Study on sanitary condition and the microbiological quality of water and ice in ice plants in Sri Lanka

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Abstract

Ice is the most versatile, abundant and economic chilling agent in fish supply chains from point of harvesting to final stages of processing of fish, globally. Fish and fishery products destined as food for human and also as feed for certain animals with commercial and social significance such as seal (Pinnipeds) reared in Zoological Gardens, have been reported as contaminated with pathogenic bacteria. This study, therefore, aimed at investigating the microbial quality of ice using in fishery industry in Sri Lanka. Quality of water used for making ice and ice produced were investigated in 73 ice plants located 16 districts. Source of water used for making ice (disinfected water from municipal water supplies, well or tube-well water); ice stored in cold store; and crushed block-ice which represented three main stages of an ice production line, were sampled from each ice plant, transported to NARA, and analyzed for faecal coliforms, *Escherichia coli,* and *Salmonella* using methods of Sri Lanka Standard (SLS) and International Standards Organization (ISO). The *Salmonella* isolated from samples were characterized into serotyping within Kauffmann-White scheme. In six ice plants, all three types of samples in ice production lines found with acceptable microbiological quality complying to the potable water quality (Sri Lanka Standard 614:2013). In 67 ice plants, all or at least one type of samples showed contaminations with faecal coliforms (1 - 1800+ MPN/100 mL) and *E. coli* (1 to 920 MPN/100 mL). At least ten different serotypes of genus *Salmonella* including *Salmonella* Brunei, *Salmonella* Tananarive, *Salmonella* Edinburg, *Salmonella* Kentucky, *Salmonella* Wilmington, *Salmonella* Hvittingfoss, *Salmonella* Sekondi, *Salmonella* Graba vi, *Salmonella* Braenderup and *Salmonella* Agona were detected among sixteen comprising all three types of samples collected from 67 ice plants. This study demonstrated a trend of gradual increase in both number of samples and/or level of contaminants down the three stages of ice production lines indicating a need of improving the infrastructure facilities and handling practices of local ice plants. It is suggested introducing a code of practice for ice plants; providing regular training programs for ice handling staff and operators on implementing of good manufacturing and sanitary practices; conducting regular monitoring programs on quality of water and ice produced in ice plant by competent authorities in order to mitigate presently occurring microbiological contaminations at high levels in ice plants.

Keywords: Ice plant, water, faecal coliform, *E. coli*, *Salmonella* serotypes, fish contamination

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Introduction

Ice plays a vital role in fisheries industry of Sri Lanka and similarly in other countries. Ice is used as the most abundant, economic and primary chilling agent of fish during handling dressing or processing of fish in fish processing plants. Also, fresh edible fish is stored in ice until the destination is reached since fish is a highly perishable commodity compared to other sources of animal meat. Fish is consumed as one of the main protein sources by local consumers and also part of high value fish is exported in return of significant amount of foreign revenue to Sri Lanka. Significant amount of ice is used by local fishery industry since present fleet size of local fishing boats is about 5590 including about 4800 of multi-day fishing boats which are in the range of 36 to 59 feet in length and making fishing trips for 14 days with about 20 days variation (Anon., 2020c, Internal Report of NARA). The total annual production of fish produced locally is about 505,830 mt in 2019 and the production of off shore or deep-sea fish by multi-day fishing boats was about 172,910 mt in 2019 (Anon., 2020c). A significant amount of foreign exchange is earned by local fish export industries and quantity of fish and fishery products exported from Sri Lanka in 2019 was about 28,771 mt in return of about LKR 53,483 Mn (Anon., 2020c).

About 3580 Mt of ice is produced daily by about 90 ice plants in Sri Lanka (Anon., 2020c). Nevertheless, demand for ice by users are in the rise due to continued expansion of local fishery industries with the concern of high-quality finished products. Block ice is produced in many of the local ice plants and are large quantity of block ice, in the form of crushed ice, is provided to fishing boats including multi-day boats that are harvesting large quantity of high value fish such as yellowfin tuna targeting for export market. Large amount of ice is used in fish holds of multi-day boats to maintain freshness of high value fish that has an export potential, during its fishing trips with long durations in the offshore.

Ice dispatched from Ice plants are also used for fish transport systems connected from fishery harbors and fish landing sites in remote areas to wholesale markets in Colombo and other town areas such as Kurunegala, Kandy and Balangoda and fish selling places in all part of Sri Lanka. Part of block ice produced is channeled to cement based construction industry in Sri Lanka (Personal communication) while some amount of block ice and flake ice is also supplied to other food industries. Present quantity of ice produced in ice plant is not sufficient to keep the total fish catch reported locally if such fish is required to be chilled practically between 0-4 °C under tropical ambient temperatures around 25 °C. Therefore, there is a shortage in production of ice for fishery industry from local ice plants in Sri Lanka.

Microbiological quality of fish is directly associated with the level of degradation of fish and fishery products. Therefore, making a better understanding on microbial contamination of fishery products and associated main utilities such as water and ice through scientific assessments could support to optimize the product quality as well as optimum utilization of the aquatic resources (Geethalakshmi *et al*., 2021; Svanevik, 2015; Tantrakarnapa, 2010). Quality of fish could be optimized by handling of fish under high level of hygienic conditions at early phase of the production line (Svanevik, 2015).

Faecal coliforms are naturally existing profusely in intestinal tracts of humans and other warm-blooded animals and eventually released to the external environment through their faeces as well.

E. coli is found widely in the intestinal tracts of warm- blooded animals and is generally reported as non-pathogenic. However, gastrointestinal diseases caused by *E. coli* strains containing toxigenic genes including Entero Toxigenic *E. coli* (ETEC), Entero Pathogenic *E.coli* (EPEC), Entero Invasive *E. coli* (EIEC), Entero Hemorrhagic *E. coli* (EHEC), Siga Toxin-Producing *E. coli* (STEC), Entero Aggregative *E. coli* (EAEC or EAggEc), and Diffusely Adherent *E. coli* (DAEC) are reported contaminating food materials including seafood (Barbosa *et al*., 2016; Costa, 2013). Some *E. coli* strains are reported capable of forming histamine in harvested fish. Therefore, using of ice contaminated with such *E. coli*, for chilling fish could make fish unsafe for consumption due to its direct pathogenicity and potential as histamine former in fish tissues (Refai *et al*., 2020).

Salmonella is reported to be naturally present in the environment and even in intestinal tract of some humans and more than 2,500 serotypes of *salmonellae* have been identified to date. Some of the routes of the initiation and spread of *Salmonella* infection in human are reported as consumption of food and beverages that were contaminated directly or cross-contaminated with animal faeces/ and sewage or indirectly through contaminated equipment and infected personnel as carriers in food-processing facilities. *Salmonella* is a clinically significant pathogen that bring about critical illness and even fatal to individuals (Shin, Chang, and Kang, 2004). As one of most versatile indicator organisms for faecal contamination in seafood, *E. coli* is enumerated in water and ice in relevant samples worldwide (Kumar *et al*., 2005).

Animal effluent born bacteria groups are more often found in high numbers in nutrient-rich effluents systems such as septic and animal sewage tanks; and run-off from farmlands. There may be opportunities to enter and contaminate sources of ground water that are used for manufacturing the ice in ice plants.

With the concern of microbiological contaminations found in commercially producing ice, scientific evidence based advanced technologies has been suggested for producing safe ice such as potential usability of activated ice containing bactericidal agents through cold atmospheric plasma and acidic electrolysis (Katsaros *et al*., 2021). Use of antibacterial ice which contains chlorine dioxide (ClO_2) at levels of 40 - 50 ppm is permitted in seafood by Food and Drug Administration (FDA), USA. Shin Chang, and Kang, (2004) reported the efficacy of reducing foodborne pathogenic bacteria including *Escherichia coli* O157: H7, *Salmonella typhimurium*, *Listeria monocytogenes* on fish surface during storage of fish in ClO_2 containing ice.

It is essential and mandatory to use water and ice of acceptable microbiological quality standards as specified for potable water in all stages of handling of fish after the harvesting such as cleaning and preprocessing; chilling; transporting and storing of fish and fishery products intended for human consumption in order to prevent the cross contamination of fish and fishery with fecal origin and other pathogenic microflora (Anon., 2007; Anon., 2020a; Anon. 2020b; Samakupa, 2003). Many of the studies conducted previously reported that ice has a high potential to be the main source of microbiological contaminant in fish since some of ice used as utility for chilling agent in food and also water used in fishing boats and fish landing harbors. Ice used in fish sales places are also contaminated with faecal contaminant bacteria and pathogenic bacteria including *Salmonella* and faecal streptococci (Ganegama Arachchi *et al*., 2000; Kariyawasam *et al*., 2007; Tantrakarnapa, 2010; Teixeira *et al*., 2019; Mako *et al*., 2014, Noor Izani *et al*., 2011; Vieira, De Souza, and Patel, 1997). In a study conducted across 13 ice plants from seven districts in Sri Lanka in 2007, high level of fecal contaminations in ice were found while *Salmonella* was not detected in water used for making ice and ice produced in those ice plants (Kariyawasam *et al*., 2007).

Fish exporters and competent authorities emphasize the need of the availability of acceptable quality and microbiologically safe ice for use in chill chain of fish distribution channel especially the supply chains destined at export-oriented fish processing industry in complying with Good Manufacturing Practices (GMPs) and Hazard Analysis Critical Control Point (HACCP) as specified in regulation for fish products export in 1998 (Anon. 2013). Therefore, potable water quality ice should be available for using in all stages of fish handling starting from fishing boats up to storage of processed products including packaged chilled fresh fish, Ready- To-Eat (RTE) fish products such sashimi or other minimally processed fish products in processing plant, and consequent stages of transportation of finished products.
Present study planned to investigate microbiological quality of ice produced together with survey on infrastructure facilities and handing operations in ice production lines in ice plants located in different districts of Sri Lanka.To our knowledge this is the first study conducted covering more number of ice plants located in 16 Districts in order to evaluate sanitary condition and microbiological quality of water and ice

along production line of ice plants which are commercially producing ice mainly for fishery sector in Sri Lanka.

Materials and Methods

Ice plants which produced ice mainly for the fisheries sector, were investigated in 16 districts from March, 2018 to May, 2019. Present status of ice producing line including condition of infrastructure of facility, handling operations, and sanitary practices were studied by making one field visit to each ice plant. Three types of samples required for microbiological examination were obtained from ice producing line of each ice plant.

Sample types obtained were the source of water used to produce ice, the block or flake ice stored in cold room, and the crushed-block ice made by using ice-crushing machine before dispatching the block ice from ice plant. About one liter of water or one kg of ice samples were collected in to sterile plastic bottles and pouches by following aseptic techniques as per ISO 19458:2006; samples were packed among clean ice in sample storing insulated boxes to maintain temperature at about 2 – 4 °C; and these boxes were transported under chill condition to Quality Control Laboratory in NARA. Samples were then analyzed within 24 hours after sampling for faecal coliform and *E.coli* according to methods given in SLS 1461 Part 1/Sec 3:2013. *Salmonella* was examined following methods given in ISO 19250:2010 (E) and isolated *Salmonella* cultures were characterized by serotyping according to Kauffmann-White classification method in Food and Water Microbiology Laboratory of Medical Research Institute (MRI), Colombo. Recommendations required for upgrading the status of ice plants based on the findings of present study were made by conducting consultative workshop with key stakeholders of ice manufacturing industry and fisheries sector.

Results and Discussion

Handling practices of ice in ice plants

Study was conducted on 73 ice plants located in 16 Districts (Trincomalee, Batticaloa, Jaffna, Mullaithivu, Anuradhapura, Dambulla, Polonnaruwa, Puttalam, Chillaw, Kalpitiya, Mannar, Amapara, Ratnapura, Moneragala, Kurunegala, Galle, Matara, Hambantota, and Kaluthara) (Table 1).The four main steps of a ice production line are inflow of water to ice making molds; freezing of water in ice mold (50 kg) dipping in brine solution of freezing tank; removing from molds and transferring of ice blocks to cold store (−5 to 10°C); and moving ice blocks to the ice crusher and crushing the block ice. Generally, the block ice is crushed in an ice crusher (ice crushing machine) and crushed ice is instantly packed in to polypropylene bags at the time of dispatching upon sales. Present survey found that many of ice plants operated under poorly maintained infrastructure facilities and with untrained or apprentice staff. Improper handling of ice by such staff could be linked with the cross contamination of ice with harmful microflora and extraneous material existed along ice production line in those ice plants.

Water supplied by municipalities was used as source of water manufacturing ice in 21 ice plants while ground water obtained from well or tube well water was used by 30 and 22 ice plants, respectively (Table 1). Block ice was produced in 66 ice plants while flake ice was produced in remaining eight ice plants (Table 1).

Microbiological quality of water used and ice produced in ice plants

Out of 73 ice plants, in six ice plants produced ice with acceptable quality complying with potable water quality standards. In all these six ice plants municipal water disinfected with chlorine was used for making ice and therefore, water used for making ice; ice stored in cold store; and ice crushed in the ice crusher were found not contaminated with faecal coliform, *E. coli* or *Salmonella* (Table 2).

Table 1. Source of water used for making ice and type of ice produced in 73 ice plants located in 16 Districts

District	Number of ice plants	Number of ice plants				
		Source of water for ice making			Type of ice produced	
		Municipal water	Well	Tube-well	Block ice	Flake ice
Trincomalee	5	1	3	1	5	-
Batticaloa	4	-	4	-	4	-
Jaffna	4	1	2	1	4	-
Mullaithivu	2	-	2	-	2	-
Anuradhapura	2	-	-	2	2	1
	1	-	-	1	1	-
Polonnaruwa	1	1	-	-	1	-
Puttalam	1	-	-	1	1	-
	2	-	-	2	2	-
Mannar	7	1	2	4	7	-
	5	‘	1	4	5	-
Ampara	3	-	-	3	3	-
Ratnapura	1	1			1	
Monaragala	1	-	1	-	1	-
Kurunagala	1	-	1	-	1	-
Galle	8	4	2	2	7	1
Matara	15	2	12	1	15	-
Hambantota	5	5	-	-	2	3
Kalutara	5	5	-	-	2	3
	73	21	30	22	66	8

Infrastructure facilities of ice plants have developed to maintain clean and sanitized condition in ice producing line such as inlet water lines, ice freezing cans, cold rooms and ice crushing machine made with stainless steel, protective floor areas for moving ice from cold store to ice crushing machine. Ice handling staff of these six ice plants also explicated the understanding on good sanitary practices and were wearing attire which could prevent contamination of ice during storing and dispatching of crushed ice to the buyers. Sixty-seven (67) out of 73 ice plants produced and dispatched unacceptable quality ice due to non-compliances occurred in at least one of the stages of ice production line including microbiologically contaminated water for making the ice, post contamination of ice blocks during storing in cold store and/or in the ice crusher. (Table 2).

Microbiological contamination of source of water used for making of ice:

Water supplied for manufacturing of ice in ice molds was found contaminated with faecal coliform and *E. coli* in 51 and 42 ice plants, respectively, and both contaminants were detected in the range of 1 to 1600 MPN/100 mL (Table 2). Therefore, such ice is unacceptable to be used in food industry.

Ice should be made with potable quality water that is devoid of faecal contaminant bacteria including faecal coliforms and *E. coli* bacteria (Anon., 2007; Anon., 2013; Anon., 2020a; Anon., 2020b). Municipal water supplies that were disinfected by chlorination were used to make ice in 21 ice plants which were located in Trincomalee, Jaffna, Polonnaruwa, Kalpitiya, Ratnapura, Galle, Matatra, Hambantota, and Kaluthara (Table1).

Salmonella were detected in water used for making of ice in four ice plants located in Trincomalee, Kalpitiya, Mannar, and Kalutara areas (Table 2 and Table 3). Serotypes of three isolates have been identified as *S*. Brunei, *S*. Kentucky, and *S*. Hvittingfoss (Table 3). Contamination of inlet water could be linked with the corroded and rusty water lines directed for water freezing chambers, lack of and not implementing regular cleaning and sanitation schedules and inadequate sanitary measures of working staff in ice plants.

Microbiological contamination of ice stored in cold room of ice plants

Ice manufactured in the form of blocks or flakes by freezing water in ice plants were then transferred to cold room operated at temperature between -5 to -10 °C at the ice plant. Ice stored in cold room was contaminated with faecal coliforms in the range of 1 to 1600 MPN/100mL in 61 ice plants and *E. coli* in the range of 1 to 920 MPN/100 mL in 58 ice plants (Table 2). *Salmonella* was isolated in ice obtained from cold store in 5 ice plants situated in Trincomalee, Mullaithivu, Kalpitiya and Tangalle. *Salmonella enterica* isolates were characterized as five different serovars including Kentucky, Edinburg, Wilmington, Agona, and Sekondi (Table 2 and Table 3). Ice blocks frozen in freezing molds (cans) are separated mechanically from molds, then transferred and stacked in walked-in cold store by ice plant operators.

Table 2. Level of contaminations of faecal coliform, *E. coli* and occurrence of *Salmonella* in ice making water, ice stored in cold store and crushed ice using ice crusher in ice plants before selling of ice

Total No. of ice plants	No. of ice plants (Quality of ice)	Sample types	Number of ice plants		
			Faecal coliforms (MPN/100 mL)	*E.coli* (MPN/100 mL)	*Salmonella* (100 mL)
73	6 (Acceptable quality)	Source of water*	ND	ND	ND
		Ice in cold store	ND	ND	ND
		Ice from crusher	ND	ND	ND
	67 (Unacceptable quality)	Source of water§	51 (1 to 1600)	42 (1 to 1600)	4
		Ice in cold store	61 (1 to 1600)	58 (1 to 920)	5
		Ice from Crusher	62 (1 to 1800+)	57 (1 to 1800+)	7

ND, Not Detected; *Municipal water; § Municipal water, well or tube well

Sanitary measures were found inadequate in ice plants that contained contaminated ice in cold store since staff working in area of cold store, lacks proper sanitary outfits specific for the task such as gloves, shoes or gum boots; and movements of all staff is not controlled across the floor areas of the ice production line. Therefore, it is more likely to cross contaminate the passage of floor on which ice blocks are moved from ice molding tanks to cold store and interior of cold store itself.

Microbiological contamination of crushed ice dispatching from ice plants

In 62 ice plants, faecal coliforms were detected in the range of 1 to 1800+ MPN/100mL in crushed ice (Table 2). *E. coli* was detected in crushed ice in the range of 1 to 1800+ MPN/100 mL 57 ice plants (Table 2). Seven isolates of *Salmonella* were found from crushed ice that were prepared instantly by moving the ice blocks on a passage of floor (corridor) from the adjacent cold store to the ice crusher and then, crushing the ice blocks loaded in to the ice crusher.

It was observed that there is a possibility to contaminate ice at site of preparation of crushed ice as the final stage of ice production line since floor area of ice moving path which is not demarcated for restricting the movement of the unauthorized staff for between cold store and corridor near ice crushing machine. Ice handling staff were not in appropriate clothing, and outfits required for maintain good sanitary conditions. Tantrakarnapa *et al*., (2010) have suggested the need of establishing and implementing proper sanitary programs in ice plants as they have found the presence of coliform bacteria in ice plants where workers are wearing net caps, aprons and boots. In the present study, *Salmonella* isolated from crushed ice belonged to three serovars including *S*.Tananarive, *S*.Graba vi, and *S*.Braenderup. Ice crushing machines used at many of ice plants were with corroded and rusty interior surfaces making those difficult to clean and sanitize properly. Harbouring of stray animals and birds in ice handling area which is not covered with protective barrier fence or cover for keeping stray animals, and bird droppings could be identified as other sources of contamination of crushing ice with faecal origin bacteria and *Salmonella*.

A trend of gradual increase in number of incidences and level of faecal contaminant bacteria (faecal coliforms and *E. coli*) was observed along ice production line (Table 2). Similarly, gradual increase in incidences of *Salmonella* was detected as 4, 5 and 7 in samples of ice making water, ice in cold store and crushed ice, respectively, in the present study (Table 2).

Salmonella is a significant food and seafood born pathogen in concern of public health that could enter seafood supply chain from fish contaminated with *Salmonella* naturally present in the aquatic environment, or fish, water, ice and handling surfaces contaminated with sewage and faecal matter originated from human and animals (Olgunoglu, 2012). Additionally, ice contaminated with *Salmonella* also has the potential for spreading infections through other chill products such as beverages prepared with and or cross contaminate other foods in food processing or cooking facilities. Centers for Disease Control and Prevention (CDC) in USA has reported about 62 people infected due to the consumption of frozen raw tuna with *Salmonella* across 11 states of USA in 2016 (Sanjee and Karim, 2016). Local and international regulations and standards specify that fecal coliform, *E. coli* and *Salmonella* should not be contained in water and ice used in food industry (Anon., 2007; Anon., 2013, Anon., 2020a; Anon., 2020b). Information on *Salmonella* infections or outbreaks in Sri Lanka is not abundant due to the common practice of not consuming raw or mildly cooked fish products by local consumers and poor recording of such clinical data. Sanjee and Karim (2016) have reported a similar situation in Bangaldesh as foodborne illness related to fresh or frozen seafood consumption has not been traced and reported or data on cases are still lacking and they have suggested that the scientific information on analysis for pathogenic bacteria related to seafood industry would help in preventing and controlling future outbreaks related to seafood consumption.

As effective mitigatory measures for controlling *Salmonella* in seafood, implementing integrated programs including the monitoring of water quality; disease surveillance; consumer education; harvesting, processing, and marketing seafood industry by competent authorities and experts from sector of public health, veterinary and food safety who are responsible for seafood industry have been suggested (Amagliani *et al*., 2012). Present investigation also emphasized a need of taking appropriate measures for improving manufacturing lines of local ice plants to combat high levels faecal coliform counts and *Salmonella* in water and ice from ice plants ensuring food safety of local consumers as well as local fish export industry that brings considerable amount of foreign exchange to Sri Lanka.

Preparation of recommendations for upgrading ice plants for producing microbiologically acceptable quality ice

A consultative workshop organized and held in NARA, was attended by 73 stakeholders representing owners of ice plants, buyers or users of ice, traders or distributors of ice, personnel from Department of Fisheries as Competent Authority, officials from Food Control Unit of Ministry Health, Sri Lanka Standards Institute, and Consumer Affairs Authority.

Results of microbiological analysis of water and ice from 73 ice plants were communicated individually with relevant ice producers in view of poor sanitary conditions of ice plants by posting the test reports on water and ice in advance. Further discussions were extended at the workshop as a common forum on the mitigatory measures and practical solutions on how to upgrade infrastructure facilities and unit operations of ice manufacturing line of their ice plants to a level of producing acceptable quality ice under good sanitary and GMPs by providing them with a printed copy of hand book which contained information on way of producing good quality ice. Chlorination of water for making potable quality water is given in detail by World Health Organization (Anon., 2017).

Table 3. Serotypes of *Salmonella* identified in 15 samples (ice making water, ice from cold store and crushed ice) obtained from ice plants

Sample type	Plant located area	Serotype of *Salmonella enterica* sub species *enterica*
Ice making water	Trincomalee	Brunei
	Kalpitiya	Kentucky
	Mannar	NC
	Kaluthara	Hvittingfoss
Ice from Cold Store	Trincomalee	Kentucky
	Mullaithivu	Edinburg
	Kalpitiya	Wilmington
	Kalpitiya	Agona
	Tangalle	Sekondi
Ice from Ice Crusher	Trincomalee	Tananarive
	Moneragala	NC
	Galle	Graba vi
	Galle	Graba vi
	Tangalle	Braenderup
	Tangalle	NC

NC: Not Characterized

Hampikyan and his team (2017) have suggested the importance of complying with important prerequisites such as the maintenance, cleaning and disinfecting of ice machines which should be carried out effectively and periodically; and the availability of adequately sanitized water with sufficient amounts of chlorine or other proper methods such as UV and ozone treatments to ensure the production of acceptable quality ice in ice plants.

For manufacturing good quality ice, it is also required to have well trained technical staff for operating the ice producing line hygienically and attending the routine maintenance of ice manufacturing infrastructure facilities; the periodic checking of microbiological quality of ice and the hygienic conditions of ice machines; and ensuring the hygiene of staff working in ice plants as per the requirements of HACCP and ISO 22000 food safety management systems etc. (Hampikyan *et al.*, 2017, Mako *et al*., 2016).

Participants of many of ice plants at the consultative forum admitted that many of ice plants are in need of upgrading to suit producing high quality ice as infrastructure of some ice plants were old more than 20 years without any refurbishment. Nevertheless, they also stated that it is difficult to allocate funds required for upgrading their ice making facilities over the presently incurring high electricity costs and taxes. Representatives of six ice plants shared their protocols and experiences voluntarily on how they managed to produce good sanitary quality ice using their existing basic infrastructure facilities that were well maintained, despite the prevailing high utility costs such as electricity power and taxes incurred in manufacture of ice in their ice plants.

At an interactive session in consultative workshop, it was ratified nearly all challenges faced by ice manufacturing industry against producing good quality ice at a fare selling price affordable for fisheries industry, and accordingly, a set of recommendations to be implemented as practical solutions for preventing the presently existing high level of bacterial contaminations during then ice manufacturing processes. Matters discussed and recommendations required for initiation of implementing GMPs in local ice plants are mentioned in Table 4.

Conclusion

In conclusion, this study found the presence of high level of fecal coliforms, *E. coli* and 15 isolates of *Salmonella* belong to at least 10 serovars in water used for ice making, ice stored cold stores, and crushed ice in ice crushers of 67 ice plants located in 16 districts. All ice plants which used ground water from well or tube wells directly without performing disinfection treatments, found producing unacceptable quality ice. Whereas six ice plants were producing acceptable quality ice by using disinfected water obtained from municipal water supplies and therefore, it is suggested the importance of commencing the chlorination of water before using in ice manufacturing line as one of the immediate practical solutions to mitigate microbiological contamination of ice.

At the consultative forum, recommendations made in view to mitigate high level microbiological contamination of ice produced in ice plants, were the improvement and proper maintenance of basic infrastructure facilities of ice production line; conducting regular training programs for working/handling staff and machine operators; introduction of code of practice for production of ice; and implementation of sanitary programs and GMPs together with regular surveillance and monitoring of quality of water and in compliance with food safety regulations (Table 4).

Table 4. Matters discussed and recommendations made by stakeholders based on the findings of the study at consultative workshop

No.	Issue/Constraint	Reason/Root cause	Recommendations/Remedial measures for upgrading ice plant
1.	Ice plant facility: Rust-decay of ice cans (metal container used to freeze water for making ice bock) are used in many of ice plants	• Commonly, ice cans are made using galvanized sheets. These galvanized – ice cans cannot be used for longer period due to rust-decay. Production cost for one ice can is about Rs. 15,000.00. High costs for stainless steel is not affordable. • Ice crushing machine: Ice holding passage of machine made with galvanize sheets, in some ice plant, are not in suitable condition due to rust-decay. • Cold room (Ice storing): Floor of cold room is made of wood; therefore, it is difficult to clean the floor. • Poor designing of ice plant lay out has led to cross contamination.	Provide funds for developing/Improving infrastructure facility of ice plant: • Government intervention is required for obtaining funds. • Loan schemes with low interest. • Provide grants for all ice plant. • Tax concession for ice industry. • Project on Enterprise Sri Lanka (Funding opportunities under Enterprise Sri Lanka) should provide loan facilities. Provide Technical support: • Marine grade stainless steel (316 stainless steel or suitable grade) material should be introduced to make ice cans. • Crusher: Should be made of stainless steel, and be Movable/portable type. • Permanent cover should be made over the ice crusher. • Use of fibreglass cover/ pellet for interior floor/fibber glass pellets of cold room is suggested. • Other alternate material with higher strength for floor of cold room is to be introduced. • Re- building of ice factories for good hygienic practices. • Establish safety equipment in ice plant.
2.	Source of Water: Unacceptable quality water is used for manufacture of ice	• Municipal water or other clean water sources that disinfected adequately to meet microbiological standards of potable quality, is not available in some areas of Districts	Guidance/Technical support: • Identify service providers/companies for water filtration and chlorination and dosing pump facilities etc. should be identified for ice manufacturing industry.

3.	Quality assurance of production process and environment of Ice Plant: *Production process*	• Lack of monitoring of ice production process.	• Establishment of regular programs for inspection/auditing/monitoring ice plant by Competent Authority. • Establish Official sample testing program for ice and water from Ice plant by Competent Authority, Health Ministry. • Implementation of Good manufacturing practices (GMPs) in ice plant. • Introduction and implementation of monthly maintenance schedule for Ice Plant. • Introduction of Code of Practice, Sri Lanka Standard Institute (SLSI)/International Standard Organization (ISO) Standards for ice production facility. • Health issues of workers: Schedules to be introduced for regular medical check- up work force (regular compiling) and obtaining medical reports by competent authorities. • Motivation program for ice producers such as rewarding of best Ice factory annually.
	Environment	• Lack of knowledge on sanitation of ice plants. • No action has taken to reduce the environment pollution of surroundings of ice plants.	• Onsite-awareness programme for staff of ice plant and ice users on sanitation and environmental pollution by competent authorities/Public Health Inspectors (PHI) and/or Medical Officers of Health (MOH). • Consumer awareness programs. Note: Many of participants of this meeting indicted that pollution of surrounding of ice plant at Galle Fishery Harbour. They emphasized need of cleaning/removing obsolete boats and other rubbish.
4.	Trainings and awareness programs for ice plant staff (Operators /Managers) and ice users	• Lack of trainings for ice plant staff members.	• Providing technical trainings/ Technology transfer programs/Awareness programs/ Occupational safety programs by competent authority/NARA/MOH/PHI and/or Food and Drug Inspectors. • Onsite tailor-made trainings on Ice plant sanitation and personal health and safety for staff of each Ice Plant. • Trainings on Good manufacturing practices (GMP) for Ice Plant, Sanitation, Personal hygiene, occupational safety etc. • Regular refresher trainings for staff.

			• Training materials: Manuals, leaflets, booklets, posters, pictures/images for creative of awareness effectively. For example, Posters explaining the cross contaminations, health risks due to presence of pathogenic bacteria in Ice Plant.
5.	Price increase for ice at Ice Plant	• Ice quality should be improved by upgrading facilities and process therefore; price of ice block is to be increased.	• Price of ice should be increased in order to produce high quality ice while improving and developing existing infrastructure facilities and operations in ice plant (to maintain best manufacturing practice, invest in better sanitary quality and setting of safety equipment and labour training etc.)
6.	Shortage of labour force	• Shortage of labour /lack of apprentice/ difficulty retain ice plant operators for several years continuously.	• Take action to retain ice plant staff by offering them with a good salary, training, good work environment etc.
7.	Contamination of ice during distribution	• Ice blocks and crushed ice purchased at ice plant are highly contaminated due to use of contaminated plastic bags, bins boxes etc for moving after the purchase .	• Establishment of procedures to avoid cross contamination of ice during the dispatch from ice plant. • Introduce clean packaging systems packaging materials of ice for buyers. • Awareness programme for buyers about the potential for cross contamination of ice during subsequent handling, transportation and storage. • Education programs should be conducted to MOHs and PHIs on present sanitary status of ice plants.

References

Amagliani, G., Brandi, G. and Schiavano, G.F. (2012). Incidence and role of Salmonella in seafood safety. *Food Research International,* **45 (2):** pp. 780-788.

Anon. (2007) Fish Product (Export) Regulations 1998 (Amendment) Gazette extraordinary No. 1528/7

Anon. (2013). Sri Lanka Standard 614 : 2013 UDC 663.6, Specification for potable water (first revision), Sri Lanka Standards Institution, Sri Lanka Standard Specification for Potable Water (first revision), SLS 614 : 2013

Anon. (2017) World Health Organization, 2017 Principles and practices of drinking-water chlorination: a guide to strengthening chlorination practices in small-to medium sized water supplies. ISBN: 978-92-9022- 536-2

Anon. (2020a). Food (Fish & Fish Products) Regulations – 2020. FOOD ACT No.26 of 1980 Accessed 11-08-2022 [Available at: http://eohfs.health.gov.lk/food/images/pdf/Draftregulations/FoodFish--Fish-ProductsRegulations-2020.pdf]

Anon. (2020b) World Health Organization. (2020). Code of practice for fish and fishery product.

Anon. (2020c) Fisheries Statistics 2020, Ministry of Fisheries Maligawatta, Colombo -10. Accessed on 02-08-2022, [Available at: https://www.fisheriesdept.gov.lk/web/images/Statistics/FISHERIES-STATISTICS--2020-.pdf]

Barbosa, L.J., Ribeiro, L.F., Lavezzo, L.F., Barbosa, M.M.C., Rossi, G.A.M., and Do Amaral, L. A. (2016). Detection of pathogenic Escherichia coli and microbiological quality of chilled shrimp sold in street markets. *Letters in applied microbiology,* **62 (5):** pp. 372-378.

Costa, R.A. (2013). Escherichia coli in seafood: A brief overview. *Advances in Bioscience and Biotechnology*, **4**: pp. 450-454.

Ganegamaarachchi, G.J., Ariyadasa, K.G.C., Perera, W.M.K. and Jayasinghe, J.M.P. K. (2000). Investigations on quality aspects of tuna catches of multi-day boats at the Negombo fish landing site, in Sri Lanka. *Sri Lanka Journal of Aquatic Sciences,* **5**: pp. 97-10.

Geethalakshmi V., Radhakrishnan Nair, V. and Gopal, N. (2021). Ice Utilization in the Fisheries Sector of Kerala. *Fishery Technology* **58 (2021):** pp.128 - 131

Hampikyan, H., Bingol, E.B., Cetin, O. and Colak, H. (2017). Microbiological quality of ice and ice machines used in food establishments. *Journal of water and health*, **15 (3):** pp. 410-417.

Kariyawasam, M.G.I.U., Jinadasa, B.K.K.K., Edirisinghe, E.M.R.K.B. and Sureshkumara, N. (2007). Ice and water sources used for commercial ice production: quality and its suitability to be used on fish. NARA.

Katsaros, G., Koseki, S., Ding, T. and Valdramidis, V.P. (2021). Application of innovative technologies to produce activated safe ice. *Current Opinion in Food Science*, **40:** pp. 198-203.

Kumar, H.S., Parvathi, A. and Karunasagar, I. (2005). Prevalence and antibiotic resistance of Escherichia coli in tropical seafood. *World Journal of Microbiology and Biotechnology*, **21 (5):** pp. 619-623.

Mako, S.L., Harrison, M.A., Sharma, V. and Kong, F. (2014). Microbiological quality of packaged ice from various sources in Georgia. *Journal of Food Protection*, **77 (9):** pp. 1546-1553.

Noor Izani, N.J., Zulaikha, A.R., Mohamad Noor, M.R., Amri, M.A. and Mahat, N.A. (2012). Contamination of faecal coliforms in ice cubes sampled from food outlets in Kubang Kerian, Kelantan. *Tropical biomedicine*, **29 (1):** pp. 71-76.

Olgunoğlu, İ.A. (2012). *Salmonella* in fish and fishery products. In: *Salmonella:* a dangerous foodborne pathogen, ed. Mahmoud, B. S. M. pp. 91-105. InTech. doi: 10.5772/1308

Refai, M.A.E., El-Hariri, M., Ahmed, Z.A.M., and Jakee, J.E. (2020). Histamine Producing Bacteria in Fish. *Egyptian Journal of Aquatic Biology and Fisheries*, **24 (7):** pp. 1-11.

Samakupa, A. P., (2003) hygiene indicators in a fish processing establishment-a case study in a white fish processing establishment, (Final Project 2003, The United Nations University) [Available at: https://www.grocentre.is/static/gro/publication/129/document/alberthprf.pdf]

Sanjee, S.A. and Karim, M. (2016). Microbiological quality assessment of frozen fish and fish processing materials from Bangladesh. *International journal of food science*, **2016**: pp 1 – 6.

Shin, J.H., Chang, S. and Kang, D.H. (2004). Application of antimicrobial ice for reduction of foodborne pathogens (Escherichia coli O157: H7, Salmonella Typhimurium, Listeria monocytogenes) on the surface of fish. *Journal of applied microbiology*, **97 (5):** pp. 916-922.

Svanevik, C.S., Roiha, I.S., Levsen, A. and Lunestad, B.T. (2015). Microbiological assessment along the fish production chain of the Norwegian pelagic fisheries sector-results from a spot sampling programme. *Food Microbiology*, **51**: pp. 144-153.

Tantrakarnapa, K., Makkaew, P., Vatanasomboon, P. and Kengganpanich, T. (2010). Association of sanitary conditions and bacteriological quality of tube ice in ice Plant in Metropolitan Bangkok, Thailand. *Environment Asia*, **3 (1):** pp. 8-12.

Teixeira, P., Brandão, J. Silva, S., Babič,M.N., Gunde-Cimerman, N., Pires, J., Costa, S., and Valério, E. (2019). Microbiological and chemical quality of ice used to preserve fish in Lisbon marketplaces. Journal of Food Safety. **39(4):** pp.1-6.

Vieira, R.H., de Souza, O.V. and Patel, T.R. (1997). Bacteriological quality of ice used in Mucuripe Market, Fortaleza, Brazil. *Food Control*, **8 (2):** pp. 83-85.