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Editorial

International Journal of Sanitary Engineering Research is dedicated to advancing the careers of scientists and promoting the field of public and environmental health research. We are providing the transparency and integrity of the papers with the open-access model. Moreover, we launched a new journal website last year and developed a new and fresh printed design of the journal. We aim to establish the best platform for the researchers to publish their research papers.

This issue provides peer-reviewed research papers from different fields. For example, Rozman, Strah, and Jevšnik from the National Institute of Public Health of Slovenia and the University of Ljubljana presented interesting results of the case study about using of nudging tools in kindergartens and their contribution to the better implementation of hygienic behaviour in childcare workers and children. Alič and Ovca from the University of Ljubljana had explored shortcomings and potential negative consequences that might occur as unwanted side effects of preventive and control measures implemented worldwide to prevent the spread of SARS-CoV-2. In research of Bićanić, Mežnarić, and Gobin from the University of Rijeka the anti-*Legionella* activity of five exotic essential oils and five Mediterranean essential oils characteristic for coastal Croatia was examined. And lastly, Girvan and Mitchell from Liverpool John Moores University had been exploring the knowledge attitudes and perceptions of farmers regarding health and safety in Northern Ireland.

I am grateful to have the ability to work with the multidisciplinary and highly motivated group of editors and reviewers, and the successful researchers who had published their research papers in our journal. Together we are achieving high standards for the journal and the public and environmental health science as well.

On behalf of the editorial board and authors, I wish you a pleasant reading.

Aleš **KRULEC***
Executive editor

* Inštitut za sanitarno inženirstvo
Institute of Public and Environmental Health
Zaloška cesta 155, 1000 Ljubljana, Slovenia
E-mail: ales.krulec@institut-isi.si

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Address of the Editorial Board and Administration

Inštitut za sanitarno inženirstvo
Institute of Public and Environmental Health
Zaloška cesta 155, 1000 Ljubljana, Slovenia
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An evaluation of the effectiveness of nudge techniques in improving hygiene behaviours in Kindergartens

Natalija **ROZMAN**[1*], Branka **STRAH**[2], Mojca **JEVŠNIK**[1]

Original scientific article

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ABSTRACT

Good hygiene practice is an important element in terms of preventing the spread of infections, but it is not always carried out according to instructions among employees in hygienically sensitive work processes. To improve this, tools for nudging hygienic behaviour have been developed, which subconsciously encourage the individual to perform the desired hygienic behaviour. Examples of activity where employees and children constantly come into contact with pathogenic microorganisms are educational institutions (kindergartens). By observing the working process in the selected kindergartens, we wanted to determine the time, technique, and frequency of handwashing among childcare workers and children. In the case of the first ones, we wanted to find out whether they also wear personal protective work equipment. Based on the findings, we wanted to implement the selected nudging tools for better hygiene behaviour. In the first half of the observation, we found that the hygienic behaviour regarding handwashing of childcare workers and children is poor. After setting the nudging tools, hygienic behaviour improved in all the observed groups. The results suggest that the use of nudging tools in kindergartens can significantly contribute to the better implementation of hygienic behaviour (especially handwashing) in childcare workers and children. Consequently, we conclude that with the tools for promoting hygiene behaviour, the incidence of infectious diseases in kindergartens can be reduced. We can direct children towards the healthier and hygienically appropriate way of life by means of the appropriate hygiene behaviour.

Key words: preschool education; handwashing; hand hygiene; behaviour; nudging tools

POVZETEK

Dobra higienska praksa je pomemben element v smislu preprečevanja širjenja okužb, vendar se med zaposlenimi v higiensko občutljivih delovnih procesih ne izvaja vedno po navodilih. Za izboljšanje le-tega so se oblikovala orodja spodbujanja higienskega vedenja, ki podzavestno spodbudijo posameznika k

[1] Faculty of Health Sciences, University of Ljubljana, Zdravstvena pot 5, 1000 Ljubljana, Slovenia

[2] Kindergarten Kekec Grosuplje, Trubarjeva cesta 15, 1290 Grosuplje, Slovenia

[*] *Corresponding author*
Natalija Rozman, MSc Sanitary Engineering
Currently at National Institute of Public Health, Trubarjeva 2, 1000 Ljubljana, Slovenia
E-mail: natalija.rozman1@gmail.com

izvajanju želenega higienskega vedenja. Primer dejavnosti, pri kateri zaposleni in otroci pogosto prihajajo v stik s patogenimi mikroorganizmi, so vzgojno varstveni zavodi (vrtci). Z opazovanjem delovnega procesa v izbranih vrtcih smo želeli ugotoviti čas, tehniko in pogostost umivanja rok pri strokovnih delavkah in pri otrocih. Pri prvih tudi ali uporabljajo osebna zaščitna sredstva. Na osnovi ugotovitev smo želeli uvesti izbrana orodja spodbujanja higienskega vedenja in ugotoviti, ali ta izboljšajo higiensko vedenje opazovancev. V prvi polovici opazovanja smo ugotovili, da je higiensko vedenje glede umivanja rok strokovnih delavk in otrok na nizki ravni. Po namestitvi spodbujevalnih orodij se je higiensko vedenje izboljšalo pri vseh opazovancih. Rezultati nakazujejo, da lahko uporaba spodbujevalnih orodij na področju umivanja rok v vrtcih bistveno pripomore k boljšemu izvajanju higienskega vedenja (predvsem umivanje rok) strokovnih delavk v oddelkih in otrok. Posledično sklepamo, da lahko z orodji spodbujanja higienskega vedenja zmanjšamo pojavnost nalezljivih bolezni v vrtcih ter hkrati otroke z ustreznim higienskim vedenjem usmerjamo k bolj zdravemu in higiensko ustreznemu načinu življenja.

Ključne besede: predšolska vzgoja; umivanje rok; higiena rok; vedenje; spodbujevalna orodja

INTRODUCTION

Nowadays, there are many theoretical and practical training courses on good hygiene practice (referred as GHP) such as proper hand hygiene. According to the scientific literature, such implementation is a constant challenge [1, 2, 3, 4] due to poor knowledge, superficiality, overload and/or employee disinterest and skin irritation. The fact is that an individual's behaviour in the field of hygiene practices affects the health of everyone, that he or she comes into contact with. For more consistent implementation of hygiene practices, nudging tools have been developed to encourage the individual to perform the desired action (e.g. handwashing) [3]. Nudging tools in the field of hand hygiene are important, as many studies shows an association between improved hand hygiene and a reduction in the number of diseases [2, 5, 6]. An example of an activity in which employees and children often come into contact with infections are educational institutions (kindergartens). There, regular and proper exercise of handwashing is crucial, as otherwise the health of employees, children and parents is at stake. Simple, cost-effective tools for promoting hygienic behaviour can help target behaviours to be improved and motivated by childcare workers and children [3, 7].

The term "nudge" was first described by the authors Thaler and Sunstein (8) as a "gentle push" with the main goal of directing people's behaviour towards a better decision. This definition has been labelled in scientific circles as too broad and imprecise. Therefore, they stipulated that incentives must meet certain requirements. Nudges must be low-cost, simple, easy to reject (without coercion) and nudges need to help people make better decisions (safer and healthier).

Nudges must be low-cost, simple, easy to reject (without coercion) and nudges need to help people make better decisions (safer and healthier).

The health hygiene regime in kindergarten is based on ensuring a safe and healthy environment. An important factor is regular and proper

The main purpose of handwashing is to prevent the transmission of microorganisms that are applied to the skin of the hands in contact with surfaces and other persons, objects and the environment. This prevents the contact spread of infectious diseases.

During the handwashing process itself, in addition to the time and technique of washing, the encouragement (supervision) of children is also crucial.

handwashing. The main purpose of handwashing is to prevent the transmission of microorganisms that are applied to the skin of the hands in contact with surfaces and other persons, objects and the environment. This prevents the contact spread of infectious diseases. Handwashing of children and childcare workers in kindergarten is essential: before entering the playroom, before preparing meals, before and after meals, after outdoor activities, after using the toilet, after nose cleaning, coughing, sneezing and after changing diapers. During the handwashing process itself, in addition to the time and technique of washing, the encouragement (supervision) of children is also crucial [9, 10].

The aim of the research was to determine: a) time, technique and frequency of handwashing among childcare workers and children, b) in the case of the first ones, we wanted to find out whether they comply with hygiene tidiness criteria and wear personal protective work equipment and c) based on the findings, we wanted to implement the selected nudging tools for better hygiene behaviour and measure its improvement.

METHODS

Type of research methodology, techniques and methods of data collection

In the research a qualitative methodology and descriptive method of work were used. The method of data collection is open observation of childcare workers and children in the practice of handwashing (time, technique and frequency), in the case of the first ones, also the hygienic tidiness and whether they wear personal protective work equipment.

For observation, we created and used an observation list with criteria for proper handwashing (time, technique, frequency) of all observers and with criteria for hygienic tidiness and use of personal protective work equipment of childcare workers.

Research strategy, sample and data analysis

We used a case study. The units of study are two kindergartens. We selected purposeful and non-random samples consisting of two wards of children with first age range (2-3 years), two wards of children with second age range (4-6 years) and childcare workers from each ward. The whole observation took place for eight weeks and simultaneously in both kindergartens with the prior given oral consent by the kindergarten principals. Then we asked childcare workers to give their written consent. When they agreed to participate, we also informed children's parents about the research process in written statement. The kindergarten health and hygiene regimen staff then confirmed to us through e-mail the participation of all childcare workers and children in the survey.

In the first kindergarten, we firstly observed the ward of the first age range for two weeks. After that, we have selected several nudging tools to promote hygienic behaviour, set and tested them in a childcare work

environment. The observing time (2 weeks) after the installation of nudging tools was the same as the observing time before the installation of those tools. The ward of the second age range was then observed in the same kindergarten for two weeks, followed by the installation of the same tools as in the first age ward, and then observed for another two weeks. The same procedure was then repeated in the second kindergarten, where the selected groups were observed half the time less than those in the first kindergarten. All observation data were marked in the observation list.

The selected nudging tools were:

- a poster made in A4 size, showing (hygiene requirements) when the handwashing is necessary;
- plasticized rectangular pictures, measuring approximately 8 × 6,5 cm. The first picture showed handwashing with running water and soap. Second picture showed a cheerful smile, which was used as a hint for a well done job (thumbs up). Both images were placed next to the soap dispensers in the selected observed groups/wards;
- the story of a tractor that illustrates proper handwashing technique, which was introduced in the morning round (an educational work process in which children and childcare workers sit on cushions and learn new concepts) [11];
- poster created on A0 format. Handwashing technique, shown step by step with pictures of hand movements, mowing and hay harvesting with tractor. The poster was hung in the washrooms above the sinks;
- practical learning of handwashing at the sink for each child individually.

In the end, an analysis of all the obtained data was made and a comparison with the observation results before and after the introduction of the nudging tools. The analysis of the data was prepared in summary form so that the individual cannot be recognized and thus the anonymity of all participants was guaranteed. The data were analysed using an Excel computer program. The Equation 1 was used to calculate consistency of proper handwashing of childcare workers.

Equation 1. *Basic consistency calculation of handwashing [12]:*

$$\text{Consistency of proper behavior (\%)} = \frac{\text{number of actions}}{\text{number of opportunities}} \text{ x } 100$$

For analysing children's results, we used the scaling method to compare the results before and after the use of nudging tools (Equation 2).

Equation 2. *Scaling calculation:*

$$\text{Scaling method (scaled No. of children who perform specified criterion appropriately)} = \frac{\text{No. of children who perform the specified criterion appropriately}}{\text{smaller No. of all children present}} \times \frac{\text{smaller No. of all children present}}{\text{larger No. of all children present}}$$

In this way, we adjusted the results of the number of all present children for all observed parameters so that the groups of children before and after the nudging tools were identical. The scaling results were then inserted into the consistency equation for performing handwashing by children (Equation 3).

Equation 3. *Consistency calculation of children's handwashing using scaling:*

$$\text{Consistency of handwashing (\%)} = \frac{\text{scaled No. of children who performs the specified criterion appropriately}}{\text{larger No. of all children present in the observed wards}} \times 100$$

RESULTS

In the practical part of the research, we made a total of 60 observations of hygiene behaviour through the elaborated observation list. Of these, 30 observations were made before the introduction of nudging tools and 30 observations after the introduction of nudging tools. **Table 1 and 2** show the observation results of the hygiene tidiness and handwashing of children and childcare workers. The results in table 1 and 2 are shown by the number of observations of proper hygiene behaviour and by percentages (%). A 100% share means that the observed parameter out of a total of 30 observations or opportunities has been correctly (appropriately) performed each time. The most common causes (disruptive factors) of inadequate hygiene behaviour are also listed. **Figure 1** shows two of the selected nudging tools, that were used during practical part of the research.

Figure 1.
Two of selected, set and tested nudging tools

Note:
Two of selected, set and tested nudging tools are hint pictures, placed next to the soap dispensers and poster of handwashing technique, hung above the sinks.

Table 1. Observation results of hygienic tidiness of childcare workers before and after the use of nudging tools and causes for their inadequate hygiene behaviour

Observation criteria	Before using NT		After using NT		Causes of inadequate hygiene behaviour
	A (n)	A (%)	B (n)	B (%)	
1. Unvarnished and trimmed nails	19	**63**	21	**70**	Not complying the prescribed health and hygiene regimen (subjective cause).
2. Absence of wearing jewellery	20	**67**	19	**63**	Not complying the prescribed health and hygiene regimen (subjective cause).
3. Appropriate health condition	30	**100**	30	**100**	/

Note: NT – nudging tools; A (n) – the number of observations of proper hygiene tidiness before the introduction of NT; A (%) – the number of observations of proper hygiene tidiness before the introduction of NT, shown as a percentage (%); B (n) – the number of observations of proper hygiene tidiness after the introduction of NT; B (%) – the number of observations of proper hygiene tidiness after the introduction of NT, shown as a percentage (%).

Table 2. Observation results of handwashing of childcare workers and children under certain hygiene requirements and causes for their inadequate handwashing

Observation criteria		Before using NT						After using NT						Causes of inadequate hygiene behaviour
		A (n)			A (%)			B (n)			B (%)			
		T	Tq	S	T	Tq	S	T	Tq	S	T	Tq	S	
1. Washing children's hands after entering the playroom	parents	0	0	0	**0**	**0**	**0**	0	0	0	**0**	**0**	**0**	There were no sinks available.
	childcare workers	2	0	2	**7**	**0**	**7**	0	0	0	**0**	**0**	**0**	Superficiality, rushing, unattended children.
2. Handwashing before meal preparation	childcare workers	6	3	19	**20**	**11**	**68**	5	9	19	**18**	**31**	**68**	Rushing, superficiality.
3. Handwashing before meal	childcare workers	1	2	19	**2**	**7**	**64**	8	9	20	**27**	**30**	**66**	Rushing, superficiality.
	children	3	3	11	**10**	**10**	**37**	21	21	27	**70**	**70**	**90**	Rushing (on the command of childcare workers) and superficiality.
4. Handwashing after meal	childcare workers	1	1	7	**2**	**2**	**23**	6	8	14	**20**	**27**	**47**	Rushing, superficiality.
	children	4	3	11	**13**	**10**	**37**	21	21	27	**70**	**70**	**90**	
5. Handwashing after completed activities	childcare workers	3	3	12	**10**	**10**	**40**	11	11	18	**37**	**37**	**60**	Rushing, superficiality and belief that they have enough clean hands.
	children	6	4	15	**20**	**13**	**50**	23	21	26	**77**	**70**	**87**	Rushing, superficiality.
6. Supervision and assistance in washing children's hands	childcare workers	6	6	11	**20**	**20**	**37**	7	13	16	**23**	**43**	**53**	Lack of encouragement and only verbal referral to children for wash their hands.
7. Handwashing after changing diapers	childcare workers	4	2	10	**24**	**13**	**67**	4	6	10	**24**	**40**	**67**	Rushing, superficiality.
	children	16	4	16	**53**	**13**	**53**	19	15	20	**63**	**50**	**67**	Rushing (on the command of childcare workers) and superficiality.
8. Handwashing after cleansing nose	childcare workers	2	0	1	**15**	**0**	**8**	0	0	2	**0**	**0**	**15**	Superficiality.
	children	3	1	6	**10**	**3**	**20**	3	1	3	**10**	**3**	**10**	Lack of encouragement, rushing and superficiality.
9. Handwashing after using the toilet	children	3	3	11	**10**	**10**	**37**	21	21	27	**70**	**70**	**90**	Rushing (on the command of childcare workers) and superficiality.

Note: NT – nudging tools, T – time of handwashing, Tq– handwashing technique, S – use of soap; A (n) – the number of observations of proper handwashing before the introduction of NT; A (%) – the number of observations of proper handwashing before the introduction of NT, shown as a percentage (%); B (n) – the number of observations of proper handwashing after the introduction of NT; B (%) – the number of observations of proper handwashing after the introduction of NT, shown as a percentage (%).

Table 3. Observation results of the use of personal protective work equipment of childcare workers before and after the use of nudging tools and causes of their inadequate hygiene behaviour.

Observation criteria	Before using NT		After using NT		Causes of inadequate hygiene behaviour
	A (n)	A (%)	B (n)	B (%)	
1. Wearing work clothes and shoes	25	**83**	25	**83**	Same footwear for indoor and outdoor playroom areas → superficiality.
2. Wearing hygienic apron to distribute food	9	**30**	10	**33**	Childcare workers at one kindergarten did not have an apron available (not provided).
3. For the first age range only: Use of protective gloves (diaper changing of children in the event of illness and potty cleaning)	10	**67**	15	**100**	Rushing, superficiality.

Note: NT – nudging tools; A (n) – the number of observations of proper hygiene behaviour before the introduction of NT; A (%) – the number of observations of proper hygiene behaviour before the introduction of NT, shown as a percentage (%); B (n) – the number of observations of proper hygiene behaviour after the introduction of NT; B (%) – the number of observations of proper hygiene behaviour after the introduction of NT, shown as a percentage (%).

Table 3 shows whether childcare workers used personal protective work equipment appropriately. The results in table 3 are shown by the number of observations of proper hygiene behaviour and by percentages (%). A 100% share means that the observed parameter out of a total of 30 observations or opportunities has been correctly (appropriately) performed each time. The most common causes (disruptive factors) of inadequate hygiene behaviour are also listed.

DISCUSSION

Hygienic tidiness and handwashing of childcare workers before the use of nudging tools and causes for their inadequate hygiene behaviour

Childcare workers do not follow the kindergarten's health hygiene regime, which stipulates that nails must be trimmed and unvarnished and jewellery must be removed before starting childcare work.

Hygienic tidiness of childcare workers is important for the protection of children's health and to avoid potential health hazards (e.g. long nails and jewellery can injure children and at the same time allow the retention of microorganisms and their spread to children and objects) [12]. Prior to any use of nudging tools, childcare workers performed best in their health condition that was adequate throughout the observation (did not pose a health risk). Obervers performed worse in the first two observation criterias (Unvarnished and trimmed nails; Absence of wearing jewellery). The causes of inadequate hygiene behaviour of these two criterias are difficult to determine and are mostly of subjective origin (superficiality, rushing and thinking that long and varnished nails and wearing jewellery do not pose a health risk). The fact is that in this regard, childcare workers do not follow the kindergarten's health hygiene regime, which stipulates that nails must be trimmed and unvarnished and jewellery must be removed before starting childcare work [9].

Obtained results also shows that childcare workers do not perform handwashing for a sufficient amount of time, with proper technique, and not often enough with every hygiene requirement.

Obtained results also shows that childcare workers do not perform handwashing for a sufficient amount of time, with proper technique, and not often enough with every hygiene requirement. The lowest results

were technique and time of handwashing (less than 20 seconds). The most common causes for inadequate behaviour are rush, superficiality and the assumption that the hands are already clean enough. They also performed poorly in supervision and assistance in washing children's hands. In most cases, encouragement was present only as a verbal referral to children for washing their hands, but not in detail in terms of their control over appropriate timing and washing techniques and the use of soap. As there is no other research available on observing handwashing of childcare workers, we can compare our findings with those in the field of health. Lack of hand hygiene (handwashing and hand disinfection) has been identified in a number of studies in healthcare professionals [4, 13, 14]. They, like the observers in our study, performed handwashing/hand disinfection with lacking frequency (they did not comply with hygiene requirements). Due to their rush and superficiality, they also performed in some cases inappropriate time and technical execution of handwashing / disinfection. Studies around the world, therefore, suggests that hand-washing is insufficiently controlled in hygienically sensitive institutions (even in developed countries). At the same time, too few measures have been put in place to properly and regularly implement it.

The most common causes for inadequate behaviour are rush, superficiality and the assumption that the hands are already clean enough.

Use of personal protective work equipment of childcare workers before the use of nudging tools and causes of their inadequate hygiene behaviour

We also wanted to find out if childcare workers use personal protective work equipment in the work process. They performed best when wearing work clothes and shoes. However, the most common causes of poor hygiene behaviour were wearing the same footwear in the indoor and outdoor playroom areas (e.g. when children were playing on the patio, childcare workers wore the same footwear as in the indoor playroom). With that, they enable the pollution of the indoor playroom and also possible transfer of microorganisms from the outside to the inside of the playroom. The use of protective gloves was observed only in first age range (ward), as there were no longer daily diapers changing in the older age ranges (wards) (except in the case of illnesses, which were not discovered in the time of observation). In comparison with the childcare assistants, the childcare teachers performed better. The reason for the incorrect use of protective gloves was because of the rushing to the following tasks. Observers performed worst when wearing an apron to distribute food. When distributing food, we come in contact with it and wearing an apron is absolutely essential. Also, in one of the two selected kindergartens observers used an apron for distributing food while in the other it was not possible (the kindergarten did not provide it). Poor and/or lack of knowledge of the importance of personal hygiene and the use of personal protective work equipment of workers in the food industry has identified many similar studies worldwide. They all came to the conclusion that in order to protect the health of consumers and employees and to prevent cross-contamination, the knowledge of workers who comes in food contact, needs to be constantly upgraded, repeated and verified [15, 16, 17]. Knowledge

The most common causes of poor hygiene behaviour were wearing the same footwear in the indoor and outdoor playroom areas.

With that, they enable the pollution of the indoor playroom and also possible transfer of microorganisms from the outside to the inside of the playroom.

The reason for the incorrect use of protective gloves was because of the rushing to the following tasks.

A higher age of children (greater ability to think) does not yet mean a better handwashing practice.

All of the nudging tools were installed in a visibly place at all times, allowing children and childcare workers to constantly repeat and learn how to properly wash their hands.

and awareness of the importance of good hygiene practice in food management is essential to reduce food-related outbreaks/poisonings [18].

Handwashing of children under certain hygiene requirements before the use of nudging tools and causes for their inadequate hygiene behaviour

Regarding children's handwashing, all children together and also as individual age classes (wards), performed best when using soap during handwashing, while time and technique of handwashing were poorer. Nevertheless, the share of soap use was still low or below 50%. One of the most common causes for inadequate washing of children 's hands is the rush on command of childcare workers. During the observation, we found out that children do not know that after sneezing, coughing and/or cleansing their nose, they should always wash their hands. Dreibelbis et al. [6] found out that children with the absence of the nudging tools do not perform proper hygiene behaviour (especially handwashing). They were aware that children with new hygiene habits would be able to live healthier also in adult life. From the obtained results, we can also conclude that a higher age of children (greater ability to think) does not yet mean a better handwashing practice. Results indicate that children of the first age ward performed better handwashing practice. A similar finding was made by Au et al. [2], who concluded that for children (4-6 age), improved theoretical knowledge of proper handwashing does not necessarily mean improved practical handwashing knowledge.

Given the obtained results before any use of nudging tools, we found out that both theoretical and practical knowledge of handwashing at selected kindergartens were low. Therefore, we have chosen simple and affordable tools to promote hygienic behaviour. We sat in a morning circle (round) in the playroom with children and childcare workers. Then we began with a detailed explanation and meaning of the poster, pictorially showing when to wash hands (after coughing, after using the toilet, after playing, before cooking, etc.) and placed it in a visibly place in the playroom and at the height of children. For the proper handwashing, we introduced the story of mowing and hay harvesting with tractor to all observers. Through it, we learned together the time (at least 20 seconds) and technical implementation of handwashing, including the use of soap. In order to better remember the story, we transferred it pictorially to a poster (A0) and hung it in the washrooms above the sinks.

Next to the soap dispensers, we installed a picture of handwashing with running water and soap, and a picture of a cheerful smile that indicated a well done job (thumbs up). In order to provide the best possible visualization and regular handwashing, to each child individually the procedure of proper handwashing at the sink (use of running warm water, soap and towels) was shown. All of the nudging tools were installed in a visibly place at all times, allowing children and childcare workers to constantly repeat and learn how to properly wash their hands. After that, we began to re-watch all the observers. In addition, during the observation

period in each morning circle, we reiterated the importance of the made posters and stories.

Hygienic tidiness and the use of personal protective work equipment of childcare workers after the use of nudging tools

After the use of nudging tools, the hygienic tidiness of childcare workers in varnished and trimmed nails improved by 6%, while wearing jewellery increased by 3%. The health condition remained the same (100%) as before the introduction of the nudging tools. Because we did not use direct nudging tools to remind observers of their hygienic tidiness, the obtained results are not surprising. Nevertheless, after the use of nudging tools, the situation could be better, since in the morning round with children and childcare workers we told them what the proper hygienic tidiness means. Very similar goes for wearing work clothes and footwear, and an apron (criteria for personal protective work equipment). The opposite result was observed in the use of protective gloves, with 36% use improved. The reason for this is probably our mention of the importance of protecting the health of employees and children, which is also reflected in the use of protective gloves when changing diapers.

After the use of nudging tools, the hygienic tidiness of childcare workers in varnished and trimmed nails improved by 6%, while wearing jewellery increased by 3%.

Handwashing of childcare workers and children under certain hygiene requirements after the use of nudging tools

The highest improvement was observed in handwashing of all observers, where direct nudging tools were used. Namely, all observers experienced nudging tools positive. Handwashing of childcare workers improved about 20-30%, where they performed best in the technical and timely implementation of handwashing. Even more improvement was seen in children who washed their hands about 50-60% more appropriately. Nudging tools that were used in the research, have advantage in its simplicity and affordability. The same conclusion reached also other studies, which used nudging tools for improving children's handwashing in kindergarten and school [2, 6, 19].

To improve handwashing, we advise childcare workers to practice the appropriate time (at least 20 seconds) and technique (to cover all areas of the hands) of handwashing and to use a sufficient amount of soap (1 push or 1 ml of liquid soap per person for a single wash) [20]. In doing so, it is crucial to avoid rushing and superficiality and to not encourage children to do so. In addition, it is important to finish a certain educational process (e.g. playing in a playroom, outdoor activities, etc.) a few minutes earlier to instruct children to wash their hands in a timely manner. They will therefore have sufficient time to perform handwashing. Also, children should be regularly encouraged, taught and assisted in the process of handwashing (through various stories, songs, games, folders and posters). All of these are affordable and easy to use nudging tools for which there should be no excuse for not using them. Despite important findings, the survey has some limitations related to the relatively small sample of observers in relation to the total number of kindergartens in Slovenia, the questionable longevity of nudging tools and the potential bias of the

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It is important to finish a certain educational process (e.g. playing in a playroom, outdoor activities, etc.) a few minutes earlier to instruct children to wash their hands in a timely manner.

The use of nudging tools in kindergartens can significantly contribute to a better implementation of hygienic behaviour of childcare workers and children.

The importance of hygiene behaviour (handwashing) must be constantly emphasized, encouraged, repeated and taught.

We believe that more emphasis should be placed on pre-school education in topics that include general hygiene, with an emphasis on personal hygiene and the prevention of the spread of infectious diseases.

Nudging tools used in the research can also be used in home environment and in other educational institutions (primary and secondary schools, faculties, educational institutions, etc.) for their simplicity and affordability.

observer, which may have a slight impact on the reliability of the survey. To minimize this, we have created an observation list and validated it through the observation test of participants before the observation itself. In doing so, we achieved repeatability of the research. Regardless of the limitations, we have demonstrated that simple and affordable nudging tools can improve handwashing of childcare workers and children in the kindergartens.

CONCLUSION

Based on the conducted research, we found out that the use of nudging tools in kindergartens can significantly contribute to a better implementation of hygienic behaviour of childcare workers and children. However, we emphasize that installing the nudging tools in wards alone is not sufficient or likely to work in the short term. Nudging tools should therefore be changed and designed for a limited period of time (e.g. once a month) so that they are always attractive, enjoyable and positive for children. In addition, the importance of hygiene behaviour (handwashing) must be constantly emphasized, encouraged, repeated and taught. Our research is the first of its kind to provide insight into the hygienic behaviour of childcare workers and children in two selected kindergartens in Slovenia, and the first study in which we used nudging tools to improve hygienic behaviour in Slovenian kindergartens.

In order to get a better overview of the actual state of hygiene behaviour, more kindergartens should be included in the research and the theoretical and practical knowledge of hygiene behaviour of childcare workers should be improved. We believe that more emphasis should be placed on pre-school education in topics that include general hygiene, with an emphasis on personal hygiene and the prevention of the spread of infectious diseases. In order to ensure proper hygienic behaviour of childcare workers and children in the wards, each kindergarten could introduce greater control over hygiene requirements.

Such supervision could be carried out by health and hygiene regimen professional staff (e.g. once a month using an observation list). A weak point in our study is the comparison of handwashing among children of the first and second age groups (wards). Further research would have to elaborate more precisely on working methods, identifying and determining the same number of children to observe.

Nudging tools used in the research can also be used in home environment and in other educational institutions (primary and secondary schools, faculties, educational institutions, etc.) for their simplicity and affordability. There are no sufficient excuses for their non-use or absence, since the nudging tools used in the research can only have a positive response to the targeted behaviour. It is also important to emphasize, that our study was undertaken before the pandemic COVID-19 was declared. Current situation shows even higher importance in complying efficient hygiene behaviour (especially handwashing) in kindergartens to control the spread of COVID-19.

We conclude that with nudging tools for hygienic behaviour, we can reduce the incidence of infectious diseases in kindergartens, while at the same time directing children towards the healthier and hygienically appropriate way of life by means of the appropriate hygiene behaviour.

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SARS-CoV-2: A critical review of preventive and control measures in the context of the virus' characteristics

Manca **ALIČ**[1a], Andrej **OVCA**[1*]

Review scientific article

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ABSTRACT

The year 2020 has been marked by the novel coronavirus, named Severe Acute Respiratory Syndrome 2 (SARS-CoV-2), which causes coronavirus disease COVID-19. The World Health Organization (WHO) declared a global pandemic on the 11th of March 2020 due to the spread of this very contagious virus throughout the world. Since the outbreak, we have gained many insights about the virus, its presence and persistence in the environment and its possible and most common transmission routes. Such knowledge about the virus is invaluable for establishing effective preventive and control measures (also referred to as Non-Pharmaceutical Interventions (NPIs)) that have become a key to tackling this pandemic in the absence of a SARS-CoV-2 vaccine. In this review, we discuss five main groups of NPIs: 1) ventilation, 2) cleaning and disinfection, 3) hand hygiene, 4) physical distancing, and 5) protective masks. We explore their shortcomings and potential negative consequences that might occur as unwanted side effects.

Key words: SARS-CoV-2; transmission routes; presence; persistence; preventive measures; NPIs

POVZETEK

Leto 2020 je pomembno zaznamovano z novim korona virusom, imenovanim akutni respiratorni sindrom 2 (SARS-CoV-2), ki povzroča korona-virusno bolezen COVID-19. Zaradi hitrega in obsežnega širjenja je Svetovna Zdravstvena Organizacija (SZO) 11. marca 2020 razglasila pandemijo. Od pojava bolezni smo pridobili veliko informacij o virusu, njegovi obstojnosti v okolju ter o možnih poteh prenosa. Pridobljeno znanje o karakteristikah SARS-CoV-2 je ključno za vzpostavitev učinkovitih preventivnih ukrepov (angl. *Non-Pharmaceutical Interventions*), ki so ključni za obvladovanje te pandemije ob odsotnosti cepiva. Članek obravnava pet ključnih preventivnih ukrepov: 1) prezračevanje, 2) čiščenje in dezinfekcija, 3) higiena rok, 4) fizična razdalja in 5) zaščitne maske. Ob pregledu študij smo raziskali njihove omejitve ter identificirali možne negativne posledice.

Ključne besede: SARS-CoV-2; poti prenosa; prisotnost; obstojnost; preventivni ukrepi

[1] University of Ljubljana, Faculty of Health Sciences, Zdravstvena pot 5, 1000 Ljubljana, Slovenia

[1a] Master student of Sanitary Engineering at University of Ljubljana, Faculty of Health Sciences, Zdravstvena pot 5, 1000 Ljubljana, Slovenia

[*] *Corresponding author*
Assist. Prof. Andrej Ovca
University of Ljubljana, Faculty of Health Sciences, Zdravstvena pot 5, 1000 Ljubljana, Slovenia
E-mail: andrej.ovca@zf.uni-lj.si

Due to the rapid and global spread of SARS-CoV-2, the WHO declared the outbreak of a global pandemic on the 11th of March 2020, after declaring a public health emergency in January.

Unless there is a vaccine available, some of existing viruses are best controlled with appropriate preventive and control measures, which are also referred to as Non-Pharmaceutical Interventions.

INTRODUCTION

On the 31st of December 2019, the Wuhan Municipal Health Commission in China reported a cluster of cases of pneumonia in Wuhan, which is located within Hubei Province. On the 13th of January, the same pneumonia was detected in Thailand [1]. However, a recent study by Apolone et al. [2] shows that the virus had been present in Italy since September 2019. The authors of the study found SARS-CoV-2 receptor-binding domain (RBD)-specific antibodies in blood samples of asymptomatic lung cancer screening trial participants. This finding shows that the virus was circulating among asymptomatic participants in the months before it was identified in China. Later, the World Health Organization (WHO) announced an official name for the virus responsible for the above-mentioned pneumonia cases; Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (previously known as '2019 novel coronavirus') and the disease it causes; coronavirus disease 2019 (COVID-19) [3].

Due to the rapid and global spread of SARS-CoV-2, the WHO declared the outbreak of a global pandemic on the 11th of March 2020, after declaring a public health emergency in January [1]. At the time that the present paper is being prepared, the virus has spread to 215 countries, in which over 40 million people have been infected, and over 1 million of the infected people died since its appearance to mid-October 2020 [4].

This is not the first time a coronavirus has caused extensive health problems. Coronaviruses (CoVs) are a large group of viruses that usually spread among animals. However, some can infect people and cause diseases ranging from a mild cold to Severe Acute Respiratory Syndrome (SARS). In 2002, SARS emerged in China and, in about eight months, spread to 33 countries, causing over 8,000 infections [5]. Another recent pandemic, also caused by a coronavirus, was Middle East Respiratory Syndrome Coronavirus (MERS-CoV), first detected in Saudi Arabia in 2012. Since then, it has been identified in 27 countries, with the most cases (80%) reported in its country of origin [6].

Unless there is a vaccine available, some of existing viruses are best controlled with appropriate preventive and control measures, which are also referred to as Non-Pharmaceutical Interventions (NPIs). To establish effective and not overly excessive NPIs, we have to understand how the virus acts, which includes knowing where the virus is present and how persistent it is in the environment. Furthermore, we need to know the possible and the most common transmission routes for this virus to spread. Once we have this information about the virus's characteristics, we can guide people with the most appropriate NPIs specific for a certain virus, in our case SARS-CoV-2. The aim of this review is therefore to *1)* summarise existing knowledge about transmission routes of SARS-CoV-2, *2)* collect information about its presence and persistence in the environment *3)* outline existing NPIs that were adopted during this pandemic to control the spread of SARS-CoV-2, and *4)* critically review described NPIs in context of their advantages, shortcomings, and possible consequences they might bring.

TRANSMISSION ROUTES

The number of possible transmission routes varies between infectious agents [7]. SARS-CoV-2 tends to be highly infectious, which could relate to the ability of an infected individual to shed infective particles even when they have no symptoms. Such shedding of the virus can happen at three phases of SARS-CoV-2 infection by *1)* an infected person before showing symptoms (pre-symptomatic), *2)* an infected person that is not showing symptoms (asymptomatic), and *3)* an infected person after recovery who can still shed virulent particles (post-symptomatic) [8]. The duration of the above-mentioned phases differs from one phase to the other; the pre-symptomatic phase lasts approximately 2–3 days, asymptomatic 4–11 days, and post-symptomatic 11–14 days. Consequently, people can become infected if they are in proximity of an infected individual that may never even know they are/were infected and able to transmit the virus [8]. Castaño et al. [9] reported that virus shedding may happen when an infected person is sneezing, coughing, talking, spitting, singing or exhaling (i.e., that respiratory secretions are being released from the infected individual). This secretion contains infectious particles that can be categorized into droplets or aerosols based on their diameter. Droplets have a diameter larger than 5 μm, while aerosols are smaller than 5 μm in diameter.

SARS-CoV-2 can be transmitted through many different routes or even combinations of them (Figure 1). Unfortunately, we only have limited information about the specific transmission routes of SARS-CoV-2, which, consequently, makes it more difficult to accept efficient yet not excessive NPIs to confine the spread of the virus. The WHO [10] reported that it is predominantly spread with direct contact amongst people (i.e., human-to-human). However, they described many possible modes of transmission, including contact, droplet, airborne, fomite, faecal-oral, blood-borne, mother-to-child and animal-to-human transmission.

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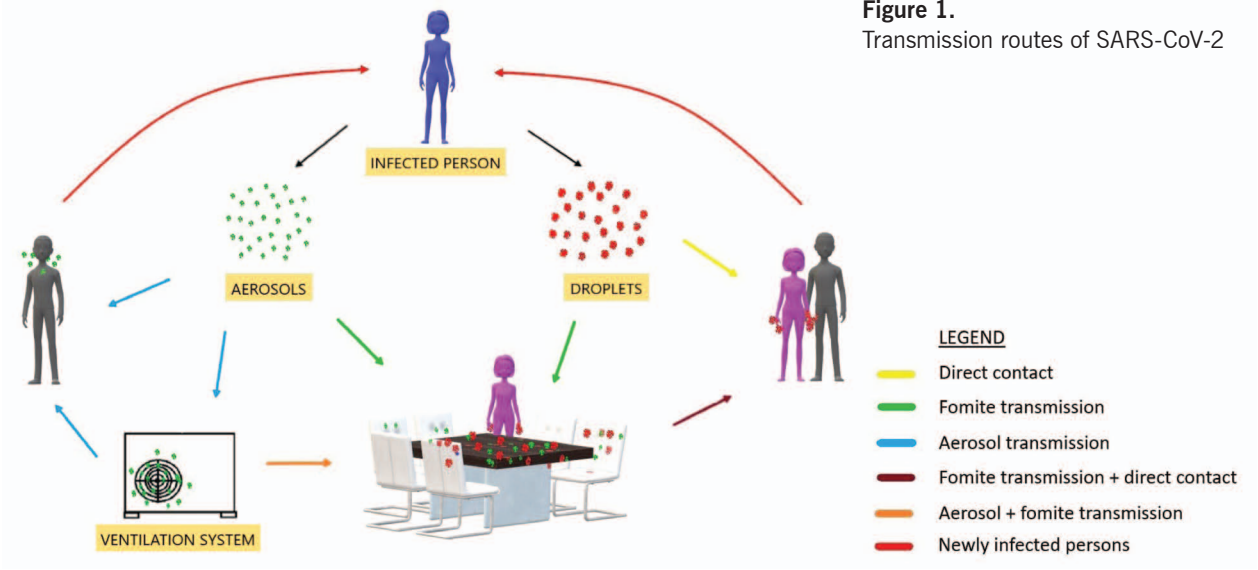

Figure 1.
Transmission routes of SARS-CoV-2

The meaning of human-to-human transmission is the immediate movement of an infectious agent to a susceptible host. Such movement is possible through 1) direct contact (touching, kissing, biting, and sexual intercourse) with an infected individual and 2) droplet dispersed by an infected person that reach the facial membranes (eyes, nose, or mouth) of susceptible individuals.

Li et al. [11] analysed the data of the first 425 confirmed cases in order to determine epidemiologic characteristics of SARS-CoV-2. They found evidence that the virus has been present since the middle of December 2019 and was transmitted human-to-human with close contact. They also estimated a reproductive number (R_0) of approximately 2.2, which means every infected individual infected another 2.2 persons. R_0 helps us predict the epidemic. As long as R_0 is greater than 1, the number of new infections amongst people will rise. In contrast, when R_0 is less than 1, it implies that the epidemic is being controlled.

An important fact about SARS-CoV-2 is its infectious dose. Thus far, no experimental studies have provided information about the exact SARS-CoV-2 infectious dose for humans, neither in droplets nor in aerosols. Furthermore, no studies have been published estimating viral loads in fomites. However, in a recent study by Basu [12], the infectious dose was estimated to be 300 infectious particles. The estimation was made with a computational characterization of inhaled droplet transport in the upper airway. The aforementioned authors also suggested that the infectious dose is probably low, considering the rapid spread of the virus.

Direct transmission (human-to-human)

The meaning of human-to-human transmission is the immediate movement of an infectious agent to a susceptible host. Such movement is possible through 1) direct contact (touching, kissing, biting, and sexual intercourse) with an infected individual and 2) droplet dispersed by an infected person that reach the facial membranes (eyes, nose, or mouth) of susceptible individuals (Figure 1). It is often limited to a distance of 1 m or less from the source [7]. What makes this transmission route so probable is the large viral load that can be emitted when an infected individual sheds the virus. Also, since it is a human-to-human transmission, the emitted viral load spends less time outside of a host. This is in contrast to other routes of transmission [9].

Indirect contact with fomites (fomite transmission)

Fomites can be formed when an infected person emits the virus in the form of respiratory droplets or secretions. These emitted droplets are too heavy to be airborne, and they thus land on the objects and surfaces surrounding the infected person.

Castaño et al. [9] summarised that fomites are objects or surfaces contaminated with an infectious agent. Fomites can be formed when an infected person emits the virus in the form of respiratory droplets or secretions. These emitted droplets are too heavy to be airborne, and they thus land on the objects and surfaces surrounding the infected person (Figure 1). Once a person touches fomites (e.g., doorknobs, shopping cart, stair railing, elevator buttons, etc.) and then touches their mouth, nose, or eyes, they can become infected [13]. On some materials, viruses can remain viable for hours or even days, especially if environmental conditions (i.e., temperature and humidity) are favourable. Another possible but less probable way of fomites forming is with aerosols settling on surface or objects [9]. A combination of indirect and direct transmission is also possible when a person catches the virus through fomites and spreads it with close contact, like ordinary handshaking [10] (Figure 1).

Airborne transmission

The WHO described airborne transmission as the spread of an infectious agent caused by the dispersal of droplet nuclei, also referred to as aerosols [10]. Castaño et al. [9] highlighted that a virus in an aerosol form can directly cause an infection by reaching an individual's respiratory tract or indirectly through settling on surfaces or objects forming fomites (Figure 1). The difference between droplets and aerosols is not only related to their size but also the distance they can travel, and the time they can remain in the air. Droplets usually spread and fall within a radius of 1–2 m from their source, all within seconds from the moment they originated. Aerosols, in contrast, can stay present in the environment for minutes or even hours while carrying their viral load and travel over a long distance (i.e., 10 metres and more). Morawska and Cao [14] discussed the possibility of aerosols being transported via ventilation systems (Figure 1). Such characteristics of aerosols (i.e., to remain present in the environment for a long time and being able to travel via ventilation systems) increase the ability of the virus to travel longer distances away from its source, thus exposing larger numbers of individuals to the virus [9].

The difference between droplets and aerosols is not only related to their size but also the distance they can travel, and the time they can remain in the air. Droplets usually spread and fall within a radius of 1–2 m from their source, all within seconds from the moment they originated. Aerosols, in contrast, can stay present in the environment for minutes or even hours while carrying their viral load and travel over a long distance.

The European Centre for Disease Prevention and Control (ECDC) reported that aerosol transmission is more probable in closed spaces in which many people stay for longer periods. It is also known to occur during aerosol-generating procedures, such as intubation [15]. Several recent studies suggest the plausibility of transmission of SARS-CoV-2 via aerosols [14, 16-18]. Setti et al. [17] suggested that confirmation of airborne transmission might explain the vast spread of the virus worldwide, which could hardly be ascribed only to human-to-human contact and fomite transmission. Shen et al. [18] reported that aerosol transmission is possible, especially if a person is exposed to high concentrations of aerosol for a long period in a relatively confined space. In a recent study, Zhang et al. [19] tried to evaluate the SARS-CoV-2 infection risk via aerosol transmission in case of a south China seafood market. The study is based on currently available information pertaining to SARS-CoV-2 and other coronaviruses. However, due to the present uncertainties about the virus, they were unable to confirm aerosol transmission between customers at a seafood market.

Shen et al. reported that aerosol transmission is possible, especially if a person is exposed to high concentrations of aerosol for a long period in a relatively confined space.

Foodborne transmission

Foodborne transmission means catching a foodborne illness when consuming contaminated food or drinks [20]. Food could be contaminated directly, or through food packaging, by respiratory droplets, contact or another route when food goes through the 'farm-to-table' lifecycle [21]. However, CoVs cannot multiply in food, as they need animal or human hosts to do so [13]. Han et al. [21] postulated that SARS-CoV-2 could be transmitted via food. In a review, they described how contaminated cold-storage food could present a risk of infection and transmission between different regions or countries. However, the transmission of SARS-CoV-2 via food or food packaging

The transmission of SARS-CoV-2 via food or food packaging was considered as highly unlikely.

Viruses spread from faeces through three primary routes: 1) water, 2) surfaces, or 3) insects that scavenge on faeces. These insects become vectors. From these environments, viruses may reach the mouths infecting both respiratory and intestinal tracts of susceptible hosts.

was considered as highly unlikely [13, 22]. In a recent paper by Anelich et al. [22], it was reported that there is no evidence for SARS-CoV-2 having a negative impact on food safety. However, they highlighted an advantage of Food Safety Management System (FSMS), which also includes Good Hygiene Practices (GHP). It could be assumed that has been helping prevent the spread of SARS-CoV-2 along with other potential microbiological contamination. The GHP standard, among others, already includes handwashing with soap and water for at least 20 s at critical moments and sanitizing of hands when needed.

Faecal-oral transmission

Heller et al. [23] hypothesised about faecal-oral transmission as being a route of SARS-CoV-2 spread and transmission. Viruses spread from faeces through three primary routes: 1) water, 2) surfaces, or 3) insects that scavenge on faeces. These insects become vectors. From these environments, viruses may reach the mouths infecting both respiratory and intestinal tracts of susceptible hosts. However, it was highlighted that there is a lack of research regarding the faecal-oral transmission of SARS-CoV-2; consequently, the hypothesis could not be confirmed.

Thus far, human-to-human and fomite transmission have been confirmed. Also, there is a high possibility that aerosol transmission has been contributing to the exponential growth of cases. However, due to the lack of studies and the absence of substantiated proof, it would be highly premature to come to a conclusion about how each transmission route contributes to the increased risk of infection. The scarcity of information is also prevalent in the area of virus infectivity, either in aerosols or fomites [9].

The behaviour of a virus after being released from an infected individual can be affected by environmental factors, such as temperature, humidity, climate change, and air pollution.

Based on current information, we presume that foodborne and faecal-oral transmission routes are very unlikely. Although aerosol transmission is probably more plausible, there are still no solid proofs. This situation could be possibly attributed to the great difficulty of detecting SARS-CoV-2 in aerosols. Morawska and Cao [14] explained that sampling for the presence of the virus requires good knowledge of the airflow from an infected person, and this sampling should be given enough time to collect enough copies of the virus. Obviously, this makes sampling even more difficult.

PRESENCE AND PERSISTENCE OF THE VIRUS IN THE ENVIRONMENT

The transmission of viruses, including SARS-CoV-2, is attributed mainly to the virus' ability to survive when travelling from an infected individual to a susceptible host, which means that a virus must remain stable on different types of materials (such as fomites) or in the air (aerosols). The behaviour of a virus after being released from an infected individual can be affected by environmental factors, such as temperature, humidity, climate change, and air pollution [24].

van Doremalen et al. [25] evaluated the stability of SARS-CoV-2 on various surfaces. They confirmed that it was present on surfaces such as personal items, restrooms, room and floor surfaces and on materials such as plastic, stainless steel, copper, and cardboard. SARS-CoV-2 was found to be more stable on plastic and stainless steel than on copper and cardboard. It remained viable for 72 h (plastic), 48 h (stainless steel), 4 h (copper), and 24 h on cardboard after it was applied to the surface. The experiment was carried out at temperature (T) 21°C to 23°C and relative humidity (RH) 40% while the titre was exponentially reduced. Another recent study detected SARS-CoV-2 on inanimate surfaces such as wood, ceramics, aluminium, glass, and waste containers and bags [26]. In both studies [25, 26], the virus persisted for days. In another experiment, a significant level of the infectious virus could still be found on the outer layer of a surgical mask seven days after the application of virus (T: 22°C and RH: 65%). In the same experiment, it was discovered that the virus is highly stable at room temperature and a wide range of pH (pH 3–10) [27].

Thus far, only a few studies have confirmed the presence and persistence of SARS-CoV-2 in aerosols. An experiment performed by van Doremalen [25] confirmed that the virus remained viable in aerosols for the duration of the experiment (3 h), while the infectious titre was reduced from $10^{3,5}$ to $10^{2,7}$ per litre of air. The experiment was carried out at T 21–23°C and 65% RH. Similarly, in another experiment, by Fengs et al. [28], it was confirmed that SARS-CoV-2 could remain viable in aerosols for a relatively long time (up to 16 h) under room-like conditions and potentially spread through aerosols. During an experiment in a hospital by Chia et al. [29], SARS-CoV-2 infectious particles, with radius sized 1-4 μm and larger than 4 μm, were detected inside an isolation room occupied by a COVID-19 patient. The contamination of surfaces was higher in the first week of disease and noticeably lower after a week passed. However, viral culture results could not prove the viability of the virus contaminating the air or surfaces. Lu et al. [30] investigated the aerodynamic nature of SARS-CoV-2 in two Wuhan hospitals. Lower concentrations of the virus were detected in isolation rooms and ventilated patient's rooms, while concentrations were higher in toilet areas (used by the patients), staff rooms, and two areas of the hospitals that were often overcrowded.

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Although foodborne transmission has not yet been confirmed for SARS-CoV-2, Han et al. [21] reported that laboratory studies found evidence that the virus remained highly stable on meat, fish, and animal skin for the duration of studies (14–21 days) at low temperatures (4°C, -40°C, and -80°C). Another unconfirmed transmission route is faecal-oral. However, due to the recorded presence of the virus in faeces, some questions had to be raised. Wang et al. [31] confirmed viable SARS-CoV-2 in faeces; in another study [32], a rectal swab tested positive despite a negative nasopharyngeal Polymerase Chain Reaction (PCR) test from the same patient.

The infectivity and stability of SARS-CoV-2 can be affected by temperature. It was confirmed that SARS-CoV-2 inactivation was

The infectivity and stability of SARS-CoV-2 can be affected by temperature. It was confirmed that SARS-CoV-2 inactivation was boosted by increasing temperature. The half-life of the virus ranged from 6.3 to 18.6 h while the temperature was 24°C; however, it was much lower with higher temperature. At 35°C, the half-life was reduced to a range from 1.0 to 8.9 h.

boosted by increasing temperature. The half-life of the virus ranged from 6.3 to 18.6 h while the temperature was 24°C; however, it was much lower with higher temperature. At 35°C, the half-life was reduced to a range from 1.0 to 8.9 h. The same pattern was observed with humidity. SARS-CoV-2 expeditiously lost its infectivity as the levels of humidity increased [33]. Chin et al. [27] ascertained that the stability of SARS-CoV-2 varies in response to the temperature. While the virus was highly stable at 4°C, it was very sensitive to heat. Casanova et al. [34] assessed the effects of air temperature and relative humidity on CoV's survival. The persistence of these viruses was higher at 4°C (28 days), and it was most difficult to inactivate at 20% RH. Inactivation was slow at 4°C, faster at 20°C and the fastest at 40°C. Also, low RH contributed to slower inactivation of the viruses.

SARS-CoV-2 could be present anywhere, spreading either by an infected individual shedding their respiratory secretions or through aerosols. Some materials might be a better habitat, thus the observed persistence of the virus. Such materials include metals (e.g., stainless steel), glass, and porous fabrics. In contrast, on surfaces like copper, latex, and less porous fabric, the virus showed less persistence [35]. SARS-CoV-2's stability is greatly impacted by temperature, relative humidity, and pH level. It tends to survive longer at low temperatures, low relative humidity, and within a wide range pH (from 3 to 10) [27, 33, 34]. In a recent research study, Biryukov et al. [33] developed a simple mathematical model to estimate the virus decay on nonporous surfaces under a range of conditions, which could help identify indoor environments with higher persistence of the virus. However, the infectively of the virus within the various aforementioned environmental factors is a crucial yet missing piece of information.

PREVENTIVE AND CONTROL MEASURES OR NPIs

In order to stop the spread of SARS-CoV-2, NPIs were implemented all over the world differing between the countries or even regions. The ECDC described NPIs as public health measures for preventing and/or controlling the transmission of SARS-CoV-2 in the community [15]. For as long as there is no vaccine available for the virus, NPIs are considered to be the most effective public health intervention against COVID-19. According to the ECDC, NPIs are organized in three main categories *1)* individual (hand hygiene, respiratory hygiene, and use of protective masks), *2)* environmental (cleaning, disinfection, and adequate ventilation), and *3)* population-related NPIs (raising awareness of physical distance, limiting or restricting movement and gathering of people) [15] (Table 1). Cheng et al. [36] reported that most widely used NPIs in the current pandemic have been travel restrictions, border closings, school and business closing, massive PCR testing, quarantining, (self)isolating, contact tracking, community-wide mask use, hand washing and disinfection, physical distancing and curfews. Below, we describe the five main NPIs: ventilation, cleaning and disinfection, hand hygiene, physical distancing, and protective masks.

Table 1. Transmission routes and recommended Non-Pharmaceutical Interventions for their prevention

TRANSMISSION ROUTE	NPIs
Direct contact (human-to-human)	– Use protective face mask – Hand hygiene – Respiratory hygiene – Physical distancing
Indirect contact (with fomites)	– Hand hygiene – Cleaning and disinfecting of objects and surfaces
Airborne*	– Use protective face mask** – Adequate ventilation of indoor places
Foodborne***	– Hand hygiene – Respiratory hygiene – Cleaning and disinfecting of objects and surfaces

NPI – Non-Pharmaceutical Intervention; *very possible transmission route with no solid proof but NPIs are still recommended; **not every kind of protective mask can prevent this transmission route; ***currently no proof for this kind of transmission but NPIs are still recommended.

Ventilation

The ECDC claims that heating, ventilation, and air-conditioning have been playing important roles in reducing the spread of SARS-CoV-2 in indoor spaces, which implies that an increased rate of air exchange, a decrease in recirculation of air and an increase in the use of outdoor air (i.e., natural ventilation) can contribute to reducing the spread of the virus [15]. Several recent studies' findings have confirmed this claim [14-16, 18, 37, 38]. Morawska and Cao [14] emphasised the significance of adequate ventilation for indoor spaces because it can significantly deter the spread of SARS-CoV-2 via air. As discussed earlier in this article, airborne particles can be carriers of the virus; therefore, if found within indoor spaces, they should be removed. Adequate ventilation can help with this removal. Additionally, they suggested avoiding staying in another person's airflow and to minimize the number of people sharing the same space. Amoatey et al. [37] added that implementing personalized ventilation and personalized exhaust systems (PV-PE) within microenvironments, where possible, should be considered. They also pointed out that natural ventilation could be impractical in some areas with high annual temperatures. For example, the Middle East has high annual average temperatures and their modern buildings' architecture, in general, only allows mechanical ventilation. Such circumstances diminish the possibility of using natural ventilation.

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Dai and Zhao [38] investigated the influence of ventilation rate on infection possibility within indoor places. The study supports that when an infector remains in an indoor space for a longer time, the infection risk becomes relatively higher (infection probability is approximately 2% at the ventilation rate of 500-2500 m^3/h per infector for 15 min of exposure). They highlighted the significance of a sufficient ventilation rate for offices, classrooms, public transport, and other confined spaces in reducing infection's possibility. Furthermore, Shen et al. [18]

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Many studies have illustrated the importance of adequate ventilation in curbing the transmission of SARS-CoV-2. These findings highlighted 1) the importance of adequate ventilation in indoor spaces (increased rate of air exchange, decrease in recirculation of air), 2) the importance of natural ventilation, and 3) the need to limit the number of people allowed indoor at the same time.

conducted research focusing on ventilation in public transport, which includes aeroplanes, high-speed rail, subways, buses, taxis, ferries, and others in China. They reported that adequate ventilation could efficiently reduce the concentration of suspended matters in confined spaces, which can lead to reductions in the transmission of pathogen droplets. Also, air-conditioning filters must be cleaned or replaced frequently. In a literature review from Chirico et al. [39] air-conditioning systems were discussed as possibly contributing to the spread of SARS-CoV-2. However, there is no strong evidence to prove this. Based on the recent outbreaks reported during a choir practice session, in a call centre, and gym classes, they suggested that a situation with inadequate ventilation in conjunction with droplet transmission and crowded indoor places can increase the risk of infection.

To summarise, many studies have illustrated the importance of adequate ventilation in curbing the transmission of SARS-CoV-2. These findings highlighted 1) the importance of adequate ventilation in indoor spaces (increased rate of air exchange, decrease in recirculation of air), 2) the importance of natural ventilation, and 3) the need to limit the number of people allowed indoor at the same time. However, to date, there is no information about the amount of viral emission in indoor places. Buonanno et al. [16] attempted to estimate the amount of airborne viral emission and strived to fill the knowledge gap by trying to evaluate the viral load emitted by infected individuals. Such information is crucial for engineers and indoor air quality experts for simulating the spread of SARS-CoV-2 through indoor spaces.

Cleaning and disinfection

Based on the thus-far known information about SARS-CoV-2 transmission routes and its presence and persistence in the environment, cleaning and disinfecting play an essential role in reducing its spread.

Based on the thus-far known information about SARS-CoV-2 transmission routes and its presence and persistence in the environment, cleaning and disinfecting play an essential role in reducing its spread. The ECDC reported that SARS-CoV-2 is an enveloped virus; consequently, it is sensitive to common detergents and disinfectants. Also, the ECDC conveyed the importance of frequent cleaning, especially for often-touched surfaces, such as door handles, bannister rails, buttons, buses, and similar [15].

Castaño et al. [9] reported that cleaning and disinfection are needed to inactivate and remove the virus from surfaces. To inactivate a virus, its ability to be infective (fusing with a host cell, intact envelope, and nucleocapsids) must be destroyed. They also described the currently used disinfecting strategies for inactivating SARS-CoV-2, including ultraviolet (UV) and solar irradiation, chemical disinfection, plasma disinfection, heat treatment, self-disinfecting materials/surfaces, and hand hygiene. DeLeo et al. [40] discussed the group of disinfectants called Quaternary Ammonium Compounds (QACs), for SARS-CoV-2 inactivation on surfaces and found them to be efficient at doing so. They also emphasized the necessity of disinfecting indoor air frequently because of the virus' ability to survive in aerosol for a prolonged period. To control the spread of this virus, they suggest the development of specific

environmental disinfection protocols. The ECDC [41] prepared guidance for environmental cleaning of non-healthcare facilities exposed to SARS-CoV-2. When a person infected with the virus uses public facilities such as public offices/transport, schools, and similar, they might contaminate the air and surfaces, consequently increasing the risk of infection amongst facilities' users. In this above-mentioned guidance, the ECDC recommends cleaning potentially contaminated premises before they are re-used. For cleaning, warm water and household detergents should be used. Disinfection should be performed with common disinfectants, such as 70% ethanol. A person who is cleaning or disinfecting surfaces should wear disposable personal protective equipment (PPE), such as gloves, goggles, gowns, and masks. PPE should be disposed of after cleaning and treated as infectious material.

For cleaning, warm water and household detergents should be used. Disinfection should be performed with common disinfectants, such as 70% ethanol.

We should be aware that SARS-CoV-2 can also be disruptive to the food industry. In a review, Dev Kumar et al. [42] discussed the importance of biocides used to control the spread of SARS-CoV-2 in the food industry, where frequent cleaning and disinfecting are essential. For sufficient surface disinfection against SARS-CoV-2, they suggested ethanol (70% or more), povidone, iodine, hypochlorite, and QACs combined with alcohol. To prevent the presence of viral load in aerosols, they suggested using hydrogen peroxide vapour, chlorine dioxide, ozone, and UV light. They also emphasised that cleaning and disinfecting must be employed collectively with other NPIs.

To prevent the presence of viral load in aerosols, they suggested using hydrogen peroxide vapour, chlorine dioxide, ozone, and UV light.

However, in the matter of food production and processing, the Food and Agriculture Organization (FAO) and the WHO [43] warned about risks of using chlorine-based disinfectants, as they can increase exposure to chemical residues, which could cause health problems. Furthermore, in this mass use of disinfectants, the ECDC advised caution when spraying disinfectants (also known as fumigation) or using UV light irradiation. They considered these two practices to be unsafe for outdoors or large indoor spaces (e.g., a classroom). The ECDC based this view on the lack of effectiveness and possible harm to the environment and people due to exposure to irritant chemicals [15]. Furthermore, particular attention should be given to the cleaning and disinfecting of households and to the preparing, storing, and discharging of cleaners and disinfectants. Gharpure et al. [44] found that 30% of the surveyed people were using non-recommended high-risk practices with the intent of preventing the transmission of SARS-CoV-2. Examples of these practices include using bleach on food products, applying household cleaning and disinfectant to the skin, and inhaling or ingesting cleaning and disinfecting products. They also found that there were significantly more calls to poison centres related to cleaning and disinfection misuse since the outbreak of the pandemic. They asserted that public messaging should be used to communicate and encourage evidence-based and safe cleaning and disinfecting practices to stop the spread of the virus in households.

Although cleaning and disinfecting are crucial in controlling the spread of SARS-CoV-2, Singh [45] warned about accelerated antimicrobial resistance during this pandemic. The reason for it is in over-use of

The recommended duration of hand washing is 20 to 40 seconds. If the hands are possibly contaminated, hand disinfectant should be used after washing.

antibiotics and many different cleaning and disinfecting products. Overuse causes problems such as alcohol-disinfectant resistance of *Enterococcus faecium,* which can cause a variety of infections in humans. Furthermore, the strengthening microbial resistance that has been observed that far could cause great harm to human health. Ejtahed et al. [46] expressed concern about the mass daily use of detergents and household cleaning products due to the pandemic. They summarised that some of these cleaning products contain chemicals that are linked to gut dysbiosis, which plays an important role in humans' immune system.

Furthermore, Getahun et al. [47] reported the wide use of environmental and personal disinfectants in both healthcare and non-healthcare settings. This wide use of disinfectants can increase a cross-resistance to some antibiotics for drug-resistant strains. DeLeo et al. [40] warned that QACs negatively impact the environment. As they are usually disposed of 'down the drain', they end up in wastewater treatment systems. From there, QACs can penetrate aquatic environments and present a potential risk for aquatic organisms.

Regardless of how serious microbial resistance increase, gut dysbiosis, and environmental damage are, we should continue with frequent cleaning and disinfection. Alternatively, if we do not, the spread of SARS-CoV-2 could worsen. It is necessary to explain that microbial resistance can be lowered again, especially with more control over antibiotics. Particular attention should be given to the use of cleaning and disinfecting products in households. A multimedia campaign could be useful for demonstrating appropriate uses and highlighting the consequences of any misuse. To lower the negative impacts of QACs on the environment, some remediating technologies should be developed. Until then, the presence of QACs should be monitored [48].

Hand hygiene

In its *Guidelines for Hand Hygiene in Health Care* the WHO recommends using two alcohol-based formulations (75–85% ethanol and isopropanol) for hand disinfection to inactivate and reduce the spread of pathogens. These two are fast-acting and have a broad-spectrum of biocidal activity. Importantly, they are easily accessible and safe.

The ECDC described hand washing as the frequent and efficient washing of hands with soap and water. It can also refer to the cleaning of hands with solutions, gels, or tissues. The recommended duration of hand washing is 20 to 40 seconds. If the hands are possibly contaminated, hand disinfectant should be used after washing. This NPI is recommended in both healthcare and community settings in order to contribute to reducing the spread of SARS-CoV-2 [15]. In its *Guidelines for Hand Hygiene in Health Care* the WHO recommends using two alcohol-based formulations (75–85% ethanol and isopropanol) for hand disinfection to inactivate and reduce the spread of pathogens. These two are fast-acting and have a broad-spectrum of biocidal activity. Importantly, they are easily accessible and safe. The WHO has extended this recommendation's applicability to include SARS-CoV-2. This recommendation was based on the efficiency of these two alcohol-based formulations in inactivating other CoVs and MERS [49]. In an experiment performed by Kratzel et al. [50], both alcohol-based disinfectants recommended by the WHO were tested. The two were found sufficient in inactivating SARS-CoV-2 within

30 s at tested concentrations of 85% (ethanol) and 75% (isopropanol). However, ethanol and isopropanol are mostly effective against enveloped viruses and Gram-positive/negative bacteria rather than non-enveloped viruses and bacterial spores [51].

Castaño et al. [9] explained that hand hygiene is essential for reducing virus transfer from fomites to facial membranes (mouth, nose, eyes). On average, adults touch their face 23 times per hour, which means the risk of becoming infected via contaminated hands is relatively high. It is important that hand washing is frequent and efficient. In addition to hand washing, hand disinfectants, such as alcohol and isopropanol-based antiseptics, can be used. Hand disinfectants are also an alternative when hand washing is not possible. Using 75% alcohol hand disinfectant gel or wipes should reduce the possibility of infection caused by hand-to-mouth, hand-to-nose, or hand-to-eye contact. Hands should be disinfected every time a person has touched a potentially contaminated object or surface [52].

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In healthcare facilities, Health Care Workers (HCWs) should follow the 'five moments for hand hygiene' recommended by the WHO [53]. This approach defines the main moments when HCWs should clean their hands. These moments are 1) before touching a patient, 2) before clean/aseptic procedures, 3) after body fluid exposure/risk, 4) after touching a patient, and 5) after touching patient's surroundings [53].

However, frequent handwashing can have some negative consequences. Cavanagh and Wambier [54] draw attention to rational hand hygiene during the pandemic. Recurring hand washing can lead to skin damage, which creates a new route of entry for SARS-CoV-2. Especially exposed to this are HCWs, who may perform handwashing with water and soap more than 10 times per day. To reduce the risk of damaged hand skin (also called hand eczema), using gloves, hand cream or moisturizers, and ethanol-based disinfectants is recommended (instead of hand-washing when only the decontamination of hands is needed). Regularly applying hand creams and moisturizers prior to handwashing can help reduce the chances of skin damage.

To reduce the risk of damaged hand skin (also called hand eczema), using gloves, hand cream or moisturizers, and ethanol-based disinfectants is recommended (instead of handwashing when only the decontamination of hands is needed).

Physical distance

Based on the ECDC guidelines, physical distancing includes 1) keeping a recommended 1–2 m distance between individuals 2) closing of public spaces (non-essential shops, restaurants, bars, and entertainment settings), 3) closing public transport, 4) closing workplaces, 5) encouraging work from home, 6) closing schools (kindergartens, primary schools, high schools, and universities), 7) protecting high-risk groups and vulnerable populations, and 8) stay-at-home orders and recommendations [15]. Another three NPIs that include physical distance are isolation, quarantine, and movement restrictions (international or domestic movement). The ECDC reported that isolation of confirmed or very plausible cases of COVID-19 is an efficient NPI, which is meant for patients who do not require hospitalization. Isolation of patients can be either nonmandatory or mandatory, depending on national regulations.

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This measure aims to reduce the possibility of someone that is probably infected to transmit the virus further. A person could presume that they are infected based on the existence of symptoms such as fever, cough, myalgia, fatigue, loss of senses of smell and taste, nausea, vomiting, diarrhoea, and other less-common symptoms. However, not developing any symptom should not permit someone not to perform or finish their isolation.

Another recommended measure is quarantine implementation. Quarantine is an isolation option considered for healthy individuals who have had a high-risk exposure to COVID-19 positive patient. In some countries, quarantine is also obligatory for individuals who could be exposed to situations with high-risk of SARS-CoV-2 transmission. For example, travellers from areas with high daily numbers of new infections and family members of confirmed infected individuals are quarantined. Just like isolation, quarantine could be either mandatory or nonmandatory based on national regulations. The ECDC mentions that the duration of quarantines can differ from country to country and often lasts from 1–14 days. This measure is the most effective if implemented early and along with other NPIs [15]. Koo et al. [55] investigated different possible actions taken to reduce virus spread between individuals at schools, workplaces and at homes. They concluded that the quarantine of infected individuals and their family members, school closure, and workplace physical distancing are the most effective actions for the reduction of virus spread.

Avoiding physical contact and maintaining physical distance is considered to be the main preventive measure in this ongoing pandemic [15]. Many governments described the physical distance that needs to be maintained is at least 1.5 or 2 m, based on recommendations by WHO [10]. The ECDC [15] recommends implementing posters, floor markings, seat markings or rearrangement to remind people to practice physical distancing. In places that tend to become crowded, such as shops, restaurants and public transport, this kind of re-organization is necessary.

Keeping a recommended physical distance seems doable in theory, but when it comes to some places, such as nursing homes, households, and refugee camps, physical distancing may be difficult or even impossible. Subbaraman [56] reported on five Aegean islands, which are located to the east of Greece, which have capacities for approximately 6,000 people, yet about 40,000 refugees are waiting to receive their asylum status. Their living conditions are poor, with no access to running water or toilets. Their temporary homes are either tents or cardboard boxes, and these areas are overcrowded. In such a situation, physical distancing, quarantine, or isolation measures cannot be applied.

In another study, Wang et al. [57] underscored the importance of practising NPIs in nursing homes, orphanages, and prisons. Such facilities are very likely to have relatively confined environments. The residents of nursing homes, orphanages, and prisons can have limited mobility or deprived freedom. Usually, they live in circumstances in

which close contact is unavoidable, which means the risk for SARS-CoV-2 spread is high. Kirbiyik et al. [58] reported about a recent COVID-19 outbreak in an American jail. They were the first to use network analyses and visualization techniques to describe a viral outbreak in a jail. The study included 5,884 infected persons of which 3,843 (65%) were detained persons and 2,041 (35%) were staff members between 1st of March and 30th of April. NPIs were applied during this outbreak, such as limited visiting, suspension of some activities (e.g., contact sports), conversion of cells to single occupancy and use of protective masks for both detained persons and staff members. The study covered only virus transmission via human-to-human contact and did not include the possible spread of SARS-CoV-2 outside the jail. Staff members contributed to the spread more than detained persons did, probably due to their frequent movement. They outlined potential high risk transmission points for staff members, including staff meetings and breakrooms. These 'high-risk transmission points' should be given more attention in order to reduce SARS-CoV-2's ability to spread.

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Households are considered as another case in which physical distancing is difficult. Wang et al. [59] studied the decreased secondary transmission of SARS-CoV-2 in households using facemasks, disinfecting, and physical distancing. They claim that transmission of a virus within families and close contacts is the reason for most of the epidemic growth. The research confirmed that mask use by both infected individuals and family members reduced the transmission of the virus. However, they noted that disinfecting hands with chlorine or ethanol-based disinfectants and physical distancing (as much as it is possible) contributed to additional reductions of transmission. They stated that NPIs should be used not only in public places but also in households.

As mentioned, movement restriction is another part of physical distancing that was applied during this pandemic. Murphy et al. [60] reported that air travel has the potential to increase the spread of SARS-CoV-2. In their study, they discussed a national outbreak of COVID-19 linked to air travel in summer of 2020. The duration of the flight was 7 h; it had 17% occupancy. The outbreak involved 59 SARS-CoV-2 cases, of which 13 cases originated from the flight, and the remaining 46 were infected via the original 13 cases. The outbreak happened even though travellers wore masks and were supposed to maintain physical distance. Flight cases could become infected in-flight, during overnight transfer or unknown acquisition before the flight. They summarised that using NPIs, prohibiting travel for symptomatic persons, restricting movement on arrival and contact tracing should be a necessity if air travel is operating.

Physical distancing should be practised along with other NPIs. Setti et al. [17] reported that keeping the recommended 1.5 to 2 m distance is only effective when protective masks are used by both infected individuals and people who could become infected. However, in the above-described facilities where physical distancing is not always possible, the use of other NPIs should be increased, for example, constant mask-wearing,

They reported that in a 14-day period of physical distancing, the number of social-media-posts talking about anxiety and depression escalated, while positive-orientated posts diminished.

more frequent cleaning and disinfection, adequate ventilation, and contact tracing.

Most physical distancing NPIs have a high impact in preventing the spread of SARS-CoV-2. However, the societal impact can differ between NPIs. The societal impact of keeping a distance of 1–2 m and working from home is low. Greater societal impact is expected from measures such as the closing of public spaces, the closing of workplaces and protecting high-risk and vulnerable populations. The highest societal impact is expected from measures, including the closing of public transport, the closing of schools, and stay-at-home orders [15]. Vieira et al. [61] discussed some side effect of physical distancing (i.e., full lockdown, quarantining, isolation, stay-at-home orders) that could have a significant impact on people's lives. They reported that in a 14-day period of physical distancing, the number of social-media-posts talking about anxiety and depression escalated, while positive-orientated posts diminished. Another negative aspect that has been happening is misinformation, which in combination with physical distancing can lead to insecurity, anxiety, fear, emotional tension, and a false sense of security. All together, these jeopardise the quality of life.

Protective masks

A medical mask is a device covering the mouth, nose, and chin to provide a barrier that limits the transmission of pathogens between medical staff and patients. These masks have to be standardized, unlike non-medical masks (also called community masks).

When SARS-CoV-2 started spreading worldwide, the WHO and the ECDC recommended that protective masks should be reserved for people with symptoms and HCWs [36]. Later, on the 6th of April, the WHO issued a temporary guideline recommending the use of masks; however, it was not mentioned that community-wide mask-wearing could prevent the transmission of the new virus [62]. On the 8th of April, the ECDC issued a technical report saying that community-wide mask-wearing should be considered, especially, in busy indoor places, despite the absence of any proof of this measure efficiency [63]. However, to date, several papers have addressed the importance of mask use [36, 64-66]. MacIntyre and Chughtai [67] reported that masks and respirators are generally used for protection against respiratory infections. Furthermore, they explained that masks are essential for respiratory diseases, especially when no medications or vaccines are available, and transmission routes are uncertain.

There are homemade and commercial masks, which can be made of cloth or other materials, including paper. These masks are not standardized and are not intended for use in healthcare settings.

Based on the ECDC [15] guidelines, two kinds of protective masks are distinct and need to be differentiated. First, a medical mask is a device covering the mouth, nose, and chin to provide a barrier that limits the transmission of pathogens between medical staff and patients. These masks have to be standardized, unlike non-medical masks (also called community masks). The latter exists in various forms and can be made from different materials. For example, there are homemade and commercial masks, which can be made of cloth or other materials, including paper. These masks are not standardized and are not intended for use in healthcare settings.

The pandemic of SARS-CoV-2 triggered a PPE crisis around the world; part of this crisis has been the shortage of protective masks. Therefore,

the public has had to start using cloth masks. In a review, Beesoon et al. [68] highlighted the concerns around reliability of cloth masks. There is also a concern about so-called 'Do It Yourself' (DIY) trend, in which people make masks on their own using all kinds of materials without knowing their filtration abilities. However, Konda et al. [69] measured the filtration efficiencies of commonly available fabrics, such as cotton, silk, flannel, various synthetics and their amalgamation that could prevent aerosol transmission (particle sizes range ~10 nm to 6 μm) of SARS-CoV-2. The experiment results revealed that cotton, natural silk, and chiffon provide acceptable protection with filtering about 50% of particles in the entire tested size range. Materials such as silk and chiffon found to be effective in combination with other materials such as cotton. The most effective filtration was recorded when multiple layers of different fabric were combined. The hybrid of cotton and silk/chiffon/flannel increased the efficiency of filtration to more than 80%. This effect might be due to a combined effect of mechanical and electrostatic-based filtration, which these materials provide. A significant decline in filtration was observed when masks were not properly fitted to individuals' faces, and there was a gap between the mask and face.

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Similarly, the efficacy of cloth masks was measured by the Jožef Stefan Institute; 150 different cloth masks were tested. The results showed filtration efficacy between 19% and 82%. Better filtration was provided by cotton masks that were creased instead of smooth. Also, fabric with high thread-count or consisting of some polymer materials was more efficient in filtration in contrast to low thread-count and non-polymer materials. Tested surgical masks had efficiencies of 77% to 81%, while the materials used for their production had efficiencies of 91% to 99.5% [70].

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Lustig et al. [71] evaluated the effectiveness of common fabrics for blocking aerosols of SARS-CoV-2-like nanoparticles. In their experiment, they included over 70 different fabrics that can be used as a cloth mask. The materials found to provide the most efficient filtration were terry cloth, flannel, and quilting cotton. Also, filtration levels increased with additional barrier layers of nonwoven polypropylene, polyester, and polyaramid.

Beesoon et al. [68] pointed out the problem of a false sense of protection amongst people while wearing masks. This sense could be especially problematic if individuals then start to engage in other risky behaviours, such as not keeping physical distance or not practising hand hygiene. Similarly, Matuschek et al. [64] reported that protective masks are suitable to prevent transmissions by droplets and are only effective when used properly combined with physical distancing of at least 1.5 m. Also, they discussed both possible shortcomings and advantages of protective masks. As shortcomings, they listed mask shortage, a false sense of security, inappropriate mask use, mask dampness, and no regular mask swapping. However, the advantages of masks are in reducing the spread of SARS-CoV-2 and reducing the possibility to being infected with it.

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On the first bus, he did not wear a mask, and he transmitted SARS-CoV-2 to 5 people on the bus. On the second bus, he wore a mask, and he did not infect anyone on that bus.

Abbasi et al. warned about the possibility of a surge of microplastic pollution in global ecosystems, as a consequence of mass mask use during this pandemic. Microplastics in marine ecosystems can contribute to colonization of pathogenic microorganisms.

In another study, Desai and Aronoff [72] explained that in the case of SARS-CoV-2, infected individuals can spread the virus even when they do not show any symptoms. In this case, cloth masks can at least limit the spread of the virus from infected persons to others. However, cloth masks may not be so successful in preventing the infection for the person wearing them, especially if the emission of a viral load is high.

An event in which masks possibly reduced the spread of SARS-CoV-2, was described by Liu and Zhang [73]. In a typical case of cluster outbreak in public transportation in China, a patient travelled from Chongqing and transferred buses once. On the first bus, he did not wear a mask, and he transmitted SARS-CoV-2 to 5 people on the bus. On the second bus, he wore a mask, and he did not infect anyone on that bus. Furthermore, in an experiment performed in 15 American states between the 8th of April and the 15th of May 2020, Wel Lyu and Wehby [66] assessed community-wide use of facemask. They confirmed that mandating the use of masks in public has a role in reducing the spread of SARS-CoV-2. However, these effects were observed while masks used alongside other NPIs, such as physical distancing. Cheng et al. [36] also explored the role of community-wide masks wearing in tackling the SARS-CoV-2 pandemic. In their study, they focused on Honk Kong Special Administrative Region (HKSAR) within the first 100 days of the epidemic (31st of December to 8th of April). In that region, community-wide mask-wearing was practised in an early stage of local epidemic notwithstanding the WHO and ECDC recommendations that masks should be reserved for HCWs. More cases were reported during off-mask activities than on-mask. They concluded that incidences of COVID-19 in HSKAR (community-wide mask-wearing) in the first 100 days of the epidemic was remarkably lower compared to non-mask-wearing countries, such as Spain, Italy, Germany, France, the USA, the UK, Singapore, and South Korea. Compared to HKSAR, these countries had similar population density, healthcare system or physical distancing measures.

To summarise, wide-community mask use tends to contribute to reducing the spread of SARS-CoV-2. It has been widely recommended and, in some countries, mandatory, especially within indoor public spaces. However, masks become waste containing microplastic. Abbasi et al. [74] warned about the possibility of a surge of microplastic pollution in global ecosystems, as a consequence of mass mask use during this pandemic. Microplastics in marine ecosystems can contribute to colonization of pathogenic microorganisms. Once these microorganisms become attached to microplastic, they can be transmitted to live organisms and cause diseases. Also, in the food industry, face mask use could present an additional health risk. When workers in the food industry wear masks and then touch them, while readjusting them, for example, they could contaminate their hands with *Staphylococcus aureus* bacteria. These bacteria can be found inside some people's noses and mouths. When a worker in the food industry has contaminated hands and then touches food, it can lead to food poisoning [75].

CONCLUSION

There is no doubt that the implemented and worldwide used NPIs can have also negative impacts on individuals, families, food safety, and the environment. However, there is a high possibility that following these NPIs will save lives by preventing the spread of SARS-CoV-2. NPIs' potential negative impact might still be less than the negative impact of an unchallenged pandemic. In order to control this pandemic, we should emphasise the importance of using a combination of NPIs collectively, as one NPI by itself does not sufficiently reduce transmissibility. In the future, once a vaccine is developed and used, most currently implemented NPIs will be cancelled. After this pandemic, however, good hand hygiene, respiratory hygiene and cleaning of surfaces should still be practised, as they can prevent other health-threatening pathogens. We should also be aware that some presently implemented NPIs can cause problems in the future. This includes microplastics in the environment as a consequence of mass mask use, microbial resistance as a consequence of frequent disinfecting, aquatic organisms' problems as a consequence of overusing QACs, and gut dysbiosis as a consequence of detergent use. We should address these problems now as early as possible.

After this pandemic, however, good hand hygiene, respiratory hygiene and cleaning of surfaces should still be practised, as they can prevent other health-threatening pathogens.

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"A farmer's time is expensive": A qualitative study exploring the knowledge attitudes and perceptions of farmers regrading health and safety in Northern Ireland

Aoife **GIRVAN**[1], Graeme **MITCHELL**[2*]

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ABSTRACT

The agricultural sector is important to Northern Ireland (NI) as it accounts for almost 10% of all jobs and 75% of all land usage. Despite a reduction in fatalities in other sectors, the number of fatalities in the agricultural sector in NI has remained stubbornly consistent. This research looked to use qualitative data to explore the knowledge, attitudes, perceptions and factors that influence health and safety measures and controls. Using a snowball sampling technique, a number of semi structure interviews were undertaken with participants to explore these areas. The findings of these semi-structured interviews identified six key themes: the importance of health and safety; the impact of poor health and safety; different generational attitudes; fear; time management and finance. This revealed that although participants feel they have some level of knowledge around health and safety, they felt this was lacking. However, a lack of knowledge did not mean they were unaware of the importance of health and safety and its potential impacts, although they perceived that farmers of a different generation to themselves were more at risk. Participants also indicated they were willing to make value judgements, where the need for action and cost of health and safety outweighs the importance implementing appropriate measures and control. Therefore, despite understanding the importance of health and safety, until the cost benefit equation is rebalanced for farmers in NI they still face significant risks to their health and safety.

Key words: farming; health and safety; barriers; fear; compliance; attitudes towards health and safety

POVZETEK

Kmetijski sektor je za Severno Irsko pomemben glede na to, da zagotavlja skoraj 10 % vseh delovnih mest in obsega 75 % celotne rabe zemljišč. Kljub zmanjšanju števila smrtnih žrtev v drugih sektorjih, le-to v kmetijskem sektorju Severne Irske ostaja nespremenjeno. V okviru raziskave smo se z uporabo kvalitativne metodologije osredotočili na znanje, stališča, dojemanje in druge dejavnike, ki vplivajo na izvajanje ukrepov za zagotavljanje varnosti in zdravja pri

[1] Public Health Institute, Faculty of Health, Education and Community, Liverpool John Moores University, 3rd Floor Exchange Station, Tithebarn Street, Liverpool L2 2QP, UK

[*] *Corresponding author*
Mr Graeme Mitchell MCIEH CEnvH, Senior Lecturer, Public Health Institute, Faculty of Health, Education and Community, Liverpool John Moores University, 3rd Floor Exchange Station, Tithebarn Street, Liverpool L2 2QP, UK
E-mail: g.k.mitchell@ljmu.ac.uk

delu. Udeleženci v raziskavi, s katerimi so bili opravljeni polstrukturirani intervjuji, so bili zajeti po metodi snežne kepe. Rezultati opravljenih intervjujev izpostavijo šest ključnih segmentov, in sicer: pomen varnosti in zdravja pri delu, posledice slabe varnosti in zdravja pri delu, različna stališča glede na generacijo, strah, upravljanje s časom in finance. Kljub temu, da udeleženci sicer menijo, da imajo določeno raven znanja o varnosti in zdravju pri delu, so mnenja, da ga še vedno nimajo dovolj. Slednje pa še ne pomeni, da se ne zavedajo, kako pomembna sta varnost in zdravje pri delu, čeprav so mnenja, da so kmetje bodočih generacij bolj ogroženi. Udeleženci so prav tako navedli, da so pripravljeni tehtati med potrebo po ukrepanju na področju varnosti in zdravja pri delu in stroški, ki zaradi tega nastanejo. Kljub zavedanju pomembnosti varnosti in zdravja pri delu se kmetje na Severnem Irskem še vedno soočajo z velikimi tveganji in bo tako tudi ostalo, dokler se enačba stroškov in koristi ne uravnoteži.

Ključne besede: kmetijstvo; varnost in zdravje; ovire; strah; skladnost; odnost do varnosti in zdravja

INTRODUCTION

The agriculture sector in the United Kingdom (UK) turns over more than £4.5 billion every year and is the cornerstone of Northern Ireland's (NI) economy. Throughout the UK, the agricultural sector supports one in eight jobs providing income for individuals, families and significantly enhancing the economy. [1]

Throughout the UK, the agricultural sector supports one in eight jobs providing income for individuals, families and significantly enhancing the economy.

Farming is the heart of many communities in NI with over 25,000 farm businesses, traditionally driven by family members for generations. In NI alone, farmers and farm workers account for 49,979 jobs (9.9% of the workforce) and the total income from farming is £360 million. [2, 3] Approximately 75% of land in NI is used for agriculture, with eggs, dairy and meat being the largest sectors, accounting for over 80% of agricultural output, comparing with around 50% for the UK average.

However, this sector is not without its dangers. During 2014 to 2018, the average number of fatalities within the agricultural sector in UK was 33. However, in 2019 this increased to 39, six more than the 5-year annual average [4]. Although farming fatalities within NI showed a downward trend between 2012/13 and 2015/16 (11 fatalities down to 6 fatalities), they have stubbornly remained at this level and indeed have started to show a slight increase. This is in contrast to the overall workplace fatalities in NI which were down in 2018 by 31% from 16 in the previous year to 11. [5]

According to data obtained as a part of a 2015 survey of over 4,000 farmers an estimated 1,276 farm accidents requiring medical attention occurred in NI in the previous 12 months [6]. Following the farm accidents which required professional medical attention, 47% took no time off work, 35% undertook no farm work for 1-30 days, 8% required 31-60 days off and 10% required over 60 days off.

Yet farming continues to have a poor safety record and in 2017/18, the Health and Safety Executive of Northern Ireland (HSENI) working in conjunction with local councils completed 7 successful prosecutions

Farming is globally one of the most hazardous occupations, where farmers are injured at a rate four times greater than the average worker.

According to Gerrard, farmers face such high levels of health and safety risks because of long working hours, seasonal patterns of work, little or no supervision, use of machinery, a lack of health and safety structure, chemicals and working in all types of weather.

amounting to fines totalling £173,750, delivered 6,233 inspections and served 216 formal enforcement notices where poor practice was found.

The idea that farming poses a greater level of risk to those employed within it is nothing new. Elkind [7] argues that farming is globally one of the most hazardous occupations, where farmers are injured at a rate four times greater than the average worker.

In comparison to other industries, agriculture has an inbuilt set of characteristics resulting in many health and safety problems. According to Gerrard [8], farmers face such high levels of health and safety risks because of long working hours, seasonal patterns of work, little or no supervision, use of machinery, a lack of health and safety structure, chemicals and working in all types of weather. Evidence gathered by Solomon [9] suggests that accidental deaths among farmers is more common in the harvesting months of July, August and September. This could suggest that farmers become less safety conscious during these months or that throughout times of mounting pressure and stress to complete the harvest, their focus to stay safe if significantly impacted. It was also found that farmer's attitudes towards safety and risk taking behaviour were influenced by the belief that accidents are inevitable. In addition, the importance of profit [10] and the ineffective of health and safety education [11] also play their part. What does seem to drive compliance with health and safety requirements is fear – fear of being injured (or someone else being injured) and fear of losing their jobs or businesses as a result of an injury [12].

All of these factors contribute to fatalities and injuries within the agricultural sector, with the most common non-fatal accidents being due to poor manual handling and fatal accidents attributable to falls from height, machinery, vehicles and electrocution [4]. Therefore using a series of semi structured interviews, the aim of this study is to explore the knowledge, attitudes and perceptions that farmers have in regards to health and safety on their farms in Northern Ireland.

The objectives for the research are:

- To determine farmers' level of knowledge in regards to health and safety on the farm.
- To identify the attitudes of farmers regarding health and safety on the farm.
- To understand the perceptions of farmers regarding health and safety on the farm.
- To explore the factors which influence health and safety measures and controls on the farm.

METHODS

Research Design

In order to explore the knowledge, attitudes and perceptions fully, a qualitative design was chosen, with semi structured interviews undertaken with 7 participants who were above the age of 18 years and had previously or were currently working as a farmer, living in NI.

A qualitative approach was believed to be more appropriate than quantitative approach. As it would provide the rich, contextual descriptions needed to analyse the data and achieve the aim and objectives. The knowledge, attitudes and perceptions of the participants are described verbally, in detail, in order to answer the research question. According to Tsai et al. [13] qualitative data is not about generalisability but creating insights about certain phenomena in greater depth and detail than is possible through quantitative designs. Qualitative research methods are valuable in providing rich descriptions of unique events and illuminating the experience and interpretation of the participants.

Sampling

A snowball sampling method was used to recruit participants to this study. According to Naderifar et al. [14] snowball sampling is a convenience sampling method and is applied when it is difficult to access participants with the target characteristics. In this method, the existing participants recruit future participants among their acquaintances and the sampling continues until data saturation.

It is believed people who chose to participate may only reflect a certain opinion, as they had to feel strongly enough to participate [15] However, due to the specific aim of the research and target population, this sampling method was deemed most appropriate. Cohen and Arieli [16] believe snowball sampling is a commonly used method to locate, access and involve participants from specific populations where the researcher anticipates difficulties in creating a representative sample. The farming population of Northern Ireland are mainly scattered across the countryside and distanced from towns or cities, making it difficult to access with ease.

Data collection

Data for this research was collected using a semi-structured interview with each participant. The use of this type of research tool allows for open-ended responses from the participants, which will generate more in depth information, whilst at the same time allowing the researcher to guide the conversation and keep the participants on tack. The questions for the semi-structure interview were generated by the authors for the purpose of this research and focused on the participants' knowledge, attitudes and perceptions of health and safety in farming in NI, as well as those factors that may influence health and safety measures and controls. Prior to the collection of data, the semi-structured interview was piloted and amended as necessary.

The first two participants were contacted by telephone through mutual connections within the Northern Irish farming population and given an overview of the research study. These participants were made aware that participation was voluntary and asked to identify any other potential participants and to direct them to contact the researcher. Potential participants who made contact with the researcher were emailed a Participant Consent form and Participants Information sheet. Once they had agreed to take part in the research, they were asked to attend an interview at a mutually agreed, public location.

Data for this research was collected using a semi-structured interview with each participant. The use of this type of research tool allows for open-ended responses from the participants, which will generate more in depth information, whilst at the same time allowing the researcher to guide the conversation and keep the participants on tack.

The researcher conducted 3 interviews within a public library in County Tyrone, 2 interviews in a public library in County Derry and 2 interviews in a public library in County Armagh, all of which are located in NI. Each interview lasted approximately 20 minutes.

Prior to each interview the researcher gave a brief overview of the topics included in the interview and the purpose of the research study. The researcher also reinforced to each participant that they did not have to provide answers for any topics they wished not to discuss. Permission was requested from each participant to audio record the interview and advised that each person would remain anonymous through pseudonyms such as, 'Participant 1, Participant 2'. Field notes were also taken throughout the interviews to ensure the researcher could differentiate between participants' voices and record non-verbal activity when transcribing.

As this research was undertaken as part of the BSc (Hons) Environmental Health degree programme, prior to collection of any data, ethical approval was obtained from Liverpool John Moores University.

Data Analysis

After the completion of each interview, the data was transcribed verbatim and names were replaced with pseudonyms, with a code to identify the participant. According to Burnard et al [17] interview transcripts, field notes and observations provide a descriptive account for the study, but don't provide explanations. The transcripts needed to identify themes and ideas that emerge from the data. According to Saldana [18], coding enables the researcher to group similarly coded data into categories because they share some characteristic- the beginning of a pattern. Williams and Moser [19] suggest the best way to code is to read transcripts and field notes in order to fully understand the themes, phrases, and topics. The researcher colour coded potential themes and assessed them further to create a thematic pattern. The data was then coded by analysing the transcripts and grouping codes of similar meaning into categories. These categories were then analysed to look for themes and relationships between them. The main findings and analysis of the data is presented in the results section, identifying the key themes and utilising verbatim quotes as supporting evidence.

RESULTS AND DISCUSSION

From the semi-structured interviews, the following key themes were identified:

Theme 1: The importance of health and safety on the farm

Theme 2: The impact of poor health and safety

Theme 3: Generational Attitudes

Theme 4: Fear

Theme 5: Time Management

Theme 6: Finance

Theme 1: The importance of health and safety on the farm

There was an acknowledgement across all participants that health and safety is an important issue when working in farming:

> *'That it's important and something that needs to be taken very seriously.' (Participant 5)*

> *'I think of it every day. It's so important, think of all the people who have died because of not taking enough care.' (Participant 7)*

Yet despite this acknowledgement, there is an acceptance that it is not always a priority for farmers:

> *'It's important, but probably something that is overlooked a lot of the time.' (Participant 1).*

Theme 2: The impact of poor health and safety

Several participants considered the impact on themselves, if there was poor health and safety practice on the farm:

> *'It's a matter of life and death, anything could go wrong on a farm in the blink of an eye. It involves so many fatalities, staying vigilant is the most important thing.' (Participant 4).*

However, awareness of the impacts extended beyond just the effects on the individual but on their businesses as well particularly if an enforcement body was to inspect:

> *'I would get a non-compliance and it needs to be rectified straight away or else. I will lose my status as free-range and won't be allowed to supply in certain supermarkets.' (Participant 6).*

Many of the participants were concerned of not meeting the requirements for their insurance policies and being held reliable for accidents on the farm, significantly impacting their businesses:

> *'In the event of an accident you might not be insured if you haven't followed the legislation and if you were being neglectful.' (Participant 2).*

> *'If you did have an accident and the farm wasn't up to date, the insurance would come out and do an assessment and not pay out for anything. They would tell you- you're reliable.' (Participant 1).*

Indeed this awareness also extend to the impacts on the wider community as well:

> *'The consequences can be deadly as we know and take such a hold on a family and community' (Participant 1).*

Participant 6 described the fatality of a young person who died due to poor health and safety on the farm as:

> *'Absolutely devastating. His poor family have never been the same since, he was only 19'.*

'I would get a non-compliance and it needs to be rectified straight away or else. I will lose my status as free-range and won't be allowed to supply in certain supermarkets.'

'If you did have an accident and the farm wasn't up to date, the insurance would come out and do an assessment and not pay out for anything. They would tell you- you're reliable.'

'When I started farming there was no focus on laws and regulations, there wasn't as much emphasis as there is now.'

'Maybe if older people were better educated and informed, they would start to actually think about it. Farms and equipment have got bigger since when they started farming, things have got faster, and yards have more electrics.'

Theme 3: Generational Attitudes

The data indicated a clear contrast of attitudes regarding farm health and safety between young and older participants:

'Younger people are better clued in.' (Participant 1).

When another participant was asked about health and safety on the farm they stated:

'The older generation don't know as much about it' (Participant 3).

Both statements were reinforced by an older participant who suggested:

'When I started farming there was no focus on laws and regulations, there wasn't as much emphasis as there is now.' (Participant 4).

Several participants contradicted these statements and felt that older people were at an advantage due to having more experience on the farm. *Participant* 2 explained that younger people did not hold the experience of an older farmer and therefore, were at greater risk on the farm:

'Inexperience is a massive danger as well. I feel like younger people are at more risk because they haven't got experience.'

Additionally, *Participant* 7 explained:

'That's why I think experience is so important because it doesn't cost anything to have experience and a wise head and to know how to keep yourself safe.'

It became clear throughout several interviews that younger people felt that they were at less risk on the farm than older people due to raised awareness of health and safety and mandatory training. The data suggested that some participants felt the older generation would suffer poor health and safety practices due to a lack of education:

'*You have to do all your training and that now, where older people wouldn't necessarily have that.' (Participant 1).*

'Maybe if older people were better educated and informed, they would start to actually think about it. Farms and equipment have got bigger since when they started farming, things have got faster, and yards have more electrics.' (Participant 6).

Some participants expressed a lack of health and safety awareness among the older generation and that older farmers had developed habits on the farm- perhaps not leading to the best safety practice:

'Older people don't know enough about it. They just do what they've always done because it wasn't a big thing 10-15 years ago. So, I think teaching older people needs to be addressed.' (Participant 1).

This was reinforced by another participant but felt that modernisation is causing farming to be of higher risk:

'*A lot of farmers have bad habits, and, in my time, you just got on with it because we never knew any better. There wasn't as many dangers when the older generation started, machinery is way more modern now and in my opinion animals have got wilder.' (Participant 4).*

Another participant suggested that training courses were becoming more accessible online and that the younger generation would benefit from this more than the older:

> *'A lot of the training you can do online and at home, but older farmers wouldn't know that.' (Participant 5).*

Some participants questioned their own attitudes towards health and safety on the farm feeling they should and didn't hold the required knowledge to obtain good health and safety practice:

> '*Truthfully, I only know the basics, not as much as I should.' (Participant 5).*

Additionally, *Participant* 4 stated:

> *'Probably like most other people, not enough and not always making the right decisions.'*

Theme 4: Fear

The interviews explored the participants' perceptions on the biggest risks and dangers on a farm and how health and safety impacted their daily lives as farmers. When exploring these topics, all participants portrayed a degree of fear concerning the repercussions of poor health and safety practice while on the farm. One of the main concerns highlighted by all participants was fear of injury:

> '*Nobody wants to be injured or god forbid die.' (Participant 2).*
>
> *'The mask so I don't breathe in dust. They talk about farmers lung I don't want that.' (Participant 1).*
>
> *'I might not always worry about lights and maintenance of the machinery but definitely PTO shafts because they can cause bad accidents.' (Participant 3).*

A number of participants indicated a fear of death and referred to 'near miss accidents' and the biggest risks on the farm that could cause this:

> '*You might be doing something and have a near miss and just think that could have been really serious. I've had a lot of close calls. It makes you really worried.' (Participant 4).*
>
> *'I have electrical checks done every year to make sure everything is working correctly, only checked by a certified electrician though, I don't know anything about that, I would get electrocuted.' (Participant 6).*
>
> *'Equipment will break all the time, for tractors there is usually a PTO shaft and it needs to be protected otherwise it can grab clothing and kill people straight away.' (Participant 7).*

Participant 1 stated:

> *'I just think, I don't want to die; it scares me.'*

Several participants described the fear they felt after hearing about a farming related injury or fatality through the media or by word of mouth:

All participants portrayed a degree of fear concerning the repercussions of poor health and safety practice while on the farm.

All participants referred to time management and the impacts it has while working on a farm. It was clear that all participants felt that time pressures and restraints were key to poor health and safety practice.

'*I would think about it most when I've heard of a fatality or serious accident that I was lucky enough not to be involved in. You know when I hear them on the media or by ear, I just think wow that could happen to anyone. It gives you food for thought, you realise how risky the work is.' (Participant 2).*

Additionally, *Participant* 7 described:

'*Oh and the slurry I mentioned before, the gases are so dangerous, I'll never forget about that story of them three lads who died because of it.'*

One participant highlighted the fear they felt after watching a television advertisement made to raise awareness of farm health and safety and the dangers on a farm:

'*Them TV advertisements as well. There was one where a child got driven over because the father was in such a rush and didn't even look behind, so scary.' (Participant 5).*

A number of participants conveyed fear when describing how poor health and safety could potentially destroy their businesses and create wider financial issues:

'*If a loose wire came out, my whole business could go on fire.' (Participant 6).*

Additionally, *Participant* 5 stated:

'*They would shut you down, then what would you do if you couldn't make any money? You would lose your business.'*

It was also highlighted that participants felt feared of not complying with regulations or policies of certain authorities and being held accountable in situations of poor health and safety practice on the farm:

'*Probably if I had someone inspecting my farm more often, otherwise I would be in legal trouble.' (Participant 3).*

'It would be a financial penalty to me if I didn't comply, which obviously I don't want.' (Participant 6).

Theme 5: Time Management

All participants referred to time management and the impacts it has while working on a farm. It was clear that all participants felt that time pressures and restraints were key to poor health and safety practice. *Participant* 4 stated that:

'Truthfully, if there is something that needs to be done quickly, I might not be as precautious as I should be.'

'If you're just in a massive rush and not looking or taking care, something bad is bound to happen.' (Participant 7).

A number of participants felt that in order to complete all of their daily tasks, they needed to work as quickly as they could and avoid time-consumption:

'A big thing on the farm is time-saving, so, sometimes cutting corners needs to be done but doesn't always lead to the best safety practice.' (Participant 1).

'You know, a farmer's time is expensive. If it takes them an extra hour, that's an hour where they're not making any money.' (Participant 6).

All participants suggested that feeling 'under pressure' has influence on time management and acknowledged that this would usually lead to poor health and safety practice on the farm:

'Someone maybe gets off a tractor in a hurry and fall or something, just time-keeping. Too much pressure involved with farming.' (Participant 2).

'Because it's quick, it's all about speed. Just needed to get the job done, but now he'll never work again.' (Participant 3).

'I was so under pressure as well. I had one million things to do and I saw that it needed fixed so I just thought I would get on with it.' (Participant 6).

Majority of participants found that assessments on machinery and wearing PPE was at times not practical because of the mounting pressures of keeping within a time frame:

'*I might not always worry about lights and machinery, just might be too busy.' (Participant 2).*

'Sometimes, in the haste of the moment and you're under pressure, it's hard to go by the book, it's about getting the job done.' (Participant 5).

Theme 6: Finance

All participants felt strongly about the expense of health and safety and some suggested that the cost of health and safety outweighed the benefit. *Participant* 6 stated that:

'Some farmers will say it's too expensive and I don't need that anyway.'

'Well, truly, farming requires a tight budget. You wouldn't invest in things that you don't really see a benefit in.' (Participant 2).

Majority of the participants felt that the expense of health and safety measures and controls on a farm were discouraging:

'*Everything health and safety wise on a farm is expensive, it really discourages you from doing it, honestly.' (Participant 7).*

'The money is a massive deterrent for practising health and safety, everything is expensive.' (Participant 1).

It was also suggested by some participants that the lack of health and safety enforcement on the farms was key for limited health and safety measures and controls:

'There aren't enough checks done for health and safety on the farms by health and safety bodies.' (Participant 4).

The research identified that younger participants felt advanced technologies and the modernisation of farms gives them an advantage in employing effective health and safety measures over the older generation.

'There should definitely be more farm health and safety checks, I haven't had any.' (Participant 6).

'There isn't any enforcement, nobody does anything about it over here.' (Participant 3).

Despite many participants feeling that expense and lack of enforcement being the main reason for poor health and safety measures and controls, several participants felt that their safety is more important. These participants spoke of the 'value of life' and that their safety outweighed the expense:

'*Usually, health and safety aren't overly expensive when you think of the value of it and the value of your own life. You just can't put a price on life.' (Participant 2).*

'It's a tough one, some farmers genuinely may not have the money to practice health and safety, but in my opinion, how do you put a price on a life?' (Participant 6).

Overall, the participants had a positive attitude to health and safety and perceived the importance of health and safety on their farms.

This research looked to explore the knowledge, attitudes and perceptions of farmers regarding health and safety on the farm in NI and the factors that influenced health and safety measures and controls of the farm. These are now discussed in light of the six themes that were generated by the semi-structured interviews.

In terms of knowledge, participants felt that whilst they possessed some knowledge of health and safety, they felt that this was perhaps incomplete. However, there did not appear to be any particular desire to address this and participants did not express any plans to improve their own level of knowledge. This supports the ideas of Murphy et al. [11] that farm health and safety education in itself is not an effective measure to reduce injuries and fatalities on a farm. The influence farm safety education has on farmers continues to be questioned and there are beliefs that the real issue is with the farmers and whether they will practice the education they have learnt. Interestingly there did appear to a generational difference when looking at knowledge, with the each generation feeling that the other was lacking. The research identified that younger participants felt advanced technologies and the modernisation of farms gives them an advantage in employing effective health and safety measures over the older generation. Whereas, older participants believed that experience was key to maintaining good health and safety practice and avoiding farm accidents – older participants described how previous accidents or near accidents had improved their safety practice while working on the farm.

Overall, the participants had a positive attitude to health and safety and perceived the importance of health and safety on their farms. In line with Elkind [7] and Gerrard [8] they recognised the intrinsically risky nature of their business. The majority of participants reflected on times of 'near miss' accidents and injuries they sustained from poor health and safety practice. Some participants discussed feeling 'lucky' to not have been involved in a serious accident but spoke of injuries or fatal accident stories which impacted their attitudes of health and safety

when working on the farm. This presented an element of acceptance with many of the participants that injuries on the farm were inevitable. This acceptance of the inevitability of accidents poses challenges for officers, who as well as enforcing legislation will look to change behaviour and develop more of a safety culture within farms.

In relation to the factors that influence health and safety measures and controls, perhaps the greatest driver requirements was fear, as established by Wilkins [12]. All participants of this study described a degree of fear regarding one or more elements of health and safety while working on the farm. The fear shared among participants was not only of injury or death but extended to the wider aspects of their businesses. Although many participants felt fear of injury or fatalities due to previous accidents and local or national accident stories, many were afraid of being held accountable for an accident and the financial consequences it could cause.

All participants of this study described a degree of fear regarding one or more elements of health and safety while working on the farm. The fear shared among participants was not only of injury or death but extended to the wider aspects of their businesses.

However, in contrast to this the participants identified issues that would prevent these measures and control being put in place. The majority of the participants discussed having a heavy workload every day and feeling pressure to complete all their work, ultimately making as much profit as possible or allowing the business to remain commercially viable. In many cases, the participants described completing a job on the farm as being more important than taking safety precautions due to time constraints and financial gain. This echoes what Durey and Lower [10] found where farmers considered profits more important than safety. It also echoes the sentiments of Solomon [9], where there are pinch points within the farming year when health and safety perhaps takes a back seat to the need to get the job done.

It is perhaps understandable that the participants believed that the expense of health and safety measures and controls act as a deterrent. Many described the cost as outweighing the benefit of health and safety measures and controls on the farm. However, there were several that considered their own safety as more important than the expense of health and safety equipment and practices. It was clear that many of the participants seemed to understand the principle of health and safety which is 'reasonably practicable'. However, they seemed to create their own 'cost benefit equations', but their view could certainly be different from that of an enforcing officer.

CONCLUSION

It is clear that farmers in NI are presented with daily challenges regarding physical health, financial stability and mental health stressors. It seems likely that health and safety on the farm in NI will continue to present issues throughout the future despite an understanding and acceptance of its importance by farmers.

All participants involved in this study expressed a lack of knowledge on health and safety and agricultural, which may be caused by a lack of health and safety enforcement within the farming community of NI.

All participants involved in this study expressed a lack of knowledge on health and safety and agricultural, which may be caused by a lack of health and safety enforcement within the farming community of NI.

Despite this lack of knowledge, there was a strong sense of participants having a positive attitude towards health and safety and being able to perceive its importance – although this seems to stem mainly from participants own previous or near miss accidents and by hearing of an accident on another farm that involved a local person.

This fear appears as the main driver for implementing good health and safety practices on the farm. The level of fear felt by all participants extended from fear of injury or death (to themselves or others) to non-compliance. Many of the safety practices discussed were in place in order to comply with insurance policies or the wider companies who employed the participants. This sense of fear was felt by majority of participants who were concerned of receiving financial penalties for poor health and safety practice or ultimately, losing their businesses and livelihoods.

However, great as this level of fear appears to be, it is dwarfed by the need to make the business financially viable and farmers are willing to compromise on health and safety standards in order to achieve this. This many participants felt that the time pressures to "get the job done" were the root cause of this.

Therefore, it is apparent that many farmers in NI are still at risk and will continue to be so until the cost/benefit equation is rebalanced. This could be achieved by looking to increasing knowledge and providing potential financial incentives for farmers.

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Antimicrobial activity of the volatile phase of essential oils and their constituents on *Legionella pneumophila*

Lucia **BIĆANIĆ**[1], Silvestar **MEŽNARIĆ**[1], Ivana **GOBIN**[2]

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ABSTRACT

Pathogenic bacteria of the genus *Legionella* cause atypical pneumonia known as Legionnaires' disease and flu – like disease known as Pontiac fever. As pathogens of the respiratory system, these bacteria represent a public health problem and there is a need for examine new alternative ways to inactivate them. These bacteria live naturally in water and are transmitted by infectious aerosols. To purify the air, essential oils that show antimicrobial properties are widely used. The anti-*Legionella* activity of five exotic essential oils and five Mediterranean essential oils characteristic for coastal Croatia was examined. Model organism used in experiments was *L. pneumophila* (strain 130b). This experiment was conducting with modified version of sealed plate method using a BCYE medium. The exotic essential oil with highest anti-*Legionella* activity was Niaouli essential oil, and the best anti-*Legionella* activity among Mediterranean essential oils showed Immortelle essential oil. Anti- *Legionella* activity of four main chemical compounds was examined and compound that show significant highest anti-*Legionella* activity was α – pinene. Volatile components of essential oils have a great potential as anti-*Legionella* agents and further research are needed.

Key words: essential oils; volatile components; *Legionella*; antibacterial effect

POVZETEK

Patogene bakterije iz rodu *Legionella* povzročajo atipično pljučnico, poznano pod imenom Legionarska bolezen in Pontiaška vročica. Tako kot drugi povzročitelji bolezni respiratornega sistema tudi te bakterije predstavljajo javnozdravstveni problem. Iz tega sledi nenehna potreba po iskanju novih alternativnih načinov preprečevanja in obvladovanja njihovega pojava. Bakterije iz rodu *Legionella* lahko najdemo v naravnih in umetnih vodnih sistemih, prenašajo pa se preko onesnaženih aerosolov. Za čiščenje zraka se pogosto uporabljajo eterična olja, ki delujejo protimikrobno. Z uporabo BCYE medija smo analizirali protimikrobno delovanje na bakterijo *Legionella pneumophila* (sev 130b). Pri tem je bilo testiranih pet eksotičnih eteričnih olj in pet sredozemskih eteričnih olj, značilnih za obalo Hrvaške. Med eksotičnimi

[1] Student at Faculty of Medicine, University of Rijeka, Brace Branchetta 20, 51000 Rijeka, Croatia

[2] Department of Microbiology and Parasitology, Faculty of Medicine, University of Rijeka, Braće Branchetta 20, 51000 Rijeka, Croatia

[*] *Corresponding author*
Ivana Gobin, PhD, Associate professor
Department of Microbiology and Parasitology, Faculty of Medicine, University of Rijeka, Brace Branchetta 20, 51000 Rijeka, Croatia
E-mail: ivana.gobin@uniri.hr

eteričnimi olji smo največjo protimikrobno aktivnost zabeležili pri olju »Niaouli«. Med sredozemskimi eteričnimi olji pa je bilo to olje »Immortelle«. Med glavnimi kemičnimi snovmi ima največji antibakterijski učinek spojina α – pinen. Velik potencial antimikrobnega delovanja hlapnih snovi eteričnih olj na bakterijo *Legionella pnemuophila* kaže potrebo po nadaljnjih raziskavah.

Ključne besede: eterična olja; hlapne snovi; *Legionella*; antibakterijski učinek

INTRODUCTION

The genus *Legionella* contain a group of pathogenic bacteria that very often cause respiratory diseases collectively called legionellosis. Species from the genus *Legionella* belong to the family *Legionellaceae*, and the main cause of most legionellosis is *Legionella pneumophila*. Legionellosis has two forms: Pontiac fever and Legionnaires' disease. Legionnaires' disease or atypical pneumonia is a very common and severe systemic disease. Another mild legionellosis that has flu-like symptoms is known as Pontiac fever [1, 2]. The largest, natural habitat of *L. pneumophila* is freshwater environment and very often can be present in various artificial and natural water systems such as cooling towers, air conditioners, humidifiers and dehumidifiers, boilers, swimming pools, fountains and other water systems [3]. The most common cases of infection with this bacterium are associated with travel and staying in different hotels [4]. For this reason, it is important to prevent the presence of this bacteria in places where people are gathering, so that epidemics do not occur. One of such important places are hotels and spa centers where water analysis must be performed regularly, and measures must be taken to prevent legionellosis.

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Essential oils are composed of volatile molecules and are produced from aromatic or medicinal plants by a process of secondary metabolism. The largest share, in essential oils, are aromatic hydrocarbons and terpenes, which give them their characteristic pleasant and intense odor. It is very important to note that when isolating oil from the same plant and the same process, do not always results with oil that have the same composition, it will largely depend on various factors such as growth and cultivation conditions and the time of harvesting the plant itself. EOs are usually obtained as a result of hydrodistillation, steam distillation, dry distillation, or the mechanical cold pressing of plants [5]. Essential oils have been used for thousands of years, not only as ingredients of perfumes or for the aromatization of food, but also in folk medicine, because of their many different biological properties, including antimicrobial properties.

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The aim of this study was to determine the antimicrobial activity of volatile phase of different Mediterranean and exotic essential oils and their active volatile components.

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MATERIALS AND METHODS

Model organism

Model organism used in experiments was *L. pneumophila* serogroup 1, strain 130b or ATCC BAA-74 (clinical isolate). This bacterial strain was obtained from the collection of the Department of Microbiology and Parasitology, University of Rijeka. The bacterium was kept in 10% glycerol broth, stored in a freezer at -80 °C. After cultivation for 3–5 days on buffered charcoal yeast extract (BCYE) agar (Oxoid, Altrincham, UK) at 35 ± 2 °C in an aerobic atmosphere, the bacterium was used in experiments.

Essential oils and their basic chemical components

The essential oils were obtained from the company Dea Flores d.o.o. (Rijeka, Croatia) and a stock solution of essential oil was prepared using DMSO (dimethylsulfoxide) (Kemika, Zagreb, Croatia) in a concentration of 100 mg/mL. The tested oils were divided into two groups. The first group consists of exotic essential oils: Spikenard (*Nardostachys jatamansi*), Niaouli (*Melaleuca quinquenervia*), Hysssop (*Hyssopus officinalis*), Palmarosa (*Cymbopogon martinii*) and Ravensara (*Ravensara aromatica*). The second group consists of essential oils from coastal region of Croatia: Juniper berry (*Juniperus communis*), Immortelle (*Helichrysum italicum*), Sage (*Salvia officinalis* L.), Lavander (*Lavandula x hybrida*) and Rosemary (*Rosmarinus officinalis*). The antibacterial activity of bioactive components of the essential oils α-pinene, β-pinene, γ-terpinene and eugenol (Sigma-Aldrich, MO, USA) were also tested. The concentration of the stock suspension was 200 mg/mL.

Preparation of bacterial inoculum

The number of bacteria in bacterial suspension was determined spectrophotometrically. The optical density of bacterial suspension was set to OD_{600} value 1,0 which indicates 10^9 CFU/mL. The bacterial concentrations of approximately 1×10^8 CFU/mL were used in the experiments. The number of bacteria in the inoculum was confirmed by cultivation of ten-fold dilutions on BCYE medium.

Determination of the antimicrobial activity of volatile components by sealed plate method

Modified version of sealed plate method has been used [6]. Briefly, using a sterile swab, bacteria suspension (10^8 CFU/mL) were spread evenly onto pre-warmed 37 °C BCYE agar plates. A 5 mm diameter cellulose disc soaked with 5 μL of the test essential oil or tested components was then placed in the center of each lid of the Petri dish. To set up the assay the bottom of plate containing the bacteria was inverted over the plate carrying volatile compound and was sealed against each other tightly using petri-seal to prevent the essential oil from evaporating outside the Petri dish. The BCYE agar were then placed in a thermostat at 35 ± 2 °C for a 72-hour incubation. Plates without volatiles served as control. After a 72-hour incubation, the

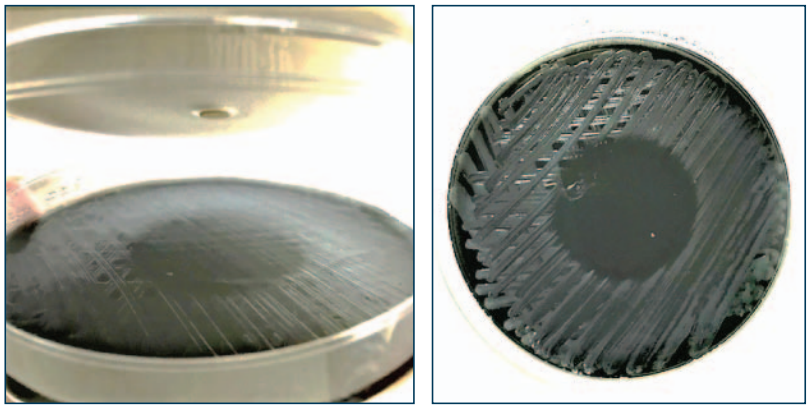

Figure 1.
The Petri dish with cellulose disc soaked with essential oil (left) and zone of inhibition made by volatile components of essential oil (right).

results were obtained by measuring the diameter of the zone of inhibition below the disc caused by the inhibitory action of the volatile components of the essential oils on *Legionella*. For each oil, the diameter of the inhibition zone was measured, and the result was expressed in millimeters. A pure DMSO control was included with each test to ensure that microbial growth was not inhibited by DMSO itself.

Statistical analysis

All experiments were performed three times in duplicate. The results are expressed as the mean ± standard deviation. Result were statistical analyzed with Tibco Statistic 13.5.0. at a significance level of $p < 0.05$. The normality of the data distribution was tested by the Kolmogorov-Smirnov test. The distribution was normal and parametric T-test was used.

RESULTS AND DISCUSSION

The antimicrobial properties of the volatile components of the exotic essential oils Spikenard, Niaouli, Hyssop, Palmarosa and Ravensara were investigated, and the results are shown in Figure 2. All tested essential oils showed anti-*Legionella* activity. The best result was obtained with the Niaouli essential oil with inhibition zone of 33.3 mm, while the lowest result of *Legionella* inhibition was measured with Spikenard essential oil (16.83 mm). In the case of essential oils from the coastal region of Croatia (Figure 3, Table 1), the inhibition zone was statistically higher from those of exotic essential oils. The strongest antimicrobial activity of volatile components was shown by the immortelle (*H. italicum*) essential oil with an average zone of inhibition of 55.5 mm. Sage (*S. officinalis* L.) and lavander (*L. hybrida* L.) essential oils showed a weaker inhibitory activity with a zone of inhibition of 25.3 mm and 24.0 mm, respectively (Figure 2, Table 1).

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The chemical components of the essential oils were also tested separately, and it was examined whether dilution affects the antimicrobial activity of the volatile phase (Figure 4, Table 1). The antimicrobial effect of two concentrations, 100 mg/mL and 200 mg/mL was investigated. The largest zone of inhibition was caused by α-pinene, whose zone of inhibition was almost the entire surface of the Petri dish (concentration 200 mg/mL). γ-terpinene showed no antibacterial effect,

Figure 2.
Antimicrobial activity of volatile components of an exotic essential oil at concentrations of 200 mg/mL. The results are expressed as a mean value ± SD of a minimum of three repeated experiments.

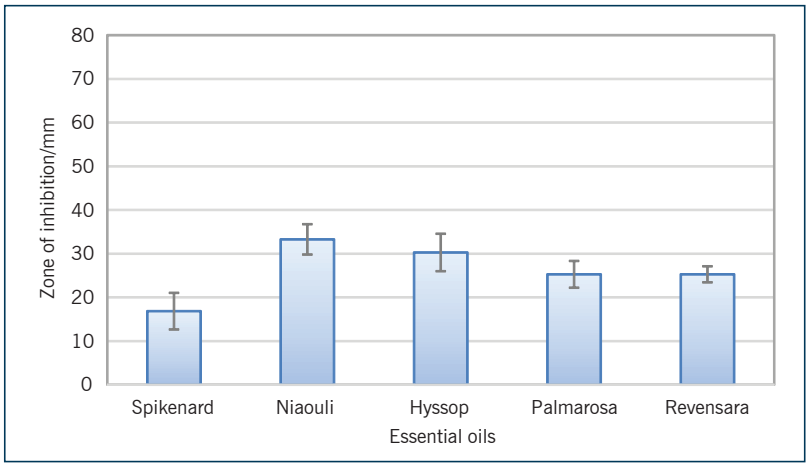


Figure 3.
Antimicrobial activity of volatile essential oils of coastal region of Croatia at concentrations of 200 mg/mL. The results are expressed as a mean value ± SD of a minimum of three repeated experiments.

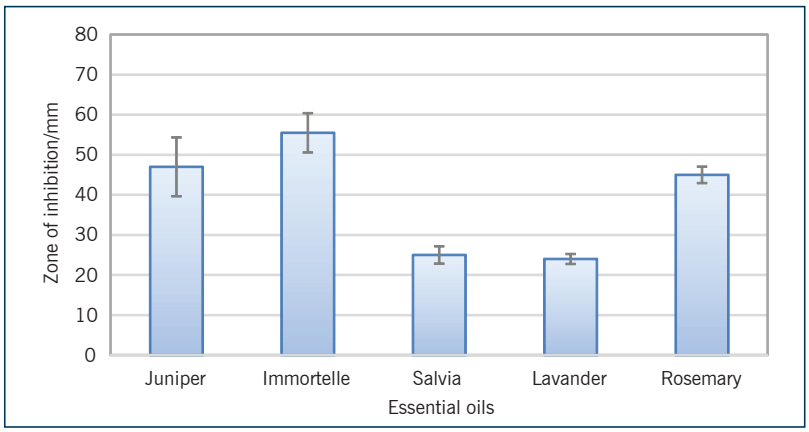
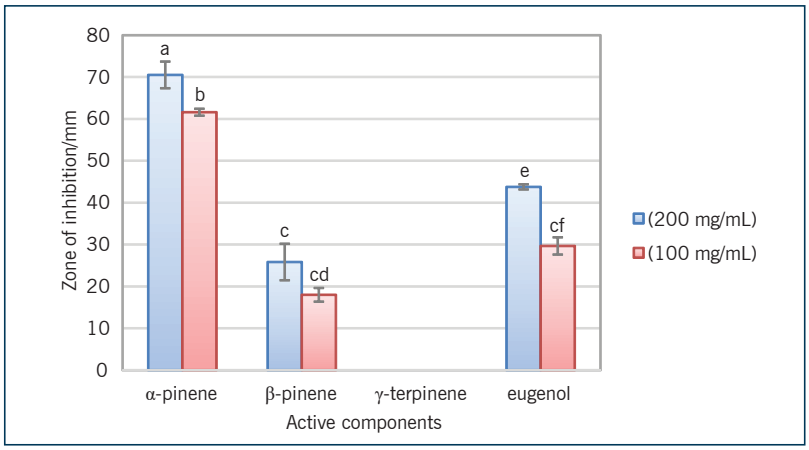


Figure 4.
Antimicrobial activity of volatile active components at concentrations of 200 mg/mL and 100 mg/ml. The results are expressed as a mean value ± SD of a minimum of three repeated experiments. Lowercase letters on top shows statistical significance ($p < 0.05$).



and we did not detect a zone of inhibition. Eugenol and β-pinene showed a statistically weaker effect than α-pinene, with a higher concentration of the test compound (concentration 200 mg/mL) showing a better antibacterial effect.

Since essential oils are complex mixtures of many phytochemicals, *it* is very difficult to determine which of them is responsible for the antimicrobial activity. Furthermore, it is also important to know ratios of individual components present in essential oil as well as their synergistic or antagonistic activity. Numerous studies have shown the antimicrobial properties of various essential oils on bacteria, however in most studies essential oils have been added to the medium in which the test was performed. The higher susceptibility of Gram-positive bacteria when

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Table 1. Antimicrobial activity of volatile phase of essential oils and active components

Essential oils	Zone of inhibition (mm)±SD
Exotic essential oils	
Nard	16,83±4,19
Niauli	33,27±3,47
Isop	30,27±4,29
Palmerosa	25,27±3,06
Revensara	25,27±1,84
Mediterranean essential oilss	
Juniper	47,00±7,35
Immortelle	55,83±4,90
Sage	23,00±2,16
Lavander	25,33±1,25
Rosemary	42,33±2,05
Volatile components	
α-pinene (200 mg/mL)	70,50±3,19
β-pinene (200 mg/mL)	25,83±4,37
γ-terpinene (200 mg/mL)	0,00
eugenol (200 mg/mL)	43,77±0,61
α-pinene (100 mg/mL)	61,60±0,83
β-pinene (100 mg/mL)	18,00±1,63
γ-terpinene (100 mg/mL)	0,00
eugenol (100 mg/mL)	29,67±2,05

compared with Gram-negative strains was found, and a large variability among essential oils in the antibacterial potential has also been observed [7-10].

The main advantage of essential oils is that they do not enhance antibiotic resistance with the long-term use what is the case for synthetic antibiotics, and they showed synergy in antimicrobial activity with conventional antibiotics [11-13]. For this reason, majority of studies carried out on extracts and pure components isolated from essential oils analyzing their antibacterial activities.

Volatile Organic Compounds (VOCs) emitted by plants or essential oils are largely lipophilic products with molecular masses under 300 Da. The vast majority are isoprenoids, including hemiterpenes (C5H8) such as isoprene, monoterpenes (C10H16), irregular acyclic homoterpenes (C11H18 or C16H26), and sesquiterpenes (C15H24) [14].

Research into the antimicrobial properties of volatile components of essential oils is rare. Laird and Phillips showed that the use of essential oil vapors in food relates to their antimicrobial activity against food pathogens and food spoilage microorganisms also [15]. Advantage of application of essential oil vapor phase, is that the components are dispersed and tend not to affect the organoleptic properties of the food like liquid essential oil. A study by Nedorostova *et al.* (2009) showed some antibacterial activity of 27 different essential oils vapors against five foodborne pathogens (*Escherichia coli*, *Listeria monocytogenes*, *Salmonella enterica ssp. enteriditis*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*) using the disc volatilization method [16].

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Our results showed that α-pinene showed a stronger effect on *Legionella* growth inhibitions.

All tested essential oils have the great potential to be used as a volatile antibacterial agent to control legionellosis and could be used as air purifiers in various rooms in hotels and spas.

Exotic essential oil with highest anti-*Legionella* activity was Niaouli essential oil, and the best anti-*Legionella* activity among Mediterranean essential oils have Immortelle essential oil.

The antimicrobial activity of essential oils on *Legionella* has been poorly investigated. Chang *et al*. examined the antimicrobial activity of essential oils extracted from *Cinnamomum osmophloeum* leaves and *Cryptomeria japonica* and its major constituent, cinnamaldehyde, possess strong anti-*Legionella* activities [17]. We have not found data on the antimicrobial activity of volatile phase of essential oils on *Legionella*. Since α-pinene shows high anti-*Legionella* activity one can assume that essential oil with high proportion of this component will give such activity. Ramanoelina *et al.* demonstrate that essential oil of Niaouli (*M. quinquenervia*) have high α-pinene [18] content and it can be cause of high anti-*Legionella* activity as is shown in figure 2. Research conducted by Han *et al.* shows that Immortelle essential oil also have high percentage of α-pinene [19]. Our research has shown a strong antimicrobial activity of volatile components of essential oils that predominantly have a α-pinene in their composition. Alpha-pinene is the most widely encountered terpenoid in nature and is highly repellant to insects. There are two structural isomers of pinene found in nature: α-pinene and β-pinene [20]. The antimicrobial activities of the isomers of pinene was shown against different bacterial and fungal species [20, 21].

Our results showed that α-pinene showed a stronger effect on *Legionella* growth inhibitions. Reason why γ-terpinene did not show any anti-*Legionella* activity could be that this compound on its own has no antimicrobial activity. All tested essential oils have the great potential to be used as a volatile antibacterial agent to control legionellosis and could be used as air purifiers in various rooms in hotels and spas. Furthermore, the potentially synergistic effect of volatile components of different combinations of essential oils remains to be investigated.

CONCLUSION

Wide use of essential oils demands a scientific background so antimicrobial activity of essential oil is examined all over the world. Exotic essential oil with highest anti-*Legionella* activity was Niaouli essential oil, and the best anti-*Legionella* activity among Mediterranean essential oils have Immortelle essential oil. Chemical compound that shows significant highest anti-*Legionella* activity was α-pinene and essential oils with strongest anti-*Legionella* activity are timely the ones with highest proportion of this compound. Essential oils show great benefits as antimicrobial agents and different approach to their use for this purpose is to be examined.

Acknowledgments

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Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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