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WOOD IN THE FOOD INDUSTRY I

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Icelandic Fisheries Laboratories Report Summary

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Ágrip á íslensku:	Verkefnið "Wood in the food industry" er styrkt af Norræna iðnþróunarsjóðnum í gegnum "Nordic Wood 2" sem er rannsóknaráætlun fyrir timburiðnaðinn. Norrænir timburframleiðendur ásamt notendum timburs hafa lagt fram viðbótarframlag. Aðalmarkmið með verkefninu hefur verið að safna saman upplýsingum um notkun á timbri í matvælaiðnaði og að finna aðferðir sem hægt er að nota til að meta örverumengun á timbri og öðrum efnum. Spurningarlisti var sendur út til 30 fyrirtækja í fiskiðnaðinum og svörum safnað saman og niðurstöður metnar hjá DTU í Danmörku. Svörunin á Íslandi var um 23%. Fimm mismunandi aðferðir voru bornar saman til að meta örverumengun: snerti-, skolunar-, flísunar-, penslunar- og áhellingaraðferð. Engin aðferð var góð en við mælum með snerti- og penslunaraðferðum sem eru mjög þægilegar í notkun á öll yfirborðsefni í iðnaðinum. Snertiaðferðin eru mjög auðveld í framkvæmd og góð til að meta hreinlætisástand á timbri. Penslunaraðferðin er nákvæmari en einnig auðveld í framkvæmd. Með henni er hægt að mæla stærri svæði og auðvelt að magngreina örverufjölda á ákveðnu yfirborði. Örverumengun á byggingarefni var kannað. Límtré var athugað eftir mismunandi meðhöndlun og niðurstöður bornar saman. Vatnsleysanleg parket-málning kom best út. Ryðfrítt stál og vatnleysanleg epoxy málning sýndu sambærilegar niðurstöður		
Lykilorð á íslensku:	*timbur, matvæli, hreinlæti, örverur,*		
Summary in English:	The project "Wood in the food industry," is funded by the Nordic Industrial Fund through the program Nordic Wood 2, which is an R&D program for the Nordic wood industry. The Nordic timber and woodworking industry and national funding authorities in the Nordic countries have raised additional funding. The main object of the project has been to collect data regarding wood products and their substitutes when used in the food industry, and to find suitable methods to identify and measure the growth of bacteria on wood and their substitutes. A questionnaire was sent out to 30 companies in the fishing industry and answers were gathered and sent out to DTI, which carried out the evaluation of the questionnaire. In Iceland the response from the questionnaire was about 23%. Five different, measuring methods were tested: contact-, rinsing-, scraping-, swabbing-method and liquid media poured on the surface. *Pseudomonas* spp. was used as a test organism. None of the five methods give optimum results. We recommend the contact and the swabbing methods as the most convenient and suitable measuring methods to be used in the industry. The contact method is easy to perform and convenient for a screening of the hygienic conditions of the wood. The swabbing method is easy to perform, quantitative, not destructive and applicable on all kinds of surfaces. Microbial contamination of wood in construction was studied. Gluelam was evaluated after different treatment. Waterbased parquet painting gave the best results and was considered the most hygienic, compared to the others. Stainless steel and water-based epoxy painting showed equal hygienic properties		
English keywords:	*wood, food, hygine, microorganism*		

Project report:

Wood in the food industry-

hygienic properties

Wood pallets and wood in construction (gluelam)

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1. Background

The project "Wood in the food industry," is funded by the Nordic Industrial Fund through the program Nordic Wood 2, which is an R&D program for the Nordic wood industry. The Nordic timber and woodworking industry and national funding authorities in the Nordic countries have raised additional funding.

Wood used to be the most common material for packaging, workbenches, shelves, tools, buildings, interiors etc., in the food industry in the Nordic countries. In Iceland, wood is still being used in the production of salted fish, in fish drying, as well as being a connective structure in processing plants and shipping aids on board for overseas transportation. The use of wood has, however, decreased, and it has been replaced by other materials such as plastic, concrete, stainless steel and aluminium. The reason for this development seems to be declining market demands for wood, partly caused by legislation in Europe and elsewhere. Because wood is a porous and absorbent material, where organic matter, along with bacteria, can become entrapped, cross-contamination is a main concern. With the development of new materials during the last decade, various polymers have become the work surfaces of choice, although research to support the change is insufficient. It has been claimed that these plastic surfaces have all the advantages of wood but none of its disadvantages. Despite of this, nearly 1,5 million cubic meters of timber are used for pallets and for packaging in the Nordic countries each year. These products are therefore of great importance for the wood industry as the alternative production of packaging materials may be chips for pulp production. Based on that background, a Nordic research project was initiated to find out more about the behaviour of wood when in contact with foodstuff.

Plastic pallets are replacing the traditional wooden pallets used in the food industry. The procedure for making the correct choice of pallets for use in particular food manufacturing is debated with regard to:

- properties of wood versus plastic pallets (strength, resonance to pressure, flexibility, max load to be carried, max height of stack for storage, whether it is difficult/easy to clean, use at low temperature)
- economic aspects (cost, breakage rate, cost of repair, expected durability, interest on capital)

Sanitation of surfaces in contact with food is an essential operation in the food industry, because such surfaces can spread microbiological contamination to the products. The efficacy of sanitation of surfaces in contact with food depends, among other factors, on the materials used in their manufacture. Some bacteria have the tendency to adhere to hard surfaces, where they multiply and produce extracellular polymeric substances, forming a so-called biofilm. Other bacteria may become entrapped in such a biofilm and can even be protected from active compounds used during sanitation. In fact, attachment of micro-organisms to such surfaces is a concern in the food industry because previous studies have shown that these cells appear to be more resistant to sanitizers. Pathogenic bacteria are of particular concern, since formation of biofilm may become a nest for them, facilitating their proliferation on contact surfaces and consequently their transfer to the products being processed.

The choice of a proper material that will be in direct or indirect contact with the food being produced is not an easy task. Various factors must be considered. The following are examples:

(1) The intended use of the material (cutting, support, packaging, etc.)
(2) The inherent characteristics of the material (porosity, absorbency, strength, etc)
(3) The durability of the material/ ease of maintenance and repair
(4) The nature of the food product: liquid, solid, fatty etc.
(5) The cleanability of the material
(6) Cost

As far as we know, no studies have been done where woodsurfaces, not in contact with food, has been identified as a health risk. The Icelandic Fisheries Laboratories is performing field studies where the use of wooden pallets is being evaluated. The main emphasis during this period has been on studying indirect contact with food.

The main object of the project has been to collect data regarding wood products and their substitutes when used in the food industry, and to find suitable methods to identify and measure the growth of bacteria on wood and their substitutes.

The project has a steering group with the following members:

- Heine Aven, chairperson	Aven AS, Norway
- Marianne Moltke, deputy chair person	Norwood AS, Denmark
- Stefan Nilsson	Åsljunga Pallen AB, Sweden
- Bjarni Ingibergsson	Límtré h.f., Iceland

Terje Apneseth and Ida Weider have been the project leaders.
The following industries, organisations and research institutes have contributed to this project:

Denmark:	Norwood A/S, Dansk Træemballage A/S, Dansk Teknologisk Institutt, Træteknik (DTI)
Iceland:	SÍF. h.f., Límtré h.f., BYKO h.f., Samskip h.f., Vörubretti h.f., Icelandic Fisheries Laboratory (IFL)
Norway:	Aven AS, Høylandet treindustri AS, Saltfiskforum, Fiskeriforskning, Norsk Treteknisk Institutt (NTI)
Sweden:	AB Gyllsjö Träindustri, Åsljunga Pallen AB, Strandbergs Trä och Pallindustri, Trätek, Institutet för träteknisk forskning,

2. Summary of results

The aim of the project is to:

- Ensure that wood gets a just treatment in regulations and specifications
- Obtain more knowledge about the attachment of micro-organisms to the surface of wood
- Find suitable cleaning methods for wood used in the food industry

The Icelandic Fisheries Laboratories has carried out most of the research work of the project in cooperation with Fiskeriforskning (Norway). The researches carried out are involved in task 2, 3and 5 in the workplan. Task 2, regarding the use and distribution of Wood in the food industry, task 3, about the measuring method to evaluate hygienic properties of wood and task 5, about field studies of hygienic properties for wood.

A questionnaire was sent out to 30 companies in the fishing industry and answers were gathered and information sent out to DTI, which carried out the evaluation of the questionnaire. The response from the questionnaire was about 23%.

Five different, measuring methods were tested: contact method, soaking of sample in water, scraping, swabbing and liquid media poured on the surface. *Pseudomonas* spp. was used as a test organism. None of the five methods gives optimum results, but of the five methods, we recommend the contact and the swabbing methods as the most convenient and suitable measuring methods to be used in the industry. The contact method is easy to perform and convenient for a screening of the hygienic conditions of the wood. The swabbing method is easy to perform, quantitative, not destructive and applicable on all kinds of surfaces.

The recovery of bacteria from treated wood samples and the hygienic properties of the wood was evaluated and the recovery of bacteria from the samples turned out to be quite low, but that conforms with the results of the preliminary experiments, where the method was evaluated (Lorentzen and Guðbjörnsdóttir, 2000). The main difference is between wet and dry samples. The recovery was higher from wet samples (0.13-5.30%), compared to dry samples (0-0.09%). Ultrawood treatment gave lower recovery, compared with untreated samples. The results from 2% wax emulsion on spruce were similar to nontreated pine, but when the strength was increased the recovery became higher and gave the best result. The lower strength of wax emulsion on pine (2%) gave higher recovery compared to higher strength (4%).

Gluelam was evaluated after different treatment. Waterbased parquet painting gave the best results and was considered the most hygienic, compared to the others. Stainless steel and 1B (water-based epoxy painting) showed equal hygienic properties. After 6 months in saltfish storage, the condition is the same as in the beginning (data not shown). No difference could be discerned between steel and the gluelam. The results from a hygiene survey in a dairy company and the hygienic conditions of the pallets were not good. Fifteen samples were taken from plastic pallets, made of polyethylene. Total bacterial count and moulds were evaluated by swabbing method. The cleaning methods used were not well organised and the pallets were only cleaned occasionally and then just flushed with water. List of published reports is in Appendix 1.

3. Material and methods

3.1 Chart range of uses and distribution of wood in the food industry

A questionnaire was sent out to 30 companies in the fishing industry. They were asked about their use of wood, where and why they were using it. Which properties of wood they considered important when choosing material? The reason why they quit using wood in some areas? The questions were directed about the use of wood in construction (buildings), storage and the processing lines, like pallets and cutting boards.

3.2 Measuring methods to evaluate hygienic properties independent of material

When developing a microbial test-methods, there are some general requirements to be fulfilled, like how easy they are to perform, and how cheap, safe, secure, fast and labour consuming they are.

All of these things were taken into consideration in this project. The experiments were based on traditional test methods, which involve 3-6 days before any result is available. A test method consists of two steps: sampling (step 1) and analysis (step 2). Step 1 must be easy to perform, and should not require any special knowledge of microbiology. To perform the analysis (step 2), there are two options. One, the analysis is performed on location at the plant, or two, the analysis is performed in an independent laboratory. Whether to perform the analysis on location or at the laboratory must be considered in each case, depending on access to laboratory facilities, knowledge etc.

In this experiment, we have tried new softwood, which is common in pallets. Although wood is not permitted in the food industry, some plants still use it (e.g. the saltfish industry). In addition, experiments of plastic and stainless steel have been performed to compare these materials with wooden samples. Scanning Electronic Microscopy (SEM) was used to evaluate the adherence of bacteria on surfaces used in this experiment.

Samples of wood, plastic and stainless steel were sterilised in an autoclave at 121 °C for 15 minutes. Before putting them into the autoclave, the samples were wrapped in aluminium paper and put in autoclaveable bags, sealed with an autoclaveable tape. Five different measuring methods were tested. At the FF, experiments on halophilic bacteria, *Halobacterium salinarum*, were carried out. At the IFL experiments on *Pseudomonas* spp. isolated from fish processing environment were done. Wood samples were contaminated by microbes and samples taken after different contact time by each method after four different contamination times.

Method 1. Contact method

The microbes were recovered by pressing the block onto a surface of agar medium in a petri plate for 2 minutes.

Method 2. Rinsing method

The microbes were recovered by soaking the contaminated surface in MRD solution in a petri plate for one minute. The number of microbes was determined by plate counting.

Method 3. Swabbing method

The surfaces were swabbed by using a sterile cotton-wool swab. Before swabbing, the swab was dipped into a sterile peptone-/salt-solution. Afterwards, the swab was stirred in the sterile liquid and the number of microbes was determined by plate counting.

Method 4. Scraping method

The surface layer was removed by scraping with a sterile scalpel. The surface was then rinsed with sterile water. Samples were taken of the scraping and the rinsed water and the number of microbes was determined by plate counting.

Method 5. Spread agar method

Soft agar was spread over the contaminated surface. The agar was on the surface during incubation for 3 days at 22°C. After incubation of the samples the number of microbes on the agar was determined.

3.3 Studies of woods hygienic properties

3.3.1 A pilot study regarding wood treatments and hygienic properties of wood

In co-operation with The Swedish Institute for Wood Technology Research have performed short study on recovery of bacteria from different treated wood sample.
One way to get a water-repellent effect is to treat the timber with a waxemulsion, which is a fairly simple and inexpensive method. Previous studies have shown that this can reduce the absorption of water by 40-60% (Nussbaum, 1992 and Beyer, 1997). The growth of blue stain and mould is also reduced. Another method is impregnation with a water-repellent agent.

In this study untreated, wax treated and wax impregnated samples were exposed to accelerated ageing, 10 cycles, in a Atlas Weather-o-Meter Ci 65, with 24 hours watersprinkling and 24 hours drying per cycle. After watersprinkling, 30 l/sample/h, the weight was examined and the absorption of water is expressed in %. The drying cycles were under exposure of UV-light for 24 hours, according to ASTM standard G26-92 (ASTM Standard).

1. Untreated samples of pine (Pinus Sylvestris), 20x100x310mm.
2. Wood samples of spruce (Picea Abies) and pine, 20x100x310 mm, were treated with a wax emulsion, Mobilcer 45, corresponding to 80-90 g/m2 (called wax1) respectively around 160 g/m2 (called wax2).
3. Wood samples of pine, 20x100x310 mm, were impregnated with Ultra Wood (UW) at two different concentrations - 1% and 2% active substance.

The samples were conditioned at 20 °C/65% RH to a moisture content of around 12% before testing. Some of the samples were also sent to the Icelandic Fisheries Laboratories for bacterial testing.

Table 1**. Ultra wood impregnation**

Impregnation		Ultrawood					
	1% impregnation with active substance						
	2% impregnation with active substance						
Sample no	Board no	Weight before	Weight after	absorption	% **	1%	
1	1	319	467	148	46,4		
2	2	314	576	262	83,4		
3	3	346	433	87	25,1		
4	4	351	581	230	65,5		
5	3	314	398	84	26,8		
6	1	304	588	284	93,4	2%	
7	2	310	502	192	61,9		
8	3	341	579	238	69,8		
9	4	366	549	183	50,0		
10	5	292	511	219	75,0		
							B*
1%B	2	299	578	279	93,3	1%	1
1%B	7	303	410	107	35,3		2
2%B	4	309	547	238	77,0	2%	3
2%B	1	320	656	336	105,0		4

*Bacterial testing
** Differences in absorption caused by different amount of heartwood piece. Heartwood cannot be impregnated.

The samples B were used for bacterial testing, according to the methods evaluated in the first partial report and regarded as suitable for wood (Lorentzen, Guðbjörnsdóttir, 2000). The swabbing method was used and at the same time, one rapid method was also performed. Adenosine Triphosphate (ATP) - bioluminescence was found to be useful and this technique is known to be a good method for assessing the hygienic status of surfaces in contact with food. A swab is taken from the surface to be examined and the ATP present is extracted and assayed by the addition of luciferase/luciferin. The amount of the light that is emitted by the reaction can be measured by portable, food factory safe instruments. The light released during the reaction indicates the contamination level of the surface; the more the light, the more the contamination. Wet and dry samples were contaminated with *Pseudomonas* spp. isolated from fisheries environment. The samples were kept in the lab for at least four days until they stopped loosing weight. The wet samples were prepared by soaking the wooden samples in water for 18-20 hours before the experiment started.

The samples were disinfected prior to the experiments. They were wrapped into aluminium paper and put in autoclavable bags, sealed with autoclavable tape. The sterilisation time was 15 min at 121°C. The microbial suspension was in brain heart infusion (BHI-Difco) and the initial level of the micro-organisms was 10^8 CFU/ml. A volume of 0.5 ml of the inoculum was spread evenly on the pith side of the wood samples. The contamination time was two hours at 20°C. The bacteriological tests were later repeated under the same conditions.

3.3.2. Microbial contamination of wood in construction

The company Límtré has been designing buildings for the fishing industry and producing samples for the hygienic research.

There are many things consider when a house, intended for production of food is designed. Two houses have already been built, where extra time and care was taken to make it as good as possible. Both buildings have concrete foundations up to 1,0 m, which are covered with the same material as the floors. The tops of all walls are designed with 20° slope to prevent dust and water from accumulating there. The wood is covered by primer & acryl coating (water based). The IFL did some studies in cooperation with Límtré.

3.3.2.1 Recovery of bacteria from surfaces measured by different methods

Bacteria was recovered from the surface of the tested samples by using the swabbing-, and the contact methods, according to the methods evaluated in the first partial report and regarded as suitable for wood (Lorentzen, Guðbjörnsdóttir, 2000). At the same time, one rapid method was also performed to estimate the bacterial load. Adenosine Triphosphate (ATP) - bioluminescence was found to be useful and this technique is known to be a good method for assessing the hygienic status of food contact surfaces. A swab is taken of the surface, which is to be examined, and the ATP present is extracted and assayed by the addition of luciferase/luciferin. Portable, food factory safe instruments can measure the amount of the light that is emitted by the reaction. The light released during the reaction indicates the contamination level of the surface; the more the light, the more the contamination. Samples were contaminated with *Pseudomonas* spp, isolated from fisheries to check the recovery from different treated spruce. The microbial suspension was grown in brain heart infusion (BHI-Difco) and the initial level of the micro-organisms was 10^8 CFU (colony forming unit)/ml. A volume of 0,5 ml of dilution 10^{-1} was spread evenly on the sample. The contamination time was 2 hours at 20°C.

3.3.2.2 Microbiological survey on different treated constructions samples

Pallets with six different treated wood samples (1-6) and one stainless steel (s) were placed on three different sites in a SÍF warehouse (A-B-C).

1. 1.A 1 x Kopal primer (water based)
   2 x Kopal acrylic painting (water based)
2. I.B 2 x Kopal epoxy painting (water based
3. II.A 2 x Parquet painting (water based)
4. III.B 2 x Epoxy painting
5. IV.A 2 x Kjörvari 14 (decay preservative)
6. * No treatment
7. ** Galvanised steel

The samples were placed in a vertical position. Ambient temperature and relative humidity in the air were measured during the study. Samples were taken after zero-two-four and six months and will continue to be taken for the duration of the WOOD project (including phase 2). In first three visits, two samples were taken from each wood block (in total 42 samples each time), but after that the two samples were pooled together and tested as one sample (in total 21 samples). In the third visit, the evaluation of mould and yeast was added to the study. Potato dextrose agar from Difco is used to evaluate the number of mould and yeast.

Bacteria was recovered from the surface of tested samples, using the swabbing- and the contact methods according to the methods evaluated in the first partial report and regarded as suitable for wood (Lorentzen, Guðbjörnsdóttir, 2000). In the beginning, one rapid method (Adenosine Triphosphate (ATP) - bioluminescence) was used to estimate the bacterial load. The results were inconclusive so it was not continued further.

3.3.3 Hygiene survey on wood- and stainless steel surfaces in the fishindustry

Hygiene surveys were conducted in two places in the fishing industry, in a processing hall and in a cold storage. In the fishing industry in Iceland, wood can still be found, mostly used in indirect contact with products.

3.3.4 Pallets for storage and transportation



Hygiene surveys have been carried out in the fishing industry, where samples were taken from different sites in the environment. In one dairy company, a survey was carried out because pallets made of plastic (polyethylene) were being used there. Samples were taken, using the swabbing- and contact methods. Total bacterial count and moulds were evaluated.

4. Results and conclusion

4.1 Chart range of uses and distribution of wood in the food industry

We did send the questionnaire to one company for testing and the people who tried to answer it found it somewhat complicated. When we received the answers we noticed that they had not answered some of the questions about the environmental effects and the advantages of using wood in the food industry. Perhaps they considered it to be irrelevant to them, we had emphasised that just the relevant questions be answered.
We had put down very precise guidelines for them and the was sent out to 30 companies and we received response from seven companies in the fishprocessing industry. The results showed that the industry is using wood mainly in the following applications:

- Roofs and walls
- Doors, windows and trimmings
- Interior, in indirect food contact
- Pallets, in direct food contact, it was 2 plants using them in the processing line
- Pallets, in indirect food contact
- Packaging, in indirect food contact

Shorten version of the questionnaire is shown in Appendix 2.

The main results are published in the report which was published by the DTI; Delrapport nr.4; “Spørgeskemaundersøgelse vedrørende brug af træ i Norden til levnedsmiddelformål”

4.2 Measuring methods to evaluate hygienic properties independent of material

Percentage of recovery could be evaluated from each method, except no. 5, which did not show any growth. All the other methods revealed some growth and 3 methods were used in further studies. No particular method was proved to have more advantage then others. The recovery was from <0.05% up to 30%, which was the highest recovery which was obtained after short contamination time with high contamination level. All measuring methods have advantages and disadvantages, especially in relation to standardising. The percentage of the recovery of micro-organism depends on the nature of the surface being tested. It is possible that there is a certain, fixed limit for removing the microbes from a wooden surface, a limit that is caused by the hygroscopic properties and porous structure of the wood. It is known that such a recovery from a surface made of stainless steel is higher than from wood, but the results from this study shows that different contamination time influences the recovery from all tested surfaces: wood, plastic and stainless steel. In our experiments, we observed a decline in the recovery when the contamination time increases. Although none of the measuring methods gives optimum results, we consider the contact- and the swabbing methods to be the most convenient and suitable for the industry. The swab method is easy to perform, it is not destructive, it is quantitative and it is possible to use on all kinds of surfaces. The contact method is easy to perform and convenient for a screening of the hygienic conditions of the wood. If the number of micro-organisms on a surface is low, it is possible to quantify the numbers of micro-organisms by using the contact method. If the surface is very contaminated, the contact method will be qualitative. When testing, for example, for the red halophilic bacteria in the salt fish industry in Norway, it is sufficient to make a qualitative test, because it is a requirement that no red halophilic bacteria be present in the salted fish (Anon, 1997).

The SEM experiments support the knowledge about the porosity of the wood compared to plastic and stainless steel. The SEM studies can not help us to choose methods. The photos only show that in wood, bacteria can find a lot of hiding places within the rough surface of wooden vessels. The photos show open porous cellular structure of wood. Photos are shown in Appendix 3.The results are published in the partial report no 3: Measuring methods.

4.3. Study of woods hygienic properties

4.3.1 A pilot study regarding wood treatments and hygienic properties of wood

The results from the bacterial testing are shown in table 2. The recovery from the sample is quite low but that is what was experienced in the preliminary experiments where the method was evaluated (Lorentzen and Guðbjörnsdóttir, 2000). The main difference is between wet and dry samples. The recovery was higher from wet samples (0.13-5.30%), compared to dry samples (0-0.09%). Ultrawood treatment gave lower recovery, compared with untreated samples. The results from a 2% wax emulsion on spruce were similar to those on nontreated pine, but when the strength was increased the recovery became higher and gave the best results. The lower strength of wax emulsion on pine (2%) gave higher recovery, compared to higher strength (4%).

Table 2. **Results of bacterial sampling (CFU/cm^2) and ATP measurement (RLU (relative light units))**

Series	No	Treatment	Condition of wood	Level of contamination CFU/cm^2	Number bacteria CFU/cm^2	Recovery (%) of bacteria	RLU
1	1	1% UW pine	dry	$6,4x10^7$	1085	0,0	104,5
1	1-2	1% UW pine	wet	$5x\ 10^7$	312.000	0,62	124,5
2	3	2% UW pine	dry	$6,4x10^7$	8550	0,01	127,5
2	3-4	2% UW pine	wet	$5x\ 10^7$	287.500	0,58	92,5
3	5	2% wax pine	dry	$6,4x10^7$	27.950	0,04	274
3	5	2% wax pine	wet	$5x\ 10^7$	1.751.500	3,50	235,5
4	8	2% wax spruce	dry	$6,4x10^7$	18.100	0,03	466,5
4	8-9	2% wax spruce	wet	$9,6x10^7$	124.000	0,13	378
5	11	4% wax pine	dry	$6,4x10^7$	13700	0,02	252
5	11	4% wax pine	wet	$5x\ 10^7$	320.000	0,64	na
6	14	4% wax spruce	dry	$6,4x10^7$	60.000	0,09	422,5
6	14	4% wax spruce	wet	$5x\ 10^7$	2.650.000	5,30	244,5
7	17	none treated pine	dry	$6,4x10^7$	18.550	0,03	102
7	17-18	none treated pine	wet	$5x\ 10^7$	850.000	1,70	195

The bacteriological tests were later repeated and the results are shown in Table 3. The results from the second experiment supported the results from the first one. The recovery was higher from wet samples (0.15-3.59%), compared to the dry samples (0.02-0.14%). Ultrawood treatment and wax treatment gave lower recovery, compared with untreated samples. The recovery of bacteria from 4% wax emulsion on spruce was highest of the treated sample. The lower strength of wax emulsion on pine (2%) gave higher recovery, compared to higher strength (4%) which is the same result as in the first experiments. Previous reports have demonstrated low recovery of bacteria from wood surfaces, as stated by Welker et al, 1996 and our study confirmed that. Significantly more bacteria were recovered from the prewet wood surface than from dry wood, as shown in tables 2 and 3.

The same report shows that wood surface gives higher ATP values, compared to plastic and stainless steel, but our study showed the opposite compared to a study performed at the IFL in 1998 (Guðbjörnsdóttir and Einarsson, 1998). This should be investigated more in the field studies.

Table 3. **Results of bacterial sampling and ATP measurement. Experiment 2. Average number of two measurements**

Series	Sampl e no	Treatment	Condition of wood	Level of contaminati on	Number bacteria	Recovery (%) of bacteria	RLU (relative light units)
1	1	1% UW pine	dry	$3,2 \times 10^7$	3330	0,01	52
1	1-2	1% UW pine	wet	$2,1 \times 10^7$	16985	0,08	14
2	3	2% UW pine	dry	$3,2 \times 10^7$	4950	0,02	55
2	3-4	2% UW pine	wet	$2,1 \times 10^7$	15900	0,08	39,5
3	5	2% wax pine	dry	$3,2 \times 10^7$	20355	0,06	47
3	5	2% wax pine	wet	$2,1 \times 10^7$	82500	0,4	33,5
4	8	2% wax spruce	dry	$3,2 \times 10^7$	34000	0,1	54
4	8-9	2% wax spruce	wet	$2,1 \times 10^7$	1480500	7,05	197
5	11	4% wax pine	dry	$3,2 \times 10^7$	8300	0,03	61
5	11	4% wax pine	wet	$2,1 \times 10^7$	39750	0,2	213
6	14	4% wax spruce	dry	$3,2 \times 10^7$	32500	0,1	54,5
6	14	4% wax spruce	wet	$2,1 \times 10^7$	77000	0,4	111
7	17	none treated pine	dry	$3,2 \times 10^7$	31800	0,1	50

The main results are published in the partial report no 5: Draft part report no. 5: Short report from a pilot study regarding wood treatments and hygienic properties of wood

4.3.2 Microbial contamination of Wood in construction

4.3.2.1 Hygiene survey on wood- and steelsurfaces in the fishindustry

Hygiene surveys were performed in two places in the fishing industry, in a processing hall and in a cold storage. In the fishing industry in Iceland we can still find some wood in use, mostly in indirect contact with products. These surveys show us how the condition of the sample sites is when samples were taken. Guidelines from the IFL were used to evaluate the hygienic condition

Guidelines used at the IFL for surface that comes in direct contact with food were as follows:

	swabbing-CFU/cm^2	contact plate - CFU/plate
Good	<1	0
Acceptable	1-4	1-10
Bad	5-50	11-100
Unacceptable	<50	<100

Table 4. **Results from a hygiene survey in salt fish processing**

Sample sites	CFU/cm^2 22°C	Contact -22°C CFU/plate	ATP (RLU/10cm^2)
cold storage			
wood-pallet	860	>100	115
wood-pallet with load	1900	>100	150
steel	18000	>100	370
packaging room			
wood board	7400	>100	161
wood pallet 1	21000	>100	1367
wood pallet 2	200	>100	59
wood pallet 3	1040	>100	57
plastic tub	1030	>100	111
steel box	1600	>100	62
plastic tub	74000	>100	126
plastic board	4000	>100	36
wood pallet - old			147
wood pallet 4			153

Compared to the guidelines, the hygienic condition of the surfaces, which were tested, were not good, in all cases unacceptable. The samples were taken when the plants were in operation so this is not a situation after cleaning, but, nevertheless, the wood pallets were not cleaned using standard cleaning procedures so this result shows that there is a need for a standardised cleaning procedure for wood pallets if they are reused. Results taken from the cold storage are shown in table 5. These surfaces are not in contact with the products, but water-condensate, which forms on these surfaces, can contaminate the product indirectly. Therefore, it is important that these surfaces are maintained clean. The hygienic condition of these surfaces was very good, according to the guidelines we used. Only one sample was evaluated to be unacceptable if used in direct contact with food. Guidelines for surface not in contact with food are not available, but these kind of guidelines should not be as stringent as those for surfaces in direct contact with food. The surface, which was tested, was in a building built 6-7 years ago. There was not a big difference between the wood and the steel but no statistical evaluation was carried out. One sample of wood and one sample of steel was taken, always at the same location in the building. However, sometimes the wood samples gave higher count than the steel samples, but were still regarded as acceptable for use in direct contact with food.

Table 5**. Results from hygiene survey in cold storage. Samples were taken from wood- and steelsurfaces used in constructions in indirect contact with food.**

	Swab(CFU/cm^2)	Contact(CFU/plate)	ATP (RLU/10cm^2)
wood	10	3	71
steel	9	79	9
wood	20	13	61
steel	125	79	9
wood	2	8	98
steel	5	1	5
wood	43	49	271
steel	3	50	3
wood	11	48	475
steel	1,8	13	13
wood	9	12	-
steel	3	0	54
wood	0	1	69
wood	5	100	24802
steel	10	14	94
wood	14	15	277
steel	4	1	10
wood	0	2	104
wood	48	6	16614

4.3.2.2 Lab study - recovery and comparison of measuring methods

The results from the recovery tests are shown in Table 6. The number of bacteria used to contaminate the surface was 3,4 x 10^7. The wood surface was 94 cm^2 and the surface of stainless steel was 150 cm^2. The results are given in CFU/cm^2, CFU/plate and RLU/10cm^2.

Table 6. **Recovery (%) of bacteria from wood-constructions sample**

Series	Contamination CFU/cm^2	LT-22°C-swabbing CFU/cm^2	Recovery(%) of bacteria	ATP RLU/10 cm^2
1A2	351.000	20	0,01	2490
1A18		20	0,01	3301
1B2		470	0,13	655
1B18		370	0,11	1177
2A2		4300	1,23	3581
2A18		3800	1,08	3550
3B2		90	0,03	1069
3B18		60	0,02	641
4A2		710	0,20	1037
4A18		na	na	1359
untreated 1		1530	0,43	124
untreated 2		320	0,10	238
Stainless steel 1	220.000	220	0,10	1057
Stainless steel 2		660	0,30	250
ATP-control				12

The highest count indicates that the microbes can better be removed compared to samples with lower count. If the microbes cannot be removed easily by the methods performed in this study, then the cleaning efficiency cannot be good. The micro-organisms are most likely absorbed into the wood and there it can stay alive for some time, especially if the wood is wet. Sample 2A are considered the most hygienic, compared to the others, and the glulam was treated with waterbased parquet paint. Stainless steel and 1B (water based epoxy paint) showed equal hygienic properties.

4.3.2.3 Microbiological survey on differently treated construction samples

The results from microbiological sampling from the beginning of this experiment are shown in Table 7 and after 6 months in saltfish storage, the condition is the same as in the beginning (data not shown). No difference can be measured between steel and the gluelam.

Table 7. **Number bacteria (CFU/cm^2) and ATP -measurement (RLU/10cm^2)**

	LT-22°C-swabbing CFU/cm^2		LT-22°C/plate - contact	ATP
	0 point	6 month	0 point	0 point
1A2	<1	2	10	50
1A18	1	1	2	44
1B2	<1	6	2	73
1B18	<1	1	4	48
2A2	1,9	4	6	16
2A18	1,2	2	33	70
3B2	<1	1	6	25
3B18	1	1	2	17
4A2	<1	1	102	95
4A18	<1	1	1	30
Control 1	<1	1	12	12
Control 2	<1	1	63	63
Stainless steel 1	<1	5		14
Stainless steel 2	<1	1	16	25
ATP-control				0

The results are very good and the total counts on the "Límtré"(glue-lam)-samples are below 5CFU/cm^2. The count of mould and yeast is also below 1CFU/cm^2. The temperature in the warehouse is very low, 0-3°C, and sometimes below zero degree Celcius and that will influence the growth of the bacteria. After 6 months, mould count was evaluated. The count for all samples was below one (<1 CFU/cm^2).

4.3.3 Pallets for storage and transportation

The results from a hygiene survey in a dairy company are shown in table 8 and the hygienic condition of the pallets is not good. Fifteen samples were taken from plastic pallets, made of polyethylene. The pallets were both clean and dirty. Total bacterial count and molds were evaluated by swabbing method. The cleaning methods used were not well organised and the pallets were only cleaned occasionally and then just by flushing them with water.

Table 8. **Hygiene survey on plastic pallets used in a dairy company**

Series	LT-22°C-swabbing CFU/cm^2	Mould/yeast CFU/cm^2
Unclean		
1	570	3
2	37000	330
3	35	10
4	38	13
5	540	300
6	38	6
7	10500	10000
8	270	59
9	8300	6000
Clean		
11	17700	8500
12	9300	9300
13	10600	6000
14	48	34
15	13	4

5. Significance of project results

Fisheries have been important in Iceland, ever since the country was settled in the ninth and tenth centuries. Today, revenue from fisheries make up some 75% of the total revenues from goods exports (around 5% of the world's total fishing exports), and yield 55% of all national foreign currency earnings. In 1995, Iceland exported marine products valued at ISK 90 billion (USD 1.3 billion), from a total catch of over one million tonnes. Annual catches in recent years have averaged around 1.5 million tonnes. In terms of catch volume, Iceland ranks 14th among the world's leading fishing nations (FAO 1993), although few, if any, others are so overwhelmingly dependent on fisheries.

Originally, fish was dried to make stockfish before being exported, and there is also a long tradition of salting as a preservation technique. Seafood production today is highly varied, with freezing and salting as the main processing categories in terms of export value, at about 60% and 20% respectively. Iceland's seafood products rank among the global leaders in quality and are sold to most market regions of the world. Seen from this perspective, it is very important to gain more information about the quality and the hygienic use of wood and wood products in the food industry.

In recent years, the use of wood has been decreasing, due to stricter rules regarding food hygiene. In the Icelandic fish industry, wood is still being used considerably, e.g. in transport, in processing, in buildings. *It is important to obtain more knowledge about the hygienic use of wood so it gets a justifiable treatment in regulations and specifications in order to prevent costly changes in the food industry.*

Because wood is a porous and absorbent material, where organic matter along with bacteria can become entrapped, cross-contamination is a main concern. With the development of new materials during the last decades, various polymers have become the work surfaces of choice, despite little research to support the change. It is claimed that these plastic surfaces have all the advantages of wood without the disadvantages. Therefore, *it is important to consider a strict control of its maintenance, if it is supposed to be safer to use than wood.* It was also shown that conditioning of wood or its refinement to increase its hydrophobicity contributed to a lesser penetration of contaminants. But many of these studies were aiming at home environments and it is probable that industrial use of wood cutting surfaces would not be as favourable due to little drying of the wood following its use. Also, because of the 3-dimensional structure of wood different cuts surely give different results.

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Appendix 1:

Partial report no.1 *Literature review on the suitability of materials used in the food industry, involving direct or indirect contact with food products*

Partial report no.2. *Legislation on foodstuff*

Partial report no 3. *Measuring methods*

Partial report no 4. *Spørgeskemaundersøgelse vedrøende brug af træ i Norden til levnedsmiddelformål*

Partial report no 5. *Short report from pilot study regarding wood treatments and hygienic properties of wood*

Partial report no 6. *Hygienic limits and cleaning procedures*

Patrial report no 7. *Wood, waxed wood, plywood, polyethylene and stainless steel- a comparison of hygienic properties*

Wood in the Food Industry

Appendix 2.: Questionnaire

1) Company information (All information will be treated confidentially)

Company ______________________________

Address ______________________________

____

Phone ______________________________

Fax ______________________________

Contact person ______________________________

E-mail ______________________________

2) Business and products

Type of business	X below
Food industry	
Transport	
Wholesale	
Retail	
Hotel/ restaurant	
Others, please specify	

Type of product	Fresh goods	Deep-freeze	Tinned goods
Fish			
Meat			
Dairy/ dairy products			
Vegetables			
Others, please specify			

3) What materials are mainly used in the following applications

	Wood	Plastic	Steel	Stainless steel	Aluminium	Concrete	Ceramics/ glass
Building structure							
Roofs and walls							
Floor							
Doors, windows and trimmings							
Interior in direct food contact							
Other interior							
Tools and equipment in direct food contact							
Packaging in direct food contact							
Other packaging							
Pallets in direct food contact							
Other pallets							

4) Do you employ procedures regarding hygiene, testing* or cleaning/disinfection for the following materials? Answer with Yes, No or ? (don´t know)

	Direct food contact			Indirect food contact		
	Hygiene require-ments	Test methods	Cleaning/ disinfection procedures	Hygiene require-ments	Test methods	Cleaning/ disinfection procedures
Wood						
Plastic						
Steel						
Stainless steel						
Aluminium						
Concrete						
Cheramics/ glass						

*)Test methods also includes sensory analysis such as smell and visual inspection.

5) What prevents the use of wood in your company?
(X to mark the most important factors)

	Direct food contact			Indirect food contact		
	Laws/ regulations	Market demands	Own requirements	Laws/ regulations	Market demands	Own requirements
Building structure						
Roofs and walls						
Floor						
Doors, windows and trimmings						
Interior						
Tools and equipment						
Packaging						
Pallets						

6) What materials have replaced wood, and for what reason?
Use the codes: L=Laws and regulations, M=market demand, O=own requirement

	Plastic	Steel	Stainless steel	Aluminium	Concrete	Ceramics/ glass
Building structure						
Roofs and walls						
Floor						
Doors, windows and trimmings						
Interior in direct food contact						
Other interior						
Tools and equipment in direct food contact						
Packaging in direct food contact						
Other packaging						
Pallets in direct food contact						
Other pallets						

7) What restricts your use of wood? Please explain the most important factors below.

7.1) Laws and regulations

7.2) Hygienic requirements

7.3) Special demands from the markets

8) Do you wish to extend the use of wood in your company (don't concider laws and regulations), and why?

Areas of use	Price	Hygiene	Quality during use	Maintain-ability	Environment
Building structure					
Roofs and walls					
Floor					
Doors, windows and trimmings					
Interior in direct food contact					
Other interior					
Tools and equipment in direct food contact					
Packaging in direct food contact					
Other packaging					
Pallets					

9) How should wood products be improved in order to gain greater acceptance in your company?

10) How much time did you spend filling in this questionnaire? ____________

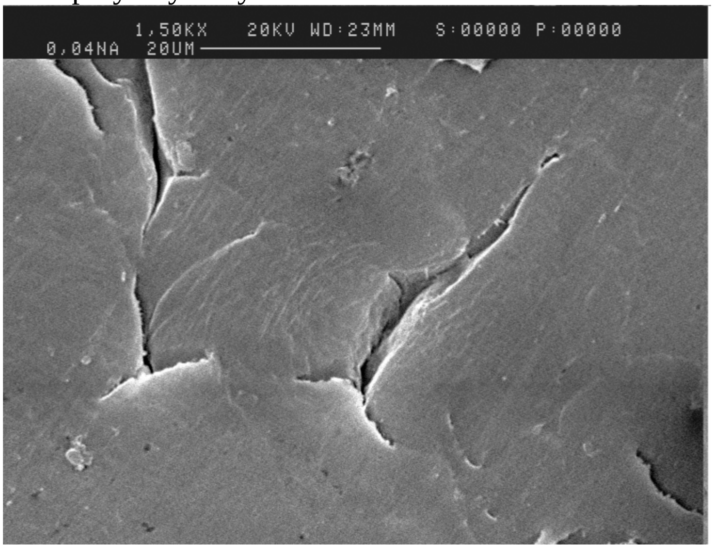
11) Any further comments?

Please return the questionnare to……………….. Within…………

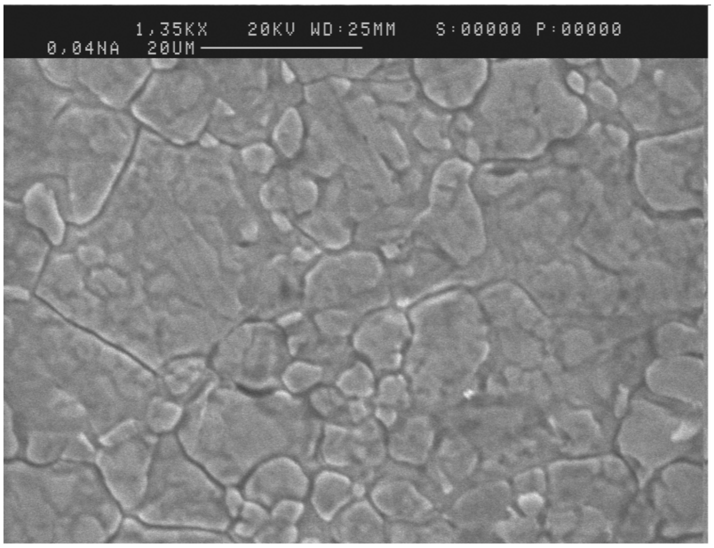
APPENDIX 3

Scanning electron photomicrograph of new food cantact surface: (polyethylene, stainless steel and wood)

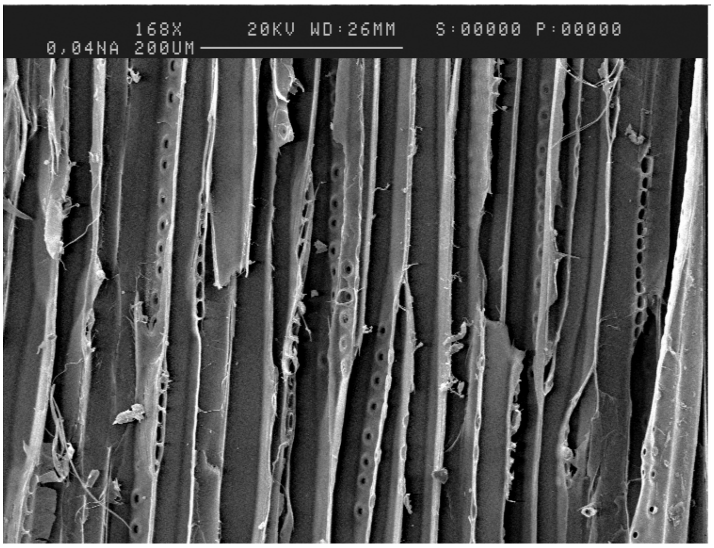
New polyethyleneylene



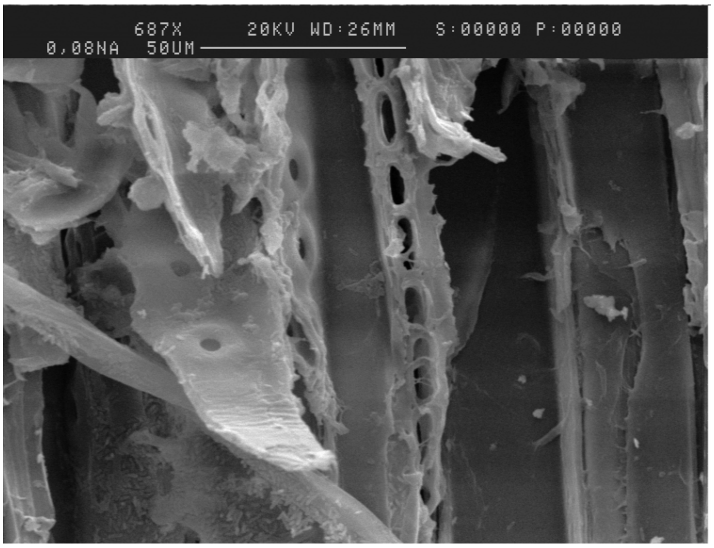
New stainless steel



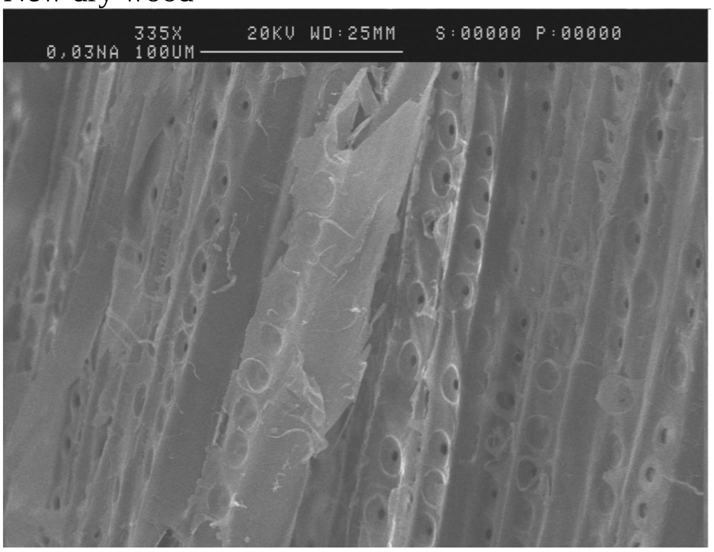
New wet wood



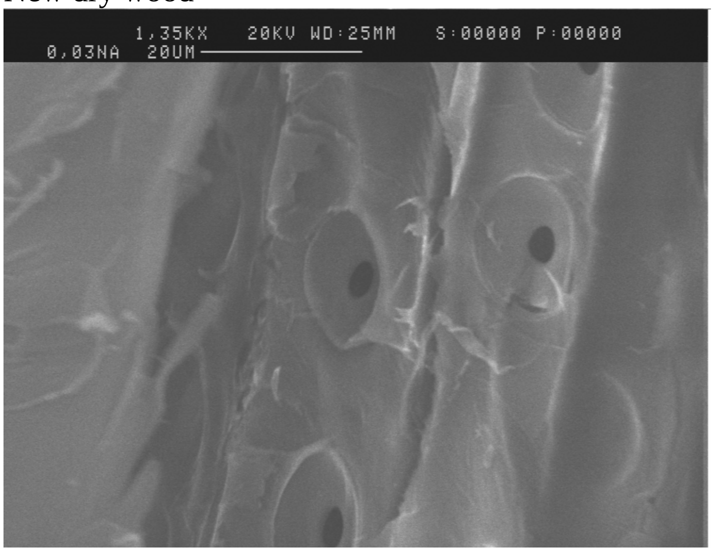
New wet wood



New dry wood

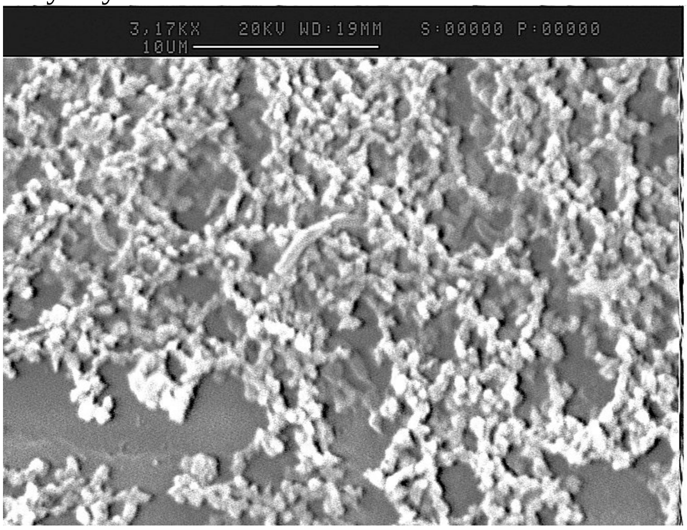


New dry wood

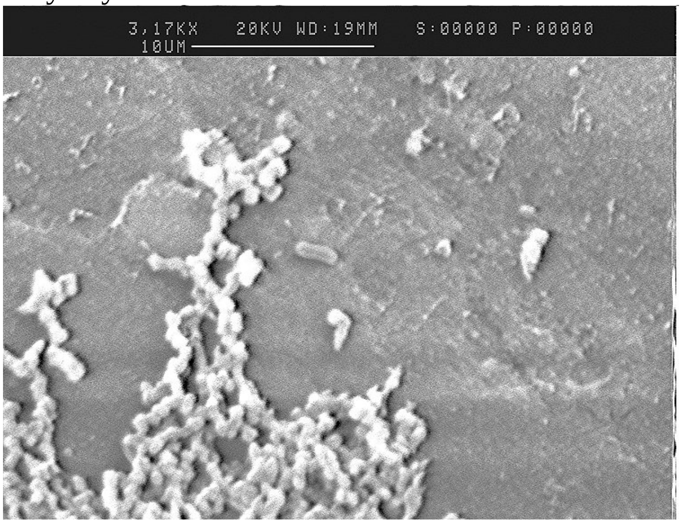


Scanning electron photomicrograph o*f Pseudomonas* attached to polyethylene, stainless steel and wood

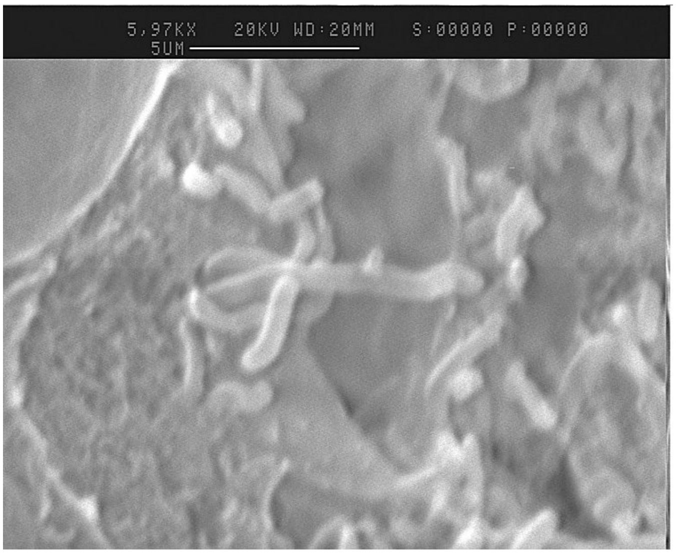
Polyethylene contaminated with *Pseudomonas*



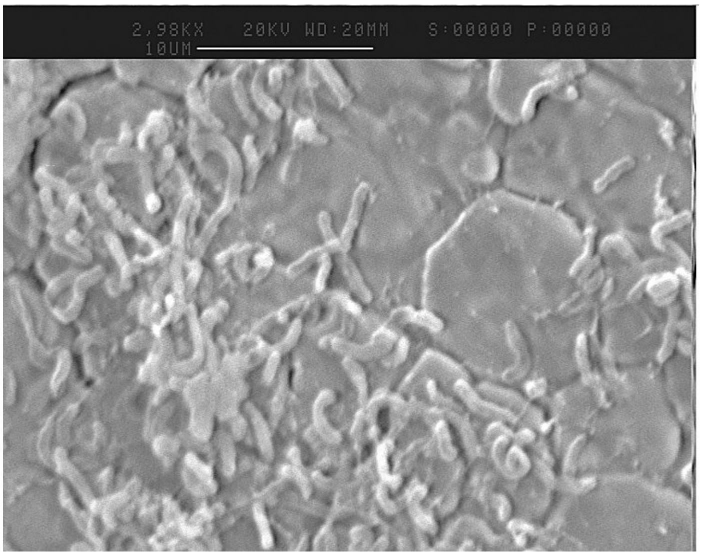
Polyethylene contaminated with *Pseudomonas*



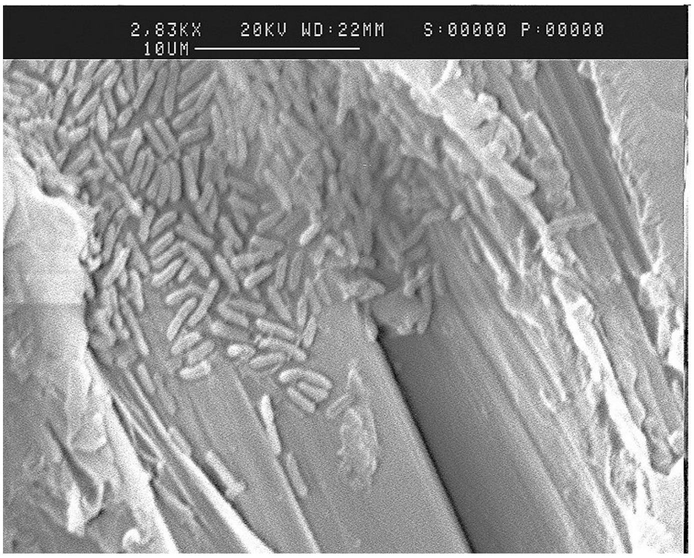
Stainless steel contaminated with *Pseudomonas*



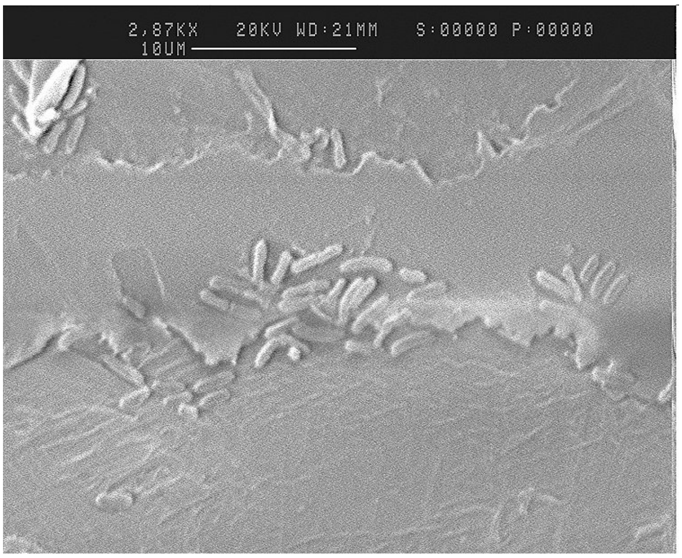
Stainless steel contaminated with *Pseudomonas*



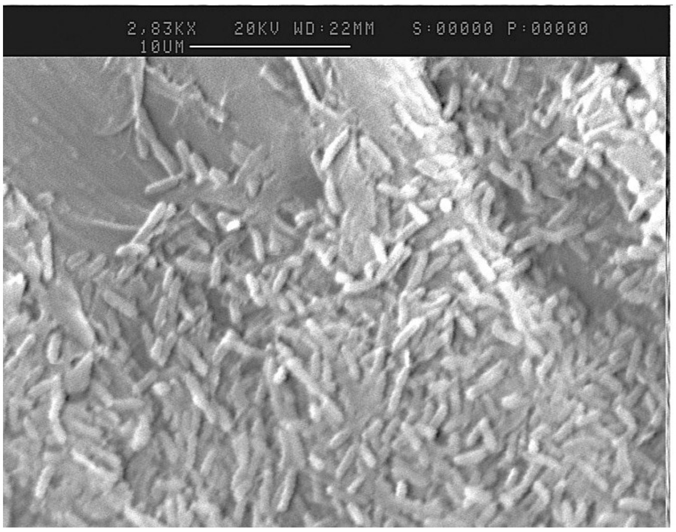
Wood contaminated with *Pseudomonas*



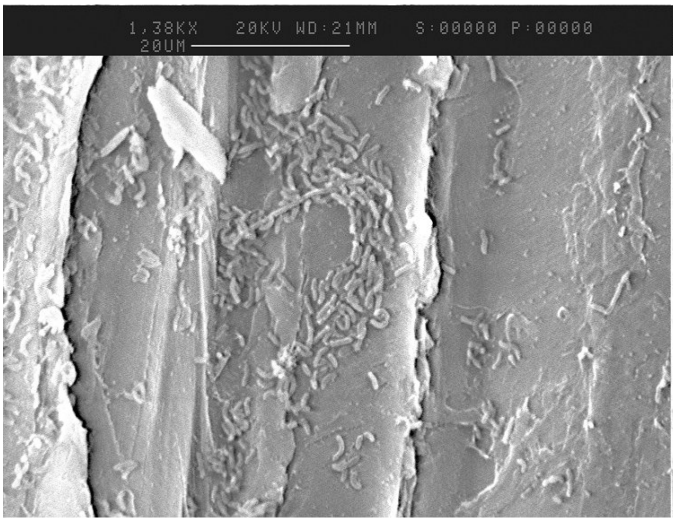
Wood contaminated with *Pseudomonas*



Wood contaminated with *Pseudomonas*

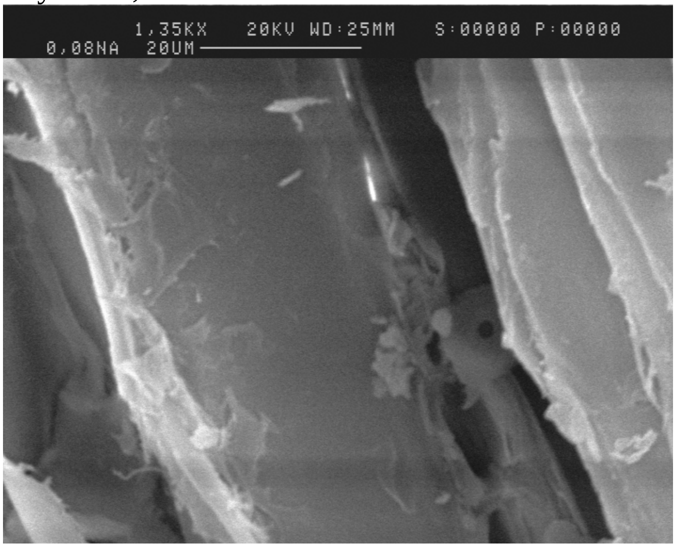


Wood contaminated with *Pseudomonas*

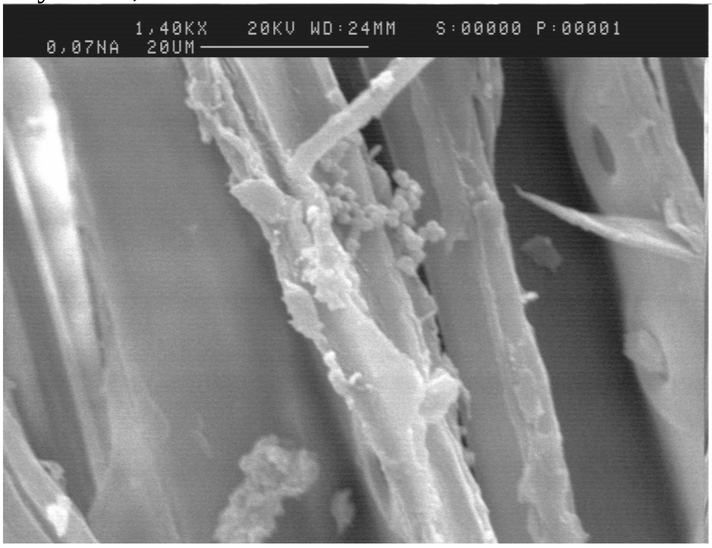


Dry wood, 10^5 CFU/ml after 30 min

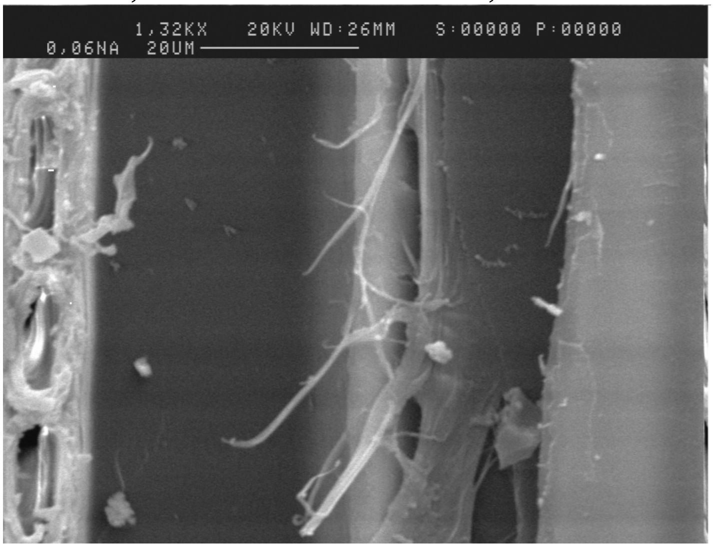
Dry wood, 10^6 CFU/ml after 16 hours



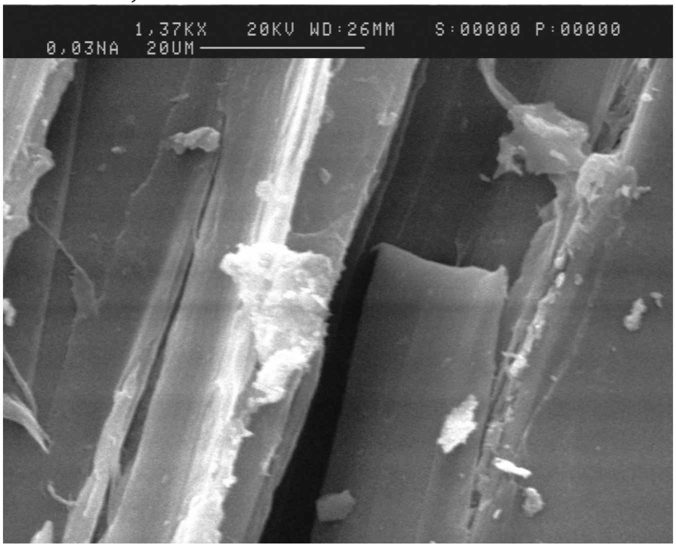
Dry wood, 10^6 CFU/ml after 30 min



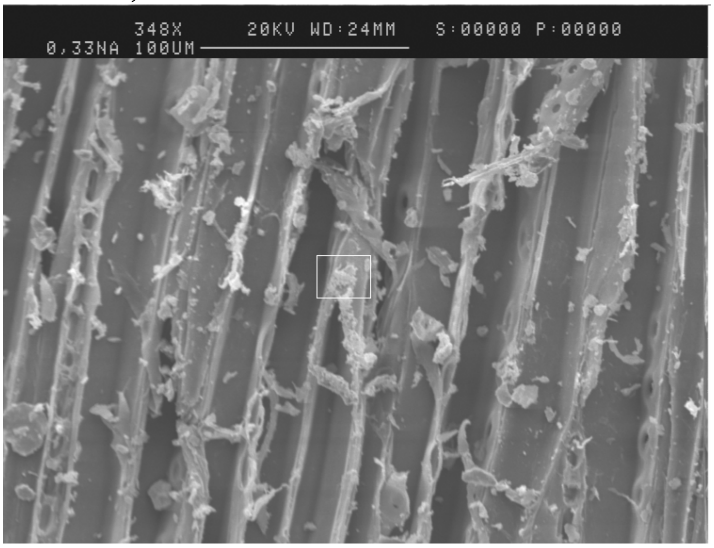
Wet wood, 10^7 CFU/ml after 16 hours, under 1mm



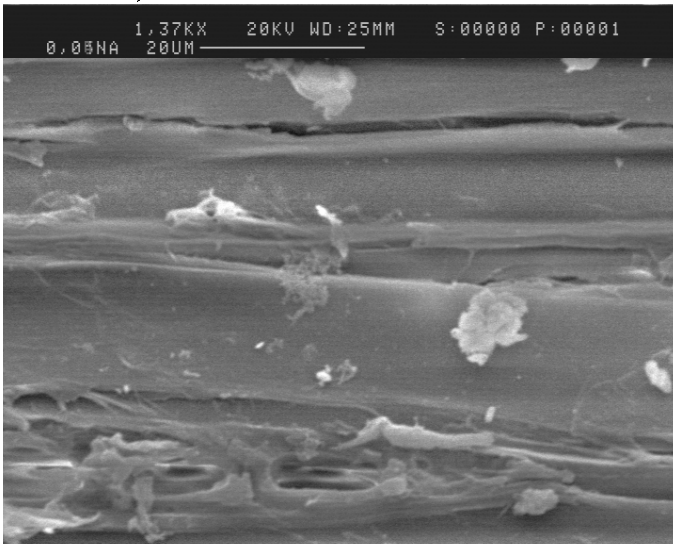
Wet wood, 10^5 CFU/ml after 16 hours



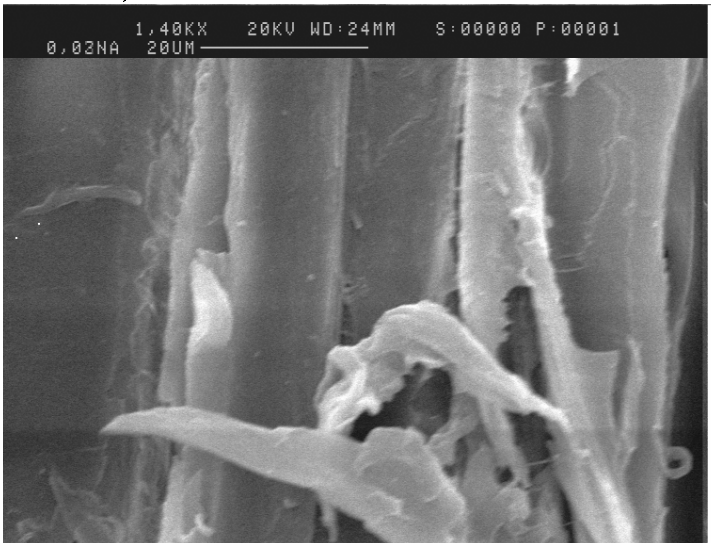
Wet wood, 10^5 CFU/ml after 2 hours



Wet wood, 10^6 CFU/ml after 2 hours



We wood, 10^4 CFU/ml after 30 min



Wet wood, 10^6 CFU/ml after 30 min