent new consumer products for the public.

4.0 The global view towards CECs

Globally, there is no specific policy on CECs. Initiatives from international organisations, such as the United Nations (UN) and its sister organisations are sectoral in nature. Regionally, the European Union (EU) leads in monitoring CECs as a conglomerate, while the US leads country-specific efforts in mitigating the effects of CECs.

Efforts on curbing AMR has been ongoing since the introduction of UN's Millennium Development Goals (MDGs), and is continued

under Goal 3 of the Sustainable Development Goals (SDG). Countries and societies will experience significant economic loss in production if AMR is not addressed immediately. It is estimated that more than 25,000 deaths in the EU were caused by AMR annually, and over 30,000 women die every year as a result of severe infection while giving birth. Member states pledged to ensure continuity of successful treatment and prevention of infectious diseases with effective and safe medicines that are quality assured, used in a responsible way and accessible to all for as long as possible. The World Health Organisation (WHO) is tasked to champion AMR initiatives globally, and monitor progress through indicators set under the United Nations Economic and Social Council (ECOSOC).

In 2015, WHO issued a document entitled "Global Action Plan on Antimicrobial Resistance", with the objective of reducing systematic misuse and overuse of antimicrobial drugs in human medicine and food production. Under this action plan, WHO underscored the need for a "one health" approach involving multiple stakeholders, through improving awareness and understanding of AMR which includes effective communication, education and training. Unfortunately, progress under this action plan has been slow. This is because there is inadequate monitoring and reporting at all national, regional and global levels. There is also inadequate recognition by all stakeholders of the need for action in their respective areas.

The European Commission (EC) undertook a watch-list mechanism in monitoring CECs that are considered hazardous to the environment. It also enabled the EC to add more CECs into the watch-list, allowing the authorities to expand the scope of CECs to be monitored in the future.

For example, three substances were highlighted in a 2013 directive, comprising:

- The natural hormone oestradiol (abbreviated E2),
- The anti-inflammatory diclofenac, and
- The synthetic hormone ethinyl oestradiol (abbreviated EE2), used in contraceptives.

Two years later, the list was expanded to include the following:

- The natural hormone oestrone (abbreviated E1),
- Three (macrolide) antibiotics,
- Several pesticides,
- An ultraviolet (UV) filter, or a chemical that prevents UV light getting though, as used in sun cream; and
- An antioxidant used as a food additive.

To date, the US is one of the few countries which has issued guidelines on water quality in order to better protect aquatic life forms from CECs. In 1985, the Environmental Protection Agency (EPA) released a guideline entitled "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Life and Their Uses". A subsequent white paper was issued in 2008, as an upgrade to the 1985 guidelines. In this white paper, a group of academics, healthcare practitioners and agency representatives, who acted as the Science Advisory Board (SAB) used ethynylestradiol (EE2) as an example to outline six recommendations to address CECs:

- Identify relevance of acute toxicity effect concentrations in setting aquatic life criteria for CECs,
- Define minimum data requirements regarding taxonomic coverage in toxicity testing,
- Use non-resident species in criteria development,
- Define appropriate chronic toxicity data,
- Select effect endpoints upon which to base criteria, and

- Involve expert panel in the criteria development process.

5.0 Raising awareness on CECs

It is important for the public to understand CECs. This will give rise to behavioural changes, which leads to changes in market forces, social norms, and policy advocacy.

A 2015 World Bank report entitled "World, Society and Behaviour" explained that individuals make decisions on a daily basis based on contextual cues, social networks, and shared mental models. It is the individual person who needs to visualise what is desirable, possible, or acceptable for their own lives, before the impact is fully felt by the people around him/her. Tools and methods in influencing the individual behaviour do not displace conventional policy approaches; rather, they complement and enhance them. This approach, also known as behavioural economics, is a combination of disciplines, involving neuroscience, cognitive science, psychology, behavioural economics, sociology, political science, and anthropology.

The public is more than capable of reducing the release of CECs to the environment through a change of habits. For example, one can choose to be less reliant on antibiotics, use environmental-friendly household and personal care products, or reduce the consumption of meat and poultry. The power of consumption will eventually follow suit, where industries are pressured to change their ways to suit consumer habits.

Farmers and agriculture workers should revisit their practices in the use of pesticides, and reduce or eliminate the use of growth hormones in their poultry. Medical practitioners would also need to prescribe medication responsibly, encouraging their patients to be mindful of the type of medication taken for their health and well-being. A focus on health risks of CECs, particularly AMR, would avoid a global antimicrobial crisis that might cripple economies and societies.

6.0 CECs in the Malaysian water supply

Malaysia relies heavily on surface water source, such as rivers, as its water resource. It has a total of 189 river basins; 89 of them are located in Peninsular Malaysia, 78 in Sabah, and the remaining 22 river basins are located in Sarawak. Rivers in Malaysia contribute over 97 percent of raw water supply for agricultural, domestic and industrial needs. It also experienced good rainfall, receiving an average of 3,000mm rainfall annually. This contributes to approximately 900 billion cubic metres to the country's water resources.

Johor is one of the states with the highest rainfall. It exports water to its neighbour Singapore for consumption. The city-state depends on Johor for water imports through treaties signed in 1961 and 1962 respectively. It gives drawing rights of up to 1,136 million litres per day until 2060, with a cost of RM 0.03 cents for every 1,000 gallons of water supplied under the agreements.

At a glance, Malaysia seemed to experience an abundance of water resources. This is not the case, as the country experienced bouts of water rations across Peninsular Malaysia with increasing frequency over the past few years. Its water resources are affected by pollution, reducing the availability of good quality raw water. More rivers are also polluted, inducing water shortages in city centres where there is a high demand for water.

The Academy of Sciences Malaysia (ASM) argued that Malaysia needs an integrated water resource management system. In 2016, it produced a comprehensive report entitled "Transforming the Water Sector: National

Integrated Water Resources Management Plan Strategies and Road Map". It is a two-volume report which outlined current status and recommendations on integrated water resource management in Malaysia. The exhaustive review highlighted strategies under four broad-based categories: enabling environment, institutional framework, management instruments, and water infrastructure investments.

CECs had been detected in Malaysian rivers, but published studies on the subject were scarce. Al-Odaini et al (2013) described a study that identified 15 out of 19 targeted pharmaceuticals for analysis in the Langat River, with mefenamic acid, glibenclamide and salicylic acid detected across all water samples. Praveena et al (2016)'s research detected four types of natural and synthetic estrogens in water samples from the same river. Yacob et al (2016)'s study of effluents located along Sungai Melayu, Johor Bahru highlighted that only acetaminophen and ibuprofen can be completely removed by the treatment systems while others achieved less than 80 percent or negative removal. Hanafi et al (2017) discovered that a total of 75 PPCPs were found in water and mussel samples obtained along the river at Kampung Sungai Temon, Johor Bahru. More studies are required to cover more rivers and generalise observations obtained from existing literature.

The Malaysian scientific community is well aware of the risks of CECs, and have taken the initiative to advance research on the subject, particularly in the areas of CECs removal from water. Belong et al (2009) investigated options in CECs removal, such as activated carbon, oxidation, activated sludge, membrane technologies and reverse osmosis membranes, and recommended nano filtration as a promising method for endocrine disrupting compound (EDC) removal. Reddy et al (2017) explored the removal of CECs by adjusting parameters such as pH and chlorine concentration.

There are clusters of interest groups that have been working on research related to CECs. For example, four groups of researchers in Universiti Teknologi Malaysia (UTM) work on chemical analysis, membrane technology, water treatment processes, and new materials to be used in the water treatment process, together with state-level water agencies. A group of researchers from Universiti Sains Malaysia (USM) explored socio-economic impacts of CECs on local communities. Professor Dr. Abdul Latiff Ahmad of USM, and Professor Dr. Ahmad Fauzi Ismail of UTM, were the joint recipients of the Merdeka Award for outstanding scholastic achievement in 2014, who worked on development of technologies in the areas of water and wastewater treatment. Both of them have demonstrated excellent scholastic capabilities of local researchers in identifying innovative solutions for CECs removal.

Focused initiatives are carried out by government agencies. An example is the range of public awareness campaigns on AMR that are organised by the Ministry of Health Malaysia. The public may approach laboratories located at national agencies, such as the National Hydraulic Research Institute of Malaysia (NAHRIM), and laboratories at research universities for services related to water sample testing. NAHRIM hosted the largest physical lab in the country, where various modelling can be done for river- and coastal- based projects.

7.0 ACS-Gii 2017: Connecting the scientific community to work on CECs

Malaysia, through the American Chemical Society (ACS) Malaysia Chapter, hosted the ACS Global innovation imperatives (ACS-Gii) meeting on 20 and 21 November 2017.

The event was held at Johor Bahru. Universiti Teknologi Malaysia (UTM) played host to the first day of the event (20 November 2017), while Newcastle University Medicine Malaysia (NUMed) hosted Day 2 (21 November 2017) of the event.

The theme selected for ACS-Gii 2017 is "Contaminants of Emerging Concern" (CECs).

Throughout the two-day gathering, scientists and policy makers across Malaysia and beyond gathered for case study presentations, discussion and networking. A site visit was also organised on the second day, allowing participants to understand community perception on CECs through an experiential approach.

This event is among the first of its kind organised by the ACS Malaysia Chapter in exploring the subject of CECs within the scientific community. It attracted over 70 participants, comprising young scientists, postgraduate students, and local researchers throughout the two-day event.

Invited keynote speakers and plenary presenters shared many interesting findings on the status of CECs within the Malaysian context. Among the salient points of discussion which merit attention are as follows:

- There were many interesting findings on CECs in Malaysia, but the findings have yet to be published in the public domain. The findings are not translated well into application that benefits the Malaysian population. Additionally, scaling technologies invented through research is costly.

- Among the CECs that are discharged the most in the environment include PPCPs, EDCs, and pesticides. Pharmaceutical pollutants have been detected in the Malaysian aquatic environment, and they are hard to remove through conventional water treatment processes.

- Given the number of river basins available, source water protection is the best method in ensuring communities quality drinking water for Malaysian communities. Protection of water source costs lesser than treating the water at the water treatment plants.

- Malaysia has yet to practice good reporting in AMR, particularly in the private healthcare system. One out of five patients are prescribed with antibiotics irrespective of ailments. Out of the 382,022 cases reported and analysed in 2016, it was found that one in four patients are penicillin-resistant, and over 33 percent of patients are erythromycin-resistant. The public has limited knowledge on antibiotic intake, as it was found that over 50 percent patients discontinued antibiotics once their symptoms have disappeared. Over 54 percent of the patients throw their medications away, while 34.5 percent of patients flushed their medications down the toilet.

- Online and real-time early detection system is critically needed in detecting CECs within communities. The communities also have to be equipped with basic knowledge on CECs. Malaysia has one of the lowest tariffs for wastewater treatment in the world, where households pay between RM 2 to RM 8 per month for water treatment services, while the industry received subsidy from the government.

- The policy makers need to be equipped with hard data before any changes in existing regulation can be carried out. The Environmental Quality Act (EQA) 1974 is currently in the process of public consultation, pending future iterations and approval.

- The scientific community in Malaysia needs to harness the strength of NGOs in conducting outreach programmes with the community. The NGOs are more than capable in helping the scientific community to gather data through public perception surveys.

- Young scientists in Malaysia are challenged to create local technologies that are cheaper and more affordable. They are also encouraged to be activists, working with NGOs to translate research findings for the community.

8.0 Recommendations

A post-event survey was conducted among participants of the ACS-Gii 2017. The survey was administered online through Google Forms. The post-event survey, conducted for a period of three weeks, invited participants to identify priority areas for action on CECs, based on the input shared by speakers and panelists throughout the event.

A total of 34 respondents replied to the call for survey sent out to all participants. This constituted over 48.6 percent of the overall ACS-Gii 2017 participant. The response rate is significantly higher than the response rate recommended by Fan and Yan (2010) for a web-based survey, which is 11 percent.

Participants were given a set of 19 recommendations in the survey. These recommendations were extracted by a team of rapporteurs on duty throughout the ACS-Gii 2017. There were required to select only 10 recommendations that they perceived as priority areas to be included in the white paper report. Table 8.1 in the next page presented findings of the perception survey.

Based on brief survey, it was found that there are six top priority areas for advocacy, research, and policy action:

- Public education,
- Guidelines on CECs,
- Creating a network of CECs researchers and practitioners,
- Increase enforcement of regulation on source water protection,
- Community-based CECs research, and
- Targeted awareness campaigns.

Table 8.1. Recommendations ranked by order of importance

Statement	%
Educate public to change habits (e.g. read product labels, correct disposal of medications)	82.4
Create guidelines on CECs to stakeholders, covering operational definition, the lists of CECs monitored, and standard operating procedures in CECs detection, analysis and removal	76.5
Establish a network of researchers and practitioners working in CECs	76.5
Increase enforcement of regulation on source water protection	70.6
Work on community-based research relating to CECs	64.7
Targeted awareness campaigns (e.g. Ministry of Health to focus on antimicrobial resistance, while DOE focuses on industry awareness on CECs)	64.7
Clear mapping on roles and responsibilities in detecting and monitoring CECs among ministries and government agencies	61.8
Identify ways to lower cost of technologies used in identifying and removing CECs	61.8
Increase technological capabilities of laboratories in CECs analysis	61.8
Educate schoolchildren and the public on CECs	55.9
Establish specific section on CECs in government acts / bills related to environmental protection	55.9
Enforcement officers understand what CECs is, and are trained in CECs analysis	52.9
Targeted enforcement by stakeholders (e.g. medical practitioners to reduce prescription of antibiotics)	52.9
Work with non-governmental organisations to disseminate information on CECs in a more accessible manner	52.9
Fines and penalties on individuals and organisations found to release CECs into water / air	52.9
Enhance data collection and sharing of findings among stakeholders	52.9
Conduct surveys to understand public perception and understanding on CECs	38.2
Use sensors / robotics / portable devices to collect data on CECs in real time	32.4
Incentivise industries in CECs-related mitigation efforts (e.g. tax exemption for industries involved in water conservation)	26.5

9.0 ACS-Gii 2017 community outreach in Kampung Sungai Temon, Johor Bahru

The ACS-Gii 2017 committee members selected Kampung Sungai Temon Eco-Tourism Village (to be written as KST from this point onwards) at Johor Bahru as a site for community outreach programme in conjunction with the scientific gathering.

KST is located along the Tebrau Straits, within close proximity of the Malaysia-Singapore border. It is inhabited by the indigenous community of Seletar, who fish for a living.

A group of students, guided by the committee members, went for a series of site visits to KST in order to obtain permission to conduct the community outreach programme at their village, as well as to better understand the lives of the KST community. A survey questionnaire was designed after the site visits, and administered by the students through random sampling method. The exercise gathered a total of 55 respondents, with 60 percent of them are male, while the remaining 40 percent are female. Over 67.3 percent of them only have primary level education. A majority of them (72.7 percent) are fishermen who earned an average income between RM 500 to RM 1,000. It has a high youth population, where over 56.3 percent of the respondents are below the age of 40.

Over 84 percent of the respondents rely on water supply from Syarikat Air Johor (SAJ), a Johor state government-linked company which is responsible for water supply services in Johor. The remaining 16 percent of them obtain their water source from rivers and wells. 12 percent of them have difficulties accessing clean water.

In terms of personal habits, Table 8.2 illustrates responses from the KST community:

Table 8.2. Respondents' habits

Personal habits	%
Boil water before consumption	93
Wash hands after using the toilet	84
Throw household rubbish into the river	47
Burn household rubbish	47

Most of the respondents reported the use of soaps, shampoo, toothpaste, and detergent on a daily basis. For those who can only use the cleaning products on a weekly basis, they explained that they need additional transportation arrangement to buy the products from nearby grocery stores, and have to ration their use.

It was found that all waste water are discharged from the household to the river. The respondents also throw medicines directly into the river. They were not aware of the proper processes in disposing medications. The river became their dumping ground as it is the most cost-effective method for solid waste management.

Over 74.5 percent of the respondents were not aware of CECs, and did not have the knowledge in managing CECs.

The respondents reported a decline in their income as they managed to catch lesser fish, shrimps and mussels over the years. This is largely attributed to the river pollution, as a result of indiscriminate dumping of waste into the river.

When asked on the relevant authorities to act on issues related to water pollution, over 48.4 percent of respondents cite the government as the key stakeholder responsible, while 38.5 percent of them would like to see volunteers from NGOs helping them in managing issues related to water pollution.

The findings of this community outreach is eye-opening and enlightening. It paved the way for more similar community outreach programmes in the future.

10.0 Summary and conclusion

This white paper has presented an overview of CECs, the discussions that has transpired during the ACS-Gii 2017, and participants' recommendations on the areas to work on through advocacy, research, and policy action.

As ascertained through the post-event survey, participants chose six priority areas to work on with regard to CECs. They are: public education; creating guidelines on CECs; creating a network of CECs researchers and practitioners; increase enforcement of regulation on source water protection; community-based CECs research; and finally, targeted awareness campaigns.

The white paper also presented a brief overview of a community outreach programme that was conducted by the ACS-Gii 2017 committee at Kampung Sungai Temon, Johor Bahru.

CECs is a promising field of study for the scientific community in Malaysia. It is high time that the ACS Malaysia Chapter take up the golden opportunity in conducting research and outreach programmes in CECs, together with other stakeholders within the overall water resource management ecosystem.

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Industry dialogue session
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Prof. Dr. Abdul Latif Ahmad, USM
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