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Dear Readers,

Welcome to the third issue of the Israel Chemist and Engineer (ICE) online magazine. This is a joint venture of the Israel Chemical Society (ICS), the Israel Society of Chemical Engineers and Chemists (ISCEC) at the Association of Engineers and Architects in Israel (AEAI), and the Israel Institute of Chemical Engineers (IIChE).

We hope you will find the magazine interesting and will be inspired to contribute to future issues. You will find articles describing the design of materials using functional peptides, corrosion and scaling prevention in water cooling systems, a historical-philosophical article on Michael Polanyi, an account of the chemistry associated with Shabbat candles in the Mishnaic period and a review of Alec Groysman's latest book (Alec is the chairman of the ISCEC). In an effort to reveal the personalities behind the impressive CVs, we include the profiles of three distinguished Israeli chemists, Avraham Baniel, Moshe Rabaev and Daniella Goldfarb. In addition, Ehud Keinan, the ICS President, has contributed an op-ed on the implications of the Professors' Report recommending the emptying of the ammonia tank in Haifa Bay (an executive summary of the report is also included). We also include a transcript of the interesting panel discussion that took place at the 2017 ICS meeting: "How can we raise the next generation of Israeli Nobel Laureates in chemistry?" How, indeed?

If you have suggestions for future editions, comments on the current issue, or would like to contribute an article, please contact me at gordon@biu.ac.il.

Arlene D. Wilson-Gordon

Professor Emerita Chemistry Department, Bar-Ilan University ICE Editor

Academia: an ivory tower or a lighthouse?



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Much has happened in the last few months since the dramatic decision of Haifa Mayor Yona Yahav to expose the "Professors' Report" (also known as the "Keinan Report") that recommended emptying the ammonia tank in Haifa Bay (for an executive summary of the report, see page 42). Since the press conference of January 31st, 2017, over 400 newspaper articles, daily interviews and commentaries in all TV and radio channels have covered the ammonia affair (http://www.ehudkeinan. com/contact), in addition to public debates and rallies of angry citizens and students. Three levels of the Israel court system, including the Haifa Magistrate Court, the Haifa District Court and the Supreme Court, have addressed the issue. Many organizations became involved, including the Histadrut, the Manufacturers' Association of Israel (MAI), the Association of Engineers, Architects and Graduates in Technological Sciences in Israel (AEAI), twenty-two municipalities in the northern part of Israel, non-profit organizations, political parties and even the Student-and-Youth-Council, which represents all Israeli high-school students. At least eight government offices became directly involved, including the Prime Minister's Office and the Ministries of Finance, Economy, Environmental Protection, Health, Defense, Public Security and Transport. The story even featured in a satirical TV show, chanting, "Jerusalem of Gold and Haifa of Ammonia".

The magnitude of the entire affair and its public consequences caught the political system and the establishment totally by surprise. This story could be added to the list of examples mentioned by Nassim Nicholas Taleb in his bestseller, "The Black Swan: The Impact of the Highly Improbable". Thus, it is not too surprising that at least three academic programs of Public Policy and Law in the higher education system have already included the ammonia affair in their curricula.

Conclusions and take-home messages

Although the story is still far from over on all fronts, including legal, economical, public and political, the incredible impact on all levels of the government, the general public, the judicial system and the media has implications for many other open issues on the public agenda. This affair also poses fundamental questions for every student and faculty member in our academic system: Do members of the academia bear any responsibility for what is going on in this country? Are they exempt from being involved in state affairs? Is it their duty to intervene in state affairs? Do they have any power to influence state affairs?

The usual answers to these questions should be reconsidered in view of the demonstration that a small group of university professors, who possess neither significant resources nor political power, can make a difference. To understand the origin of this phenomenon, one should try to define the specific characteristics of the academic world that differentiate it from the political establishment and administration. My proposed list, which is by no means complete, includes eight characteristics and I prefer to use the words of others to illuminate their meaning, rather than explicate the obvious.

<u>Independence</u>. George Bernard Shaw: "The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable."

<u>*Curiosity.*</u> Albert Einstein: "It is a miracle that curiosity survives formal education. I have no special talent, I am only passionately curious."

Long-term memory. Alphonse Karr: "We can invent only with memory." Pierre Bonnard: "Imagination is merely the exploitation of our memory."

Imagination. Albert Einstein: "Logic will get you from A to B; imagination will take you everywhere. The true sign of intelligence is not knowledge but imagination."

<u>Perseverance</u>. Brian Tracy: "You cannot control what happens to you, but you can control your attitude toward what happens to you." Edmund Vance Cooke: "It's nothing against you to fall down flat, But to lie there, that's disgrace."

<u>Critical thinking</u>. José Ortega y Gasset: "Whenever you teach, teach your hearers to doubt whatever you teach."

<u>Quantitative thinking</u>. Carl Sagan: "We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology."

Logical thinking. Bertrand Russell: "Men are born ignorant, not stupid; they are made stupid by education."

In my view, th never ending e conflict between the academic and political worlds represents a clash of civilizations on multiple levels: independence vs. pandering to interest groups, curiosity vs. conformism and indifference, long-term vs. shortterm memory, imagination vs. ticking the boxes, perseverance vs. frenzy and capriciousness, critical thinking vs. obedience to authority, quantitative thinking vs. qualitative thinking, logical thinking vs. emotional reasoning. And the judges in all the courts indeed understood and appreciated the differences and so did major parts of the public and media.

It is important to emphasize that our struggle to release one million citizens from the ammonia threat does not reflect any antagonism to the chemical industry. On the contrary, we all recognize the indispensable contribution of this industry to the national economy. We know that the State of Israel could not exist without the chemical industry. Our key message is that industry should behave in a responsible way, and most of the Israeli chemical companies are very responsible towards the surrounding population and the environment. Every year the Israel Chemical Society recognizes an outstanding company in this respect through the ICS Green Chemical Industry Prize.

It has been a long, asymmetrical war against very powerful entities, and the partial success we've experienced so far would not have been possible without the efficient cooperation of different entities, including university professors, the Haifa Municipality, the courts, the non-profit organizations, the general public and the media. Every one of these partners has provided a critical element that complemented the efforts of all the others.

There is also a significant personal component in this story, which began three years ago. We've lost more than two years since the initial understanding of the magnitude of the threat, frustrated by our inability to convey our findings to the media and to the general public. Only in June 2016, when we joined forces with the Haifa Municipality, was an opportunity created to effectively address the various courts, the public and the media (Figure 1). Obviously, the intense history of the past twelve months cannot be summarized in one article. Recognizing the importance of properly documenting the sequence of events, I have started compiling the material into a book, in the hope that it will be completed and published in the near future.



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Figure 1. Left: Demonstration of Haifa citizens against the ammonia activity in Haifa Bay. Photos (credit to Haifa Municipality) were taken on February 26, 2017, the day of the District Court session. Right: Dan Shechtman, Mayor Yona Yahav and Ehud Keinan at the Court Hall.

Guided design of materials using functional peptides – from bone-like apatite to diatom biosilica

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Abstract: Fabrication of materials akin to the ones naturally found in the hard tissue of organisms requires use of a special class of proteins which act as tiny bioengineers, sculpting, and shaping minerals into strong viable hard tissue. Using these molecules in processes that mimic nature is not only a promising avenue to generating biodegradable green materials but also ensures compatibility of biomaterials such as dental and bone replacements. Two examples are given where the power of highly potent peptides derived from this special class of proteins is used to control the morphology of hydroxyapatite, the inorganic material forming the hard part of bone, and to catalyze and shape silica, from which the protective cell wall of diatoms is made. The structure and activity of the peptides and their influence on the shape and physical characteristics of bioinspired material formed are investigated using several techniques, predominantly using NMR and computational tools.

Introduction

Proteins are typically considered as the molecular machines that perform the tasks necessary to sustain life. One unique family of proteins is active in the tiny confines of some of the world's smallest construction sites where inorganic material precursors are transformed into biogenic smart materials [1]. The result of their activities is viable hard tissue with lifeprotecting functions, such as shielding, posture, attack and counter-attack. This family of proteins, called biomin (short for biomineralization) proteins, is responsible for regulating the formation of inorganic materials in hard tissue across different taxa. Through their functionality, these proteins shape biogenic materials into sophisticated building blocks and later assemble them into protective shells, inner skeletal frameworks, teeth, spines, and other solid constructs that can withstand mechanical wear and tear [2]. They often accelerate the mineralization processes of silica formation or calcification and as such act as heterogeneous catalysts, distinguishing them from most enzymes which are known to act as homogeneous catalysts.

Biomin proteins must have diverse functional properties owing to the wide range of minerals employed by organisms to yield hard structures. Calcium carbonates and phosphates, silica, iron oxides and sulfides are some of the most common minerals utilized by flora and fauna alike to construct inorganic structures in their hard tissue [3]. The two predominant formation processes are called calcification [4] and silicification [5]. Calcifying life forms use crystalline calcium carbonate in the form of aragonite and calcite, and crystalline calcium phosphate in the form of hydroxyapatite ($Ca_5(PO4)_3OH$), as hardening building blocks; other calcium minerals are also used but to a lesser extent [6]. Silicifying (silica-forming) life forms use silicon oxide to form silicates that are amorphous at the atomic level but organized into ordered structures on the larger scale. The fundamental difference between the chemical processes of precipitation/crystallization of calcium salt ion precursors and the condensation/polymerization reaction of silicic acid into silicates is manifested in the properties of the proteins that regulate these two distinct processes.

The common method to identify proteins involved in biomineralization is extraction of these molecules from the inorganic matter in mineralized tissue. This has been extended in recent years to the analysis of the genes expressed during hard tissue development, and classification of the genes which directly code for proteins involved in the process of material formation [7].

Gil Goobes received his BSc at Tel-Aviv University. He completed his MSc and PhD with Professor Shimon Vega in the Chemical Physics Department of the Weizmann Institute of Science in 2002. Following a post-doctorate with Professors Gary Drobny and Patrick Stayton at the University of Washington, he returned to Israel in 2007 and joined Bar-Ilan University where he is heading the solid-state NMR group in the Department of Chemistry. His research interests are in expanding the molecular



understanding of surfaces and interfaces in biomaterials, advanced materials and energy-related systems.

Biomineral	Protein name	Domain sequence	Tissue/Organism	
Hydroxyapatite	Osteonectin	NPVQVEVGEFDDGAEETEEEVA	bone, dentine	
Hydroxyapatite	Osteopontin	RDDSSESSDSGSSSESDGD	bone	
Silica	Silaffin3	KASKESSMPSSKAAKIFKGSKGK	cell wall/diatom	
Silica	Silicatein	LSEQNIIDCSIPYGNHGCHGGNM	spicule/sponge	
Aragonite	CARP3	DDENDGDDEDDGDDEDDGDDE	skeleton/coral	
Calcite	MPSP	DGDDDDDEVDATLYENILGRDS	mollusks	

 Table 1
 Common amino acid sequences in biomin proteins involved in mineralization processes with acidic and basic residues respectively highlighted in red and blue.

The unique functions that biomin proteins perform are reflected in their innate amino acid sequences [8] (see Table 1). A high abundance of anionic amino acids (aspartic and glutamic acid) is found in proteins of calcifying tissue, while high repeats of cationic amino acids (arginine and lysine) are common in silica-bearing hard tissue. This straightforward distinction underlies the rudimentary difference between the requirement to regulate a precipitation/crystallization (physical) process and a condensation/polymerization reaction.

In calcifying life forms, carboxylate sidechains come in handy in affecting Ca²⁺ and Mg²⁺ ion deposition to achieve control of precipitation processes and morphology of crystallites. In silicifying life forms, amine/guanidinium groups catalyze the condensation of Si-O-Si bonds and can modulate the terminating groups on the silica surface. Interestingly, some acidic proteins were also found to be involved in silicification. Whether they play a similar or different role than in calcification is not known yet.

Beyond this fundamental understanding, there is very little known of the differential material-regulating activities of various domains in biomin proteins. It is therefore necessary to carry out more extensive structural biological studies and to advance from linking the protein amino acid sequence with the biomaterials they help form, to secondary and tertiary folding and the polypeptides and their relation to the sculpting and design capabilities, as reflected in the shape of physical properties of that material.

Many of the biomin proteins contain sequence segments that match functional domains in other proteins. Integrin-binding domains of the form RGD were found in several biomin proteins [9]. Calcium-binding motifs, such as EF hands, common in proteins involved in other cellular tasks were also found in biomin proteins. These findings helped better realize the mediating role that some of these molecules have, in coordinating the activity of the cells and non-living hard material. Structural investigations of biomin proteins bound to their substrate minerals are complex and therefore very scarce. Most studies have used solution NMR [10] or X-ray diffraction [11,12] to obtain the structures of the proteins in free-form, and have extended them to the structure in the context of the material. Computational tools have also been developed to assist in predicting the *in-situ* structure of biomin proteins [13], but, in general, there is a need for extensive structural research to better define the typical motifs that are common to biomin proteins, and the way they are employed to achieve particular material-shaping activity.

In recent years, we have examined the conformation of peptides derived from biomin proteins [14,15] involved in mineral formation and their effect on the bio-inspired materials formed [16]. I will show here two examples from very different lifeforms where we have studied the influence of the functional peptides on the physical characteristics of the biomimetic material generated and the structural properties of the peptide in complex with the mineral.

Shaping hydroxyapatite into nanorods using osteonectin peptide

Of all the mineralization processes in organisms, the one pertaining most to humans involves phosphate calcification in tissues such as bone and teeth. The prevalent mineral apatite in these tissues is made of crystalline hydroxyapatite (Ca₁₀[PO₄]₆[OH]₂) with a few substituted ions, such as Mg²⁺, Sr²⁺, COs²⁻, in the mineral crystallites [17]. The predominant organic constituent of bone is collagen, assembled into strong fibers in which the mineral is deposited [18]. The level of crystallinity of the forming mineral, the transitions it undergoes at various stages during mineralization and the reactions taking place on exposed crystal faces were investigated extensively owing to their important effect on the mechanical viability of the tissue [17].

Osteonectin is one such biomin protein which regulates mineralization of dentine and bone. It inhibits apatite crystal growth and binds specifically to collagen through an acidic N-terminal domain [19,20]. We prepared apatite by precipitation in the presence of the most acidic peptidyl segment, ON29, derived from the osteonectin's mineral binding domain. This short peptide by itself has shown a major influence on the morphology of the precipitated hydroxyapatite crystallites. High-resolution transmission electron microscope (HRTEM) images (Figure 1) of apatite prepared alone (left) and with ON29 (right) demonstrate the major morphology change from the typical thin plateshaped (platelets) crystallites grown without additives to elongated needle-like crystallites, formed in the presence of ON29.

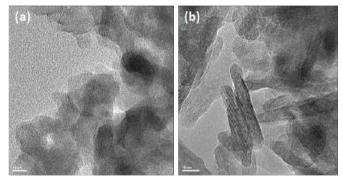


Figure 1. (a) Transmission electron micrograph of apatite synthesized alone showing platelet crystallites with average size of 30-40 nm. (b) Transmission electron micrograph of apatite prepared with ON29, exhibiting elongated needle-shape crystallites with average size of 45 nm x 9 nm. Scale bars (white) are 10 nm. Reprinted with permission from [14]. Copyright 2015 American Chemical Society

In addition to the crystallites observed, the mineral also contains a disordered hydrated calcium phosphate phase covering the apatite crystallites, as seen by solid-state ³¹P NMR measurements. The conformation of the peptide which is co-precipitated with the mineral and the mineral-peptide interface were characterized using NMR and supported by computational techniques. Carbon-nitrogen distance measurements using the ¹³C{¹⁵N} REDOR NMR [21] technique found an α-turn motif in the center of the peptide, both in the free form and when bound to the mineral. ¹³C^{{31}P} REDOR (Figure 2) and ¹H-¹³C HETCOR measurements revealed the proximity of Glu/Asp carboxylates and Thr/Ala/Val side chains to the mineral surface phosphates and hydroxyls. Using the ROSETTA-surface de novo prediction program [22], the conformation of ON29 in solution and adsorbed on hydroxyapatite crystal faces were constructed, permitting detailed insight into the peptide-mineral binding interface [14] (Figure 2). The structures predicted independently of experimental results were consistent with the NMR results and provided residue mapping in the biomaterial interface.

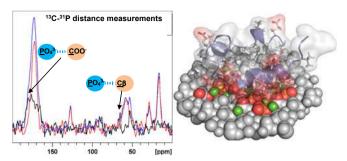


Figure 2. (left) ¹³C(³¹P) REDOR results are used to pinpoint the carbons on amino acids in ON29 that are in atomic distance to apatite surface. The ¹³C reference spectrum S₀ (blue) of ON29 before interaction is "turned-on" and the REDOR spectrum S (red) after it is "turned-on" are shown with the difference spectrum ΔS (black). The carboxylates on Glu and Asp and the polar C_{β} on Thr are clearly identified as interacting with the mineral surface phosphates and are marked by arrows. (right) The Rosetta-Surface predicted structure of osteonectin peptide bound to the Ca2+-rich hydroxyapatite crystal face (100). The surface atoms are shown as CPK with the atoms on the crystal surface proximal to the peptide highlighted in green (Ca), red (O) and orange (P). The peptide is shown as a cartoon with the calculated Van der Waals surface of excluded volume surrounding all atoms. The carboxylate sidechains on Asp (D) and Glu (E) are shown as red sticks. Favorable interactions with the mineral surface are predicted for E2, D19, E22, E26 and E27. Reprinted with permission from [14]. Copyright 2015 American Chemical Society.

Catalyzing silica polymerization into nanoparticles with silaffin peptide

Silica-made cell walls in diatoms and radiolaria are examples of the diversity of chemistry that is employed by organisms to manipulate a completely different mineral than the usual calcium salts. The mechanisms of biomolecule-regulated silica formation were explored in recent years [23,24]. Directed synthesis of biogenic silica in these organisms was shown to involve a few families of proteins that actively participate in the process. One family of proteins called silaffins was shown to play a functional role in accelerating silicic acid polymerization into silicon oxide within a designated vesicle in the diatom cell, called a silica-deposition vesicle (SDV). These proteins were implicated in regulation of the cell wall (frustule) shape through self-assembly along with polyamines into a template that dictates the final shape of the silica covering it [25,26].

Despite the low sequence homology of silaffins, recurrent segments showing favorable silica binding were identified. These amino acid stretches are rich in lysine and serine residues [27] and provide silaffins with the ability to promote silica precipitation also in vitro [25,28]. We recently showed that PL12 (KAAKLFKPKASK), a pentalysine peptide derived from Sil3, accelerates silicic acid polymerization into silica *in vitro*, in a phosphate buffer [15]. Through snapshots of silica nanoparticle growth by electron microscopy imaging (Figure 3)

in the presence of the peptide, we demonstrate a 3-fold increase in the rate of silica particle growth compared to the reference without PL12. Within 5 min, large 0.3-0.5 μ m particles grew in the presence of PL12.

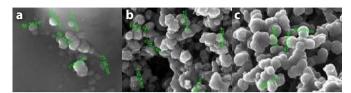


Figure 3. (a-c) High-resolution scanning electron microscope (HRSEM) images of PL12-silica as a function of time. Images a,b,c show the particles formed after 1, 5 and 30 minutes, respectively. White bar = 300 nm in a and 1 μ m in b,c. Reprinted with permission from [16]. Copyright 2015 American Chemical Society.

Dynamic-nuclear-polarization-(DNP)-enhanced 2D ¹³C double-quantum-single-quantum (DQ-SQ) NMR measurements^{21, 29} of silica-PL12 (shown in Figure 4) give relatively narrow cross peaks between directly bound carbons and enable their assignment in L5, F6, P8 and S11 as shown in Figure 4. The chemical shift differences between free and silicaembedded states are summarized in the chart in the figure. The lysines could not be uniquely assigned and thus their cross peaks are indicated in the spectrum without their index along the sequence. S11 exhibits a strong $C_{\beta+\alpha}$ - C_{α} peak and two extra weaker peaks (indicated by *) with their C_{β} shifted upfield by ~2 and ~7 ppm relative to the main cross peak. The majority of PL12 molecules have their S11 amino acid in random coil with slightly more extended character than in solution, and two smaller populations with α -helical and β -strand conformation at this position. This conformational multiplicity may result from the OH group having different H-bonding with silica, consequently causing local perturbations to the backbone structure.

In addition, some of the Ala residues acquire a major upfield shift of the C_{β} carbon (~6.6 ppm). L5 C_{α} and C_{β} carbons are also shifted upfield (~6 ppm) while the C_{γ} is shifted downfield (~3 ppm) which may indicate involvement of the specific side chains in interactions with neighboring peptide molecules to form clusters inside the silica. Previous studies of LK and R5 peptide molecules embedded in silica [30] have linked similar shifts to additional shielding by neighboring hydrophobic sidechains e.g. Leu 12 in the LK peptide tetramer (found slightly outside the hydrophobic core) and Ile 18 in the R5 peptide.

Proton-silicon proximities were extracted from 2D ¹H-²⁹Si HETCOR measurements (a representative spectrum is shown in Figure 5) to help characterize the peptide-silica interface. Known Q⁴ and Q³ silica lines at -112 ppm and -102 ppm respectively were observed along the ²⁹Si axis (where Qⁿ represents known silicon species of the form Si-(OSi)_nOH_{4-n}). Apart from the magnetization transfer from water to Q³ and Q⁴ silicon species, two additional cross peaks with a ¹H chemical shift of 2.9 ppm and ²⁹Si shifts of -111 and -112 ppm were observed. These peaks are assigned to lysine H_s protons in contact with Q⁴ silicon sites indicating close interaction between lysine sidechains and silica surface species. Similar interactions between glycine CH2 protons (adjacent to amine) and Q^4 sites in silica and between lysine residues in intact *T*. pseudonana and biogenic silica formed were reported before [31].

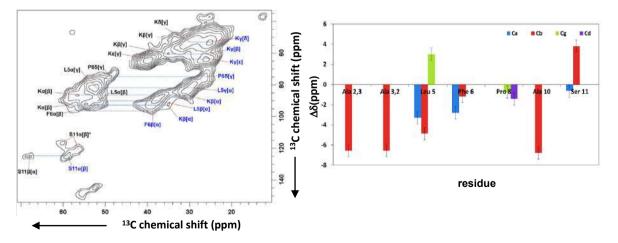


Figure 4. (left) DNP-enhanced 2D DQ-SQ ¹³C NMR spectrum of silica-PL12 at 100 K used for assigning carbon peaks of peptide embedded in the silica. Coupled carbons which give rise to pairs of cross peaks are connected by dashed lines and labelled in blue and black. **(right)** Chemical shift perturbations for the different carbons in PL12 between its silica bound state and its free state in solution (bound minus free). These perturbations are indicative of the secondary structure changes in SiO2-trapped PL12. Reprinted with permission from [16]. Copyright 2015 American Chemical Society.

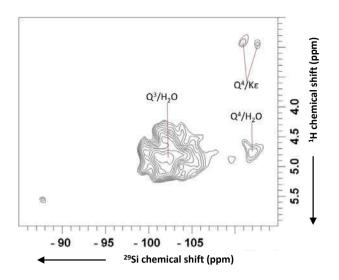


Figure 5. 2D ¹H-²⁹Si HETCOR spectrum of PL12-silica recorded using ¹H PMLG homonuclear decoupling in t₁, CP contact time of 6 ms, 384 scans, a recycle delay of 3 s, and 208 points in t₁. Reprinted with permission from [15]. Copyright 2016 American Chemical Society.

Summary

Peptides derived from functional domains in biomin proteins are shown to have regulatory properties of materials similar to ones formed within different life forms. The control of apatite particle morphology by ON29 is demonstrated and the residues partaking in binding the mineral are deduced from NMR. A model of the orientation of the peptide on apatite crystal surfaces and experimental evidence for a turn in the center of the peptide where mineral binding is strong are providing indications on the domain through which the biomolecule functions to direct the growth of apatite. Acceleration of silica condensation and the attainment of spheroidal nanoparticles by the activity of PL12 are demonstrated. Both shaperegulation and catalytic activity are also the hallmarks of the complete protein. Using solid NMR measurements of the bio-silica complex, the direct molecular interaction of lysine sidechains with sites on the silica surface is confirmed. The backbone conformation of the peptide, free and within silica, are compared, illustrating the adaptive changes it undergoes to couple well with the growing silicon oxide polymeric chain and to maintain its functionality.

Forthcoming studies are aiming at the regulatory capabilities of coral peptides on calcium carbonate mineralization, a central process in marine ecology. Having a tool such as solid-state NMR at our disposal, is pushing forward our capabilities to analyze the behavior of biomolecules and the different biological pathways used in the challenging and heterogenous setting of biomaterial interface, in order to solve the riddles of material design exercised by numerous organisms in our surroundings.

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We wish to thank to Dr Hugo Gottlieb and Dr Michal Afri for their extensive help with solution NMR measurements and Dr Yehudit Grinblat for extensive electron microscopy analysis. Financial support for the work was provided by the Israel Science Foundation (ISF), Binational Science Foundation (BSF), and the EAST-NMR and BIO-NMR projects.

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Water chemistry for copper and stainless steel cooling water systems: Corrosion and scaling prevention

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Abstract: Closed-loop cooling water systems operating at 1-30°C are used for cooling computers, control cabinets, server rooms and various other heat-emitting applications. Most common tube alloys used in these systems are copper UNS C12200 DHP and stainless steel UNS S31603 due to their good corrosion compatibility in cooling water and ease of formability. However, corrosion resistance of these alloys is based on adequate control of the cooling water chemistry, as without it premature failures and performance degradation are likely to occur. The literature on this subject is scattered, contradictory, often unclear, and does not usually refer specifically to water chemistry when copper and stainless steel are used. The aim of this work is to specify the cooling water parameters that should be monitored, their effect on the cooling system materials and functionality, and specific water parameters values that will ensure the system has a long lifespan and adequate performance.

Introduction

Water quality in relation to closed-loop cooling water systems is a complex matrix with many factors simultaneously influencing the system functionality, some contributing to it and others degrading it to the point of failure. When discussing the effect of water on the cooling system functionality we refer to two main phenomena: corrosion of the cooling system tubes, copper UNS C12200 DHP (copper hereinafter) and stainless steel UNS S31603 (SS hereinafter), and scale in the form of CaCO₃ and MgCO₃.

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as corrosion technologist, giving service to the industry in corrosion prevention and mitigation.

The corrosivity of water is significantly influenced by concentrations of dissolved gases and salts, suspended matter, microorganisms and conditions such as temperature, pressure, flow regime and flow rate. Their influence is not independent as complicated interactions exist between them. Thus, the exact specifications of water quality for copper and SS are

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not always given in the literature. Instead, the effect of the water is only described qualitatively. The reports that do give exact specifications usually deal with only one aspect of water chemistry and do not give a full overview of corrosion control.

Scale prevention has been studied (analyzed) extensively in the literature and there are very good methods for the prediction of water's tendency for scaling [1]. Nevertheless, when discussing closed-loop cooling water systems, specific recommendations must be given due to the thinness of the materials used, up to 0.30 mm of thickness of copper tubes, that can rapidly perforate if the water chemistry does not meet suitable requirements of non-aggressivity (non-corrosivity) and if the small passages that exist in the system, up to 6 mm diameter, become clogged.

In this work, exact quantitative cooling water parameters that should be monitored are specified. These requirements for water chemistry can lead to a long lifespan and adequate performance of copper and SS tubes.

cooling water system materials

Copper and SS are the most common materials used in the cooling water systems described above. The chemical composition of copper and SS is shown in Tables 1 and 2.

UNSª	Cu	Р
C12200	99.9	0.015-0.040

Table 2. Chemical composition of stainless steel UNS S31603 (SS 316L) (wt%)

UNSª	Cr	Ni	Мо	C _{max}	Mn _{max}	P _{max}	S _{max}	Simax	Fe
S31603	16.0- 18.0	10.0- 14.00	2.00- 3.00	0.03	2.0	0.045	0.03	1.00	Rem. ⁵

^a UNS - Unified Numbering System.

^b Rem. - Remainder

Pure copper which has been deoxidized with phosphorous, leaving a relatively high residual phosphorous content (DHP - deoxidized high-phosphorous copper) is distinguished by higher corrosion resistance in water than copper alloys. Copper's ease of brazing and good formability makes it the preferred candidate for cooling water system building material. When the water is considered to be aggressive to copper, SS 316 usually represent the next-in-line alternative due to its high corrosion resistance in different types of water, even in the presence of chloride ions (Cl⁻), and its good formability compared to other stainless steel alloys.

Conditions of use

When discussing recommendations of water for cooling water systems, it is important to specify the operating conditions of the cooling system, namely, temperature, flow regime, velocity, and stagnation periods. These conditions are important to the definition of adequate water chemistry and its influence on the corrosion resistance of copper and SS. Cooling water systems for industrial heat-emitting applications operate usually at 1-30°C, the flow velocity should not exceed 2.5 m/ sec to avoid erosion-corrosion phenomena [2] and stagnation periods should be no more than 1-2 days, or else the system must be emptied, rinsed, and thoroughly dried. The systems in discussion are open to air and dissolved oxygen is present in the water, in the amount equal to the oxygen saturation capability of water in contact with ambient air (~ 8 ppm at 25°C) [3].

Common forms of corrosion in cooling water systems

Common corrosion forms for copper and SS in cooling water systems are general corrosion, pitting corrosion, crevice corrosion, galvanic corrosion, erosion-corrosion, intergranular corrosion, and stress-corrosion cracking.

General corrosion

General corrosion is a uniform metal dissolution from a surface to the environment. SS does not exhibit general corrosion in cooling water, and corrosion in SS is localized and confined to a small area. Copper in cooling water systems can be subject to general corrosion, depending on the cooling water pH and the presence of aggressive ions.

Pitting corrosion

Both copper and SS form thin oxide layers on their surfaces that protect them from the environment. If these oxide layers break, due to the presence of aggressive ions in water or heterogeneity in passive layers or in the environment, a rapid local attack can occur. This form of attack creates a pit which may propagate rapidly in the material and perforate a tube in few months.

Crevice corrosion

When part of the SS or copper tube is shielded from the cooling water by deposits or by engineering issues, such as flange joint or rubber seal, crevice corrosion can occur locally at the shielded area (Figures 1 and 2). In SS, corrosion initiates due to dissolved oxygen or chloride concentration differences while, in copper, it is due to copper-ion concentration differences inside and outside the shielded area [4].

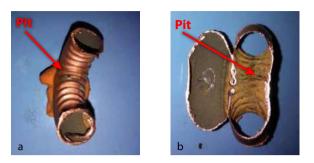


Figure 1. a. Crevice corrosion that perforated a copper tube wrinkle. **b.** Tube interior showing heavy scaling and corrosion deposits.

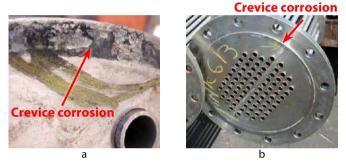


Figure 2. a. Under-seal crevice corrosion of SS heat exchanger. **b.** Under-seal crevice corrosion of SS heat exchanger.

Galvanic corrosion

When two metals with different electrode potentials are immersed in a conductive corrosive solution, electric current will flow from the less noble metal (anode) to more noble metal (cathode), causing corrosion of the less noble metal [5]. Both SS and copper are usually the more noble alloys in relation to the commonly used carbon steel in the cooling water system, and they can cause dissolution of less noble alloys such as carbon steel, aluminum or zinc.

Erosion-corrosion

Both SS and copper have a thin passive layer that protects them from the environment. When a fluid velocity is high enough to remove the passive layer by shear forces, the metal underneath is left unprotected to the water, and metal dissolution occurs, followed by formation of new passive layer, and again removal by shear forces of the fluid. These processes are mechanical and electrochemical in nature, both contributing to the degradation of the metal (Figure 3). In cooling water systems, improper design, or manufacturing issues could lead to excessive water flow followed by erosion-corrosion.

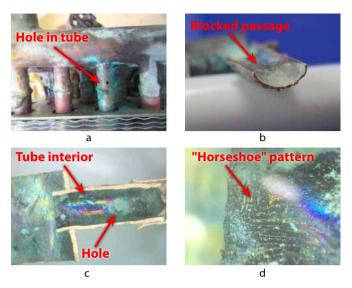


Figure 3. a. Erosion-corrosion failure. **b.** Interior of the tube, passage is partially closed by brazing material causing local accelerated flow. **c.** The tube interior showing deterioration signs. **d.** Tube interior showing "horseshoe" pattern that is typical for erosion-corrosion phenomena [6].

Intergranular corrosion

Intergranular corrosion is a localized attack that occurs along the grain boundaries in the alloy, due to impurities or segregation of elements from the alloy at the grain boundaries, that reduces the corrosion resistance of the alloy, allowing the corrosion to progress inside. SS is mainly susceptible to intergranular corrosion in a welding area due to sensitization [7]. Intergranular corrosion does not occur in copper.

Stress-corrosion cracking

Metal stressed by cold working or welding, and operating in a specific aggressive environment, can exhibit cracking. Copper is susceptible to stress-corrosion cracking when the cooling water contains ammonia. Water containing chlorides can cause stress-corrosion cracking in SS tubes.

Water chemistry requirements

Our specifications should prevent two main possible phenomena in cooling water systems: the corrosion of copper and SS materials, during years of service, and considerable scaling (CaCO₃ and MgCO₃). The recommendations are based on the analysis of numerous reports [8-43] and the personal experience of one of the authors (GK) in analyzing field failures in cooling water systems, and are shown in Table 3.

Chemical component or parameter	Designation	Units	Copper	SS
рН	рН		7.5 - 8.5	6.0 - 8.5
Ammonia	NH4 ⁺	ppm	< 5⁵	Any value
Sulfide	S ²⁻	ppm	0 ^b	Any value
Bicarbonate	HCO₃⁻	ppm	70 - 150	Any value
Carbon dioxide (free)	CO ₂	ppm	< 15	Any value
Carbon dioxide (aggressive)	CO ₂	ppm	0	Any value
Chlorine	Cl ₂	ppm	<	0.2
Suspended Solids		ppm	<	15
Chloride	Cl-	ppm	< 100	< 500
Sulfate	SO4 ²⁻	ppm	< 50	Any value
Total iron (dissolved)	Fe	ppm	< 0.2	0
Manganese	Mn	ppm	Any value	0
Total Hardness		ppm CaCO₃	60 -	- 120
Total Plate Count	TPC ^c	CFU ^d /ml	< 1	,000
Sulfate Reducing Bacteria SRB ^e		CFU ^d /ml	0 ^b	

Table 3. Water chemistry recommendations (T = 1-30°C)^a

^aValue listed in the table: all beside the "mandatory" are not a must and a deviation of 10 -20% is tolerable, but the aim should be to keep within the required limits.

^bMandatory.

CTPC - Total plate count.

^dCFU - Colony-forming units (viable cells) - unit of measurement of microorganism amounts in water.

^eSRB – Sulfate reducing bacteria.

Effect of water pH and electrode potential on copper corrosion

In 1945, a Belgian chemist, Marcel Pourbaix, presented his work on the "Thermodynamics of Dilute Aqueous Solutions. Graphical Representation of the Role of pH and Potential" [8]. The Marcel Pourbaix work provided the means to predict the phase that a metal will form in a solution, depending on the solution pH, electrode potential of the metal E_{SHE} (SHE - standard hydrogen electrode), concentration of dissolved ions, and temperature. The analysis is done using a diagram that presents graphically the different phases a metal will form, with E_{SHE} on the y-axis and pH on the x-axis. This E-pH graphic presentation is called a Pourbaix diagram and contains three different areas of thermodynamic stability: corrosion, passivity, and immunity. Usually such diagrams are shown for 25°C (Figure 4), but for copper, it was constructed for 5-150 °C [9].

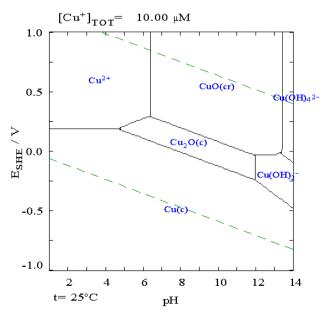


Figure 4. Pourbaix diagram for copper in water solution

From Figure 4, we learn that when the water pH is 7 and above, copper at particular electrode potentials forms a passive layer consisting of CuO or Cu₂O and is protected from the environment. When the water pH is below 7 or higher than 13 the preferred form of copper is soluble Cu^{2+} or $Cu(OH)4^{2-}$ and corrosion can occur. It is important to emphasize that the Pourbaix diagrams show only the possibility of corrosion and not its necessity. Any changes in water chemistry and conditions can result in changes in the three areas of corrosion, passivity and immunity. In addition, this diagram does not show corrosion kinetics.

Based on the Pourbaix diagram for copper and standard EN 12502-2 [10], our recommendation for the low pH value is not to go below 7.5. At the high pH value, the recommendation is to stay in the region of pH \leq 8.5. Increasing the water pH above 8.5-9, increases the tendency for scaling of calcium carbonate CaCO_{3(s)} that interfere with the heat transfer of the cooling system.

Water pH requirements for SS

For SS, there is no clear specification in the literature for the minimum pH. The general acceptance is that resistance of SS to chlorides and other aggressive ions, especially in conditions that promote crevice corrosion, is significantly reduced below pH 6-7 [11-13]. Hence, our recommendation is not to go down below a pH of 6. On the high side of the pH, the recommendation is the same as for copper, namely pH \leq 8.5, as the system alloy has no influence on the tendency for scaling. Scaling in SS systems has the same bad influence on the heat transfer as scaling in copper systems.

Ammonia (NH₃)

Microbial growth can produce ammonia in closed-water systems [14], and ammonia may be added to drinking water to prolong the effect of chlorine disinfection treatment. Ammonia can also be present in surface and underground water from normal degradation of biological matter or through discharge of industrial process wastes containing ammonia and fertilizers.

Ammonia is very dangerous to copper. Copper reacts with ammonia, and even very small amounts of ammonia can cause general dissolution of copper and its stress-corrosion cracking. Therefore, the amount of ammonia should be very low in water: less than 5 ppm.

SS has excellent resistance to ammonia [15] and is used in refrigeration systems with ammonia as a refrigerant and in ammonia stills.

Sulfide (S²⁻)

Sulfides may be present in water as dissolved sulfide salts (i.e. Na_2S) or the very dangerous dissolved gas H_2S (as a result of activity of microorganisms). Sulfides react with copper to form scale CuS (covellite) which is not protective, porous, and allows copper to continue to react with sulfide anions to complete destruction [16].

Another mode of failure in copper water cooling systems, even more dangerous than the previous, is embrittlement of brazing filler metal that contains phosphorous. Copper standard brazing material, BCu-P per AWS A5.8 [17], contains phosphorous in quantities 5-7% depending on the filler material type. The phosphorus in the filler material is selectively attacked by the sulfide, forming phosphoric acid that attacks the adjoining copper. The attack on the copper creates porous and brittle joints that can leak even after a few months of service [18]. And last, sulfide can induce pitting on copper tubes in water containing sulfides as low as 0.02 ppm [19, 20]. Due to severe problems that sulfide can induce corrosion in cooling water systems, sulfide is regarded as very dangerous to copper and must be completely absent in water.

SS exhibits excellent corrosion resistant in water containing hydrogen sulfide [21] and is regarded as safe to use in such water.

Bicarbonate (HCO₃)

A few years after the Statue of Liberty was erected in New York, it started to change its color from the original reddish brown of copper to green. The concern was that the statue was deteriorating underneath the green layer, and the intention was to paint the statue. Eventually, it was understood that the green layer does not affect the copper underneath but, in fact, protects the copper and preserves it from further corrosion. The copper sheets that compose the statue are only 2.4 mm thick and they are mostly intact, even after 130 years in service, mainly due to the protection of the green layer. This green layer is known as copper carbonate hydroxide, Cu₂CO₃(OH)₂ (malachite, or green patina), and is a corrosion product of a natural reaction of copper with the bicarbonate ions contained in the environment. This layer protects the copper against general and pitting corrosion. In cooling water systems, green patina acts as a barrier between the copper and the water and diminishes the effect of the water chemistry on the copper corrosion, without affecting the heat transfer much. The minimum concentration of bicarbonate in water, recommended in the literature, is 50-70 ppm [22, 23]. However, copper may be attacked by large HCO₃ concentrations that can induce pitting corrosion [24]. There is no concrete value, and we assess a maximum 150 ppm HCO₃

in water. Bicarbonates in water can inhibit pitting corrosion by chlorides Cl on SS. Bicarbonates act as pitting inhibitors due to their competitive adsorption with Cl on the SS surface [25]. Unlike copper, bicarbonates in high concentrations do not cause corrosion in SS, and there is no upper limit to the bicarbonates in cooling water systems containing SS tubes. Our recommendation for bicarbonate ions in water is that any value can be used in contact with SS.

Free carbon dioxide (CO₂)

Carbon dioxide presence in aqueous solutions is due to the absorption from the atmosphere or to the decay of organic matter. Carbon dioxide is more soluble in pure water (2,360 ppm at 10°C and 1,300 ppm at 30°C) than oxygen (8 ppm at 25°C). Since the carbon dioxide content in the atmosphere is ~0.03 vol.%, surface waters normally contain ~10 ppm CO₂, while wells or underground waters may contain several hundred ppm and even 1,000 ppm CO₂. Slightly less than 1% of dissolved carbon dioxide reacts with water to form non-dissociated molecules of carbonic acid (H₂CO₃).

The term *free carbon dioxide* is used for the sum of the concentrations of free hydrated carbon dioxide (CO₂(aq)) and carbonic acid. In addition to free carbon dioxide, it exists in aqueous solutions also in the combined (associated) forms as carbonate (CO_3^{2-}) and bicarbonate (HCO_3^{-}) ions.

Carbonic acid, produced from the reaction of carbon dioxide with water, releases hydrogen (H^+) ions to the solution lowering the solution pH to less than 6 where acid attack of copper can predominate [26]. Carbonic acid is corrosive to copper but not to SS [27]. Free carbon dioxide acts as a cathodic depolarizer when copper is exposed to water increasing the tendency of a pitting attack [28]. *Free carbon dioxide* is dangerous for copper and the recommended limit is 15 ppm. For SS, free carbon dioxide is less dangerous, hence the limit is 400 ppm.

Aggressive carbon dioxide (CO₂)

In order to understand aggressive carbon dioxide, we should note that calcium carbonate CaCO₃ can be dissolved only when dissolved CO₂ is present in water:

$$\begin{split} \mathsf{CaCO}_{3(s)} + \mathsf{CO}_{2(g)} + \mathsf{H}_2\mathsf{O}_{(l)} &\longleftrightarrow \mathsf{Ca}^{2+}_{(\mathsf{aq})} + 2\mathsf{HCO}_{3^{^\circ}(\mathsf{aq})} , \quad \text{(1)} \\ \mathsf{CaCO}_{3(s)} + \mathsf{CO}_{2(g)} + \mathsf{H}_2\mathsf{O}_{(l)} &\longleftrightarrow \mathsf{Ca}(\mathsf{HCO}_{3})_{2(\mathsf{aq})} . \quad \text{(2)} \end{split}$$

Equilibrium is established between $CaCO_{3(s)}$, $CO_{2(g)}$, $Ca^{2+}_{(aq)}$, and $HCO_{3^{-}(aq)}$. Carbon dioxide which is in equilibrium according to reaction (1), is called *equilibrium carbon dioxide*. If a higher amount of free carbon dioxide is present in water than that corresponding to the carbonate equilibrium, water dissolves CaCO₃. When free carbon dioxide is exhausted (e.g. by ventilation) from water, the carbonate equilibrium shifts to the left in reaction (1), and CaCO₃ has a tendency to separate from water.

Aggressive carbon dioxide is the carbon dioxide dissolved in water in excess of the amount required to precipitate a specified concentration of Ca^{2+} as $CaCO_3$. Copper is susceptible to increased attack in the presence of this aggressive CO_2 due to the calcium carbonate dissolution and accordingly, the loss of a protective $CaCO_3$ layer (scale) on copper. We should emphasize that this carbonate scale plays a dual role: positive – protective layer against corrosion and negative – decreasing heat exchange. Dissolved CO_2 in water does not influence corrosion of SS, hence its concentration in water is immaterial for SS. The absence of aggressive CO_2 in water can result in $CaCO_3$ scale formation on SS surface. Therefore, we recommend the absence of aggressive CO_2 in water for copper and any value for SS.

Chlorine (Cl₂)

Chlorine is not a natural constituent of water, but is often added for biological control to prevent bacterial growth. When dissolved in water, chlorine will convert to hydrochloric acid (HCl) and hypochlorous acid (HClO). Chlorine may accelerate corrosion of copper even at alkaline pHs and can induce localized attack and degrade the protective Cu₂O film. The minimum chlorine concentration in most disinfected drinking water is 0.2 ppm [29]. Many years of experience of use of copper tubes in such drinking water showed their good resistance. Therefore, our specification is to limit chlorine concentration in water to the value of 0.2 ppm. To control biological activities and prevent bacterial growth total elimination of chlorine is not recommended.

SS is also affected by chlorine and pitting can occur in water containing \sim 0.5 ppm chlorine [30]. Similar to copper, the recommendation limit chlorine concentration is 0.2 ppm for SS.

Suspended Solids

Suspended solids in the form of clays, silt, dust, corrosion products, biological matter and water treatment products (when added) are present in most cooling water systems. They can be deposited in low-flow areas. First, these deposits work as fouling barrier to decrease heat exchange. Second, they promote localized attack (crevice and pitting corrosion) under deposits. Therefore, we recommend controlling the amount of suspended solids to a maximum of 15 ppm.

Chloride (Cl⁻)

Copper is affected by chloride ions that degrade its protective Cu_2O layer, substitute divalent charged oxygen (O²⁻) in this layer and then eject cuprous ions (Cu⁺) into the water [24]. The CuCl layer is formed on the copper surface and continues to react with the chlorides in the solution and dissolves into the water in the form of CuCl₂. In addition, the CuCl layer allows the passage of chlorides to the copper surface, and chlorides react with the copper intensifying its corrosion [31]. There is no clear recommendation in the literature for a limit to the chloride concentration in cooling water systems containing copper equipment, and our recommendation is to limit the chlorides to 100 ppm.

Chlorides may cause pitting, crevice corrosion and chloride stress corrosion cracking of SS. Unfortunately, different recommendations are given in literature for critical chloride concentrations in water at the proper temperature causing pitting and crevice corrosion of SS, for instance, 500 and 3,000 ppm at 25°C [32, 33, 34]. In cooling water systems, we should set more stringent requirements and, therefore, limit concentration of 500 ppm was chosen in this work. However, this value is not mandatory if water flows all time. Pitting corrosion by chlorides may occur only under stagnant conditions. Even water with significantly higher concentrations of chlorides (e.g. sea water) can be used in SS tubes if water flows constantly. One should not forget to drain the equipment if the flow of water containing a high chloride concentration is stopped. Not only drain, but also rinse the equipment with pure water which does not contain chloride anions.

Pitting and crevice corrosion may occur at ambient temperatures (1-30°C). The traditional engineering view point has been that chlorides SCC does not occur in non-sensitized SS at temperature below 60°C [35]. Several cases of SS failures in swimming pools operating at ambient temperatures led to investigations that showed that SCC could happen even at 30°C under deposits of chlorides [36]. Therefore, there is a danger of this issue occurring in cooling water systems at ambient temperature, and chloride concentration should be restricted to 500 ppm in cooling water systems containing SS tubes.

Sulfate (SO₄²⁻)

Sulfate ions (SO 4^{2-}) take part in localized corrosion on copper surfaces but are not considered as directly initiating it. Copper corrosion products are affected by the presence of sulfates, and sulfate compounds can be found in the pit area but not in the pit itself [37]. Beside the effect of sulfate on the localized corrosion of copper, sulfates also take part in microbiological process. Thus, sulfate reducing bacteria (SRB) transform less aggressive sulfates to very aggressive hydrogen sulfide (H₂S). Similar to chlorides, there is no clear recommendation for sulfate ion concentration in water, and our recommendation is to allow a maximum 50 ppm of sulfates in cooling water systems containing copper tubes.

SS is not damaged by the presence of sulfates. On the contrary, sulfates, similar to bicarbonates, act as pitting inhibitors on SS [38]. Accordingly, we specify that any value of sulfate ions can be present in cooling water systems containing SS tubes.

Total iron (dissolved)

Total dissolved iron means the sum of ferrous (Fe²⁺) and ferric (Fe³⁺) ions in water. Oxidizing heavy metals salts, for example FeCl₃ and Fe₂(SO₄)₃, oxidize copper. Therefore, their concentration should be limited to 0.2 ppm. Most water contains < 0.2 ppm Fe. Corrosion of SS is also affected by oxidizing heavy metals, and it is recommended that they be absent in water.

Manganese salts

Corrosion of SS is affected by manganese ions, and the recommendation is to completely avoid the presence of manganese salts in cooling water systems. Copper is not affected by manganese ions and any concentration of these ions is allowed in water.

Total Hardness

Total hardness is the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in the cooling water, expressed as equivalent of ppm calcium carbonate ($CaCO_3$). This parameter of water is particularly important for systems containing heat exchangers.

Hard water is water which contains dissolved Ca^{2+} and Mg^{2+} in large amounts. *Soft water* does not contain (or contains in very small quantities) dissolved Ca^{2+} and Mg^{2+} . Seawater is considered to be very hard due to large concentrations of Ca^{2+} and Mg^{2+} dissolved salts. Typically seawater's hardness is in the range of ~ 6,630 ppm CaCO₃. In contrast, freshwater has hardness in the range of 15 - 375 ppm CaCO₃.

At appropriate conditions, scale (usually CaCO₃ and MgCO₃) deposits are formed on heat-exchanger surfaces. This scale can adhere on all metals and alloys and, as mentioned previously, can either contribute to the system function or deteriorate it. Soft water is more corrosive than hard water but hard water

affects heat exchange. Therefore, a "golden mean" of hard salt concentrations is needed. The rate of scale formation is a complicated function of many variables: concentration of scale-forming species, temperature, water chemistry, and hydrodynamic conditions. The United States Geological Survey uses the following classification of water hardness (Table 4) [39]:

Table 4. Classification of	of water hardnes
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Water classification	Hardness in ppm CaCO ₃
Soft	< 60
Moderately Hard	61-120
Hard	121-180
Very hard	> 181

Our recommendation is to keep the total hardness of the water in the range of 60-120 ppm CaCO₃. These values should provide adequate protection of copper and SS tube surface without significant interference with heat transfer. We emphasize that these values should not be considered as mandatory because many factors influence scale formation. Small changes in water hardness cannot be regarded as drastic.

Total plate count (TPC) and sulfate reducing bacteria (SRB)

In any cooling water system, there is a danger of microbiologically induced corrosion (MIC). Activity of special kinds of microorganisms can induce corrosion in cooling water systems in many forms, directly or indirectly, and should be monitored constantly. Bacteria can intervene in an already occurring corrosion process and intensify it by forming biological layers (biofouling) that can induce crevice corrosion, degrade passive layers both on SS and copper surface and release aggressive compounds that directly attack the metals [40].

TPC shows the general presence of microorganisms, and we define in cooling water systems a stringent value of < 1,000 ^{cfu}/_{ml} [41]. The most dangerous kind of microorganisms for metals is sulfate reducing bacteria (SRB) (Figure 5), hence, their amount should be nil.

MIC occurrence in water cooling systems is very difficult to predict due to a diversity of contributing factors and the mutual effects. Conditions that promote MIC are mineralized water under low-flow velocity or stagnation, suspended solids, low or non-existing chlorine (or other biocides) concentrations and high organic materials content [42, 43]. Therefore, bacterial activity can be prevented by adequate control of water chemistry and flow regime.

Thinning of wall thickness



Figure 5. a. Copper tubes showing heavy black deposits and thinning of the walls. Hydrogen sulfide produced by microbial activity was the cause of the copper corrosion. b. Passage partially blocked and corrosion of brazing material indicates heavy fouling by scale and/ or suspended solids and attack of the brazing material by hydrogen sulfide.

Conclusion

Due to many factors that control corrosion of copper and SS tubes, an exact definition of "safe" water chemistry that will prevent corrosion in cooling water systems and will provide proper operation is not easy to determine. Nevertheless, with knowledge, understanding, experience, and attention to important water chemistry attributes, as explained in this article, corrosion and excessive or inadequate scaling can be prevented or mitigated to reasonable and acceptable rates. This will ensure a long lifespan with proper system functionality of copper and SS tubes.

The values of different species and parameters of cooling water listed in this article represent mostly a stringent approach to monitoring of water chemistry allowing safe exploitation of copper and SS tubes. Although on some occasions small deviations would not harm the system, our recommendation is to keep to these values and not exceed them.

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Michael Polanyi (1891-1976): Reaction kinetics and personal knowledge

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Michael Polanyi was

one of the founders

of the modern field of chemical dynamics.

His chemical research included work in the areas of surface

phenomenon, x-rays,

fibers, metal crystals

and reaction rates.

Polanyi later became a philosopher of science.

He considered science

a social system based

on authority and

apprenticeship. Unlike

other philosophers of

science, who proposed

principles for theory

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Michael Polanyi

appraisal (e.g. falsifiability, simplicity, generality) and emphasized the importance of skepticism, Polanyi stressed the informal aspects of science. For him practice was the primary objective. Scientists are not driven by doubt, but by a commitment to established beliefs. Students acquire skills and

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knowledge by learning from example, and, in order to do so, they have to "submit to authority" [1].

Michael Polanyi

Michael Polanyi was born to Jewish parents in Budapest, where he grew up. He earned his medical degree at the University of Budapest in 1913. At the institute of Pathology and Physiological Chemistry, Polanyi came under the influence of Prof. Ferenc Tangl. Tangl felt that work in physiology should be based on a sound foundation of physical chemistry and required his assistants to have a thorough background in both physics and chemistry. Polanyi continued on his studies at the Technische Hochschule at Karlsruhe. Due to the war, Polanyi had to return to Austria-Hungary and his studies were further interrupted by military service. In 1919, he earned his doctorate in physical chemistry from the University of Budapest with a thesis on *Adsorption of Gases by a Solid Non-Volatile Adsorbent.* With the rise of the anti-semitic regime of Nicolas Horthy, Polanyi left Hungary in 1919 for Germany.

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Collaborations in the Sciences – Motives, Scientific Benefits, and Hidden Agendas (2016).

Polanyi accepted a position in Berlin at the Kaiser Wilhelm Institut für Faserstoffchemie (fiber chemistry) and three years later moved to Fritz Haber's Institut für Physikalische Chemie und Elektrochemie. He became Privatdozent and, in 1931, received the title of außerplanmäßiger Professor at the Technical University of Berlin (this means that he did not receive a position or salary); in 1929, he was appointed head of department at Haber's Kaiser Wilhelm Institute. With the rise of National Socialism Polanyi accepted a chair in physical chemistry at the University of Manchester. In 1948, at his request, he moved from a chair of chemistry to a chair of social studies at Manchester University. In 1958, he moved to Merton College, Oxford, as Senior Research Fellow, where he remained active for the next fifteen years [2].

Early Years

Michael's son John was honored in 1986, together with Dudley R. Herschbach and Yuan T. Lee, by the award of the Nobel Prize in chemistry for "contributions concerning the dynamics of chemical elementary processes." John Polanyi, in commenting on his father's scientific career, wrote [3]:

"The topic his first institute offered him was the study of natural fibres. Within months of his arrival he succeeded in interpreting the X -ray diffraction pattern of cellulose. This was the first analysis of the molecular structure of a natural material by X-ray diffraction. Additionally, it inaugurated the rotating crystal method that proved central, for many years, to the field of structure determination.

From the shapes of molecules he was led to their mode of stacking in solids, and to the explanation of the weakness of large-scale materials as being due to molecular dislocations; that is to say, to imperfect molecular stacking. He was now moving confidently to and fro between the macroscopic world of materials and the microscopic one of the molecule.

It was time to turn to the central question of chemistry: why are some chemicals stable and others not? Differently stated, why do chemical reactions occur? The rates of the chemical reactions must be linked at the molecular level to the rates of molecular collisions, to the strengths of chemical bonds, and to the collision energies required to sever those bonds.

It was his good fortune that the new mechanics required to describe molecular motions-- quantum mechanics -- was being developed nearby. The equations of quantum mechanics were, however, famously insoluble. With Henry Eyring, an American visitor to Berlin, he used experimental evidence ingeniously to calibrate the equations so that they could be solved. The outlines of the hills over which the molecules would have to travel in progressing from reagents to products then emerged from the mists in which they had been hidden."

Reaction Kinetics

Eugene Wigner earned his doctorate in Chemistry under the supervision of Michael Polanyi. E. P. Wigner and R. A. Hodgkin, in recalling Polanyi's work, wrote [4]:

"The experimental work consisted principally in the measurement of reaction rates-an enormous number of them... the two reacting gases entered a glass tube-about 1 m long and 3 cm in diameter—at its two ends at very low pressure. As they met, they reacted near the middle of the tube and the length of the reaction was established. Some of the reactions were accompanied by chemiluminescence and some produced solid reaction products which were then deposited on the wall. From the length of the reaction zone one could estimate, by means of the theory of diffusion and the knowledge of the gas kinetic cross section, how many scattering collisions the incoming atoms suffered before reacting, i.e., the ratio of scattering to reaction cross sections. This method underwent several modifications and was used in one form or another for the measurement of about a hundred reaction cross sections, most of them between an alkali and a compound containing a halogen, including the halogen molecule itself." The reaction rates measured spanned six orders of magnitude. These studies were of fundamental importance.

More important than his experimental work was Polanyi's investigations into the relationship between the values of the reaction cross-sections and the structures and dynamics of interacting species. He was one of the first to try to understand chemical kinetics by looking at the forces between reaction partners [5]. "For reactions of the $A + BC \rightarrow AB + C$ Polanyi adopted the theory of London (also called the Born-Oppenheimer approximation) in which the nuclei of atoms move essentially according to the laws of classical mechanics under the potential given by quantum mechanics for the given configuration of the nuclei. He made, in collaboration with H. Eyring the first reasonably accurate determination of such energy surfaces for reactions

 $H + H_2 \rightarrow H_2 + H, \ H + HBr \rightarrow H_2 + Br, \ H + HBr \rightarrow HBr + Br.$

The calculation, which gave the activation energy for these reactions, was not entirely theoretical, it also used some experimental data. The surfaces obtained were later used, also by Polanyi and Eyring, and on the basis of the transition state method developed in his laboratory by H. Pelzer and E. P. Wigner, not only to calculate the activation energy but also the reaction rate, completely." [4]

John Polanyi in summarizing his father's Manchester period wrote [3]:

"Perhaps the two major conceptional innovations that came out of Polanyi's laboratory in the Manchester years were the derivation (and rationalization) of a parallelism between reaction heat and reaction rate in related families of chemical reactions and the development of the 'transition state theory' of chemical reactions. Both of these concepts are stimulating fruitful thought and discussion over forty years later and are likely to continue to do so for years to come. The first stemmed from collaboration with an American visitor to Polanyi's laboratory in Manchester, Richard Ogg, who was there in 1934. It was later extended and clarified in collaboration with M. G. Evans.

The transition state theory took as its starting point Pelzer and Wigner's paper in which the properties of an "activated complex" or "transitional state" were calculated for the first time (using Eyring and Polanyi's then newly published potentialenergy surface). In 1935 Evans and Polanyi succeeded in generalizing Pelzer and Wigner's approach; an undertaking that was paralleled in America by Eyring in the same year, partly in collaboration with Wynne-Jones."

Philosophy

During the 1930s and 40s, Polanyi became increasingly involved in discussions about politics and economics, in particular about communism. A substantial part of British academics, among them the crystallographer J.D. Bernal, were Marxists. During a visit to the USSR in 1935, where he was invited to give a series of lectures, a meeting with the leading Marxist theoretician Nikolai I. Bukharin deeply influenced and disturbed Polanyi. He recalled that "to claim independent status for pure science was ridiculed as mere snobbery" [6] and that according to Bukharin "pure science, as distinct from technology, can exist only in a class society" [6]. Later Polanyi described the absurdity of such claims in the following words: "To declare that in a classless society the pursuit of science the search marked by the names of Copernicus and Newton, Harvey, Darwin and Einstein - will spontaneously turn to the advancement of the next Five-Year Plan is simply ludicrous" [7]. In the late 1930s and in particular from 1948, these maxims turned into a battle against 'bourgeois science,' culminating in Lysenko's campaign against Mendelism.

Polanyi wrote numerous articles about the relation of science and society and the negative effect of the social control of science, as demonstrated by the devastating impact of Lysenkoism on genetics. Of the three types of totalitarianism in Europe at the time, fascism, Nazism and communism, Polanyi considered Marxism the most virulent form, because it was a more intelligent and more complete philosophy of oppression, and because liberals and socialists did not see the danger [8].

Polanyi stressed in his philosophical works "the role that personal factors, practices, authority, and dissent have been playing in the process of discovery and in scientific progress. As he pointed out in the preface to Personal *Knowledge*: Towards a Post-Critical Philosophy, his main philosophical work, he rejected "the ideal of scientific detachment" and wanted to establish the concept of 'Personal Knowledge' as an alternative ideal. The seeming contradiction between the words knowledge, which was supposed to be impersonal and objective, and personal, he tried to resolve by modifying the conception of knowing, which he regarded as "the personal participation of the knower in all acts of understanding." Partly because of his background as a scientist, Polanyi laid particular emphasis on the informal aspects of research and discovery. Practice was primary to him. Scientists were not driven by doubt, but by a commitment to established beliefs. Students acquired skills and knowledge by learning from example, and in order to do so, they submitted to authority.

According to Polanyi, scientific practices such as theory selection or testing are ultimately personal acts, i.e. they involve not only logic but also personal judgement and imagination. This led him to a re-definition of objectivity: Science is objective not in the detachment of the knower from the known but in the power to establish contact with a hidden reality, which is based in the skills and commitment of the scientist. Personal knowledge is not made but has to be understood as a discovery and intellectual commitment: "It commits us, passionately and far beyond our comprehension, to a vision of reality. Of this responsibility we cannot divest ourselves by setting up objective criteria of verifiability - or falsifiability, or testability, or what you will." Polanyi considered these rules necessary but held that they cannot be more than "vague maxims", which in any case change over time. In his opinion, these rules, if they had been applied literally, in many cases would have impeded scientific progress.

Polanyi's philosophy of science was influenced by, both, his experiences as an experimental scientist, and his general philosophical view according to which doubt, if excessively applied, had detrimental consequences."

Polanyi's notion of science and authority

Polanyi emphasized the ability of traditional science to generate novel topics and discoveries. Consequently, he held that progress had been achieved in most cases not by revolutionary changes which strongly affected whole disciplines, but occurred within existing scientific frameworks. Despite Polanyi's conclusion that scientific authority was necessary in principle, he showed that authority included error and was subject to change. Polanyi accepted "the existing scientific opinion as a competent authority, but not as a supreme authority." [6] He considered a great scientist not as someone who is infallible but who is competent in science. "To acknowledge a person as a scientist – and even as a very great scientist – is merely to acknowledge him as competent in science, which admits the possibility that he was, or is, in many ways mistaken [6]."

Transition from physical chemistry to philosophy

When John Polanyi was asked by I. Hargittai about his father's transition from physical chemistry to philosophy, he replied in part as follows [9] :

"The fact that he made that transition isn't so surprising. There are a lot of scientists who have started to ruminate about how discoveries are made, how people learn anything, and the role of logic in this as compared with faith. And all this was of interest to him too.

What is striking, in my view, is the originality and impact that he had in his new field of epistemology, the theory of learning. He would have said confidently that what he did in that area was much more important than what he did in science.

I have a sense of wonder at all he did in science, and yet I believe he may easily have been right that his contribution to epistemology will turn out to be more lasting. The sales of his books and the interest in his ideas continue to be great. Eventually his name will, of course, be forgotten, but his philosophical ideas will live on as a significant contribution to the development of philosophical thought.

What is remarkable, then, is the quality of the contribution he made in his decades as philosopher. Actually, his first book on a nonscientific theme was being conceived in the 1930's, when he attacked the Russian economic system and at the same time confronted the leading British social scientists of the day, Sydney and Beatrice Webb, who'd published a learned volume explaining how the Soviet five-year plan constituted a superb innovation and was bringing prosperity to the USSR. My father took this thesis apart in a series of essays, which became a book in 1940, that went far beyond economics and inquired why it was that British liberals, the so-call Fabians, were so careless of the freedoms that they enjoyed; the book was called The Contempt of Freedom. It was an influential book and a prescient one. It is forgotten today. His best known book is, instead, Personal Knowledge." In Personal Knowledge, Polanyi outlined his epistemology, maintaining in part that knowledge is based on "tacit knowledge," meaning that knowledge cannot be completely communicated by words, or as Michael Polanyi wrote, "We know more than we can tell."

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- The sections of this work that discuss Michael Polanyi's ideas on the philosophy of science were presented previously by one of us (UD) in greater detail with an emphasis on his ideas regarding tradition and authority. The interested reader is referred to that work in *The Yearbook of the Leo Baeck Institute*, 2011, **56**, 249, and to the works referenced there. Excerpts from that article are used here with permission of Oxford University Press.
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Lighting the Shabbat at a Jewish home in the period of the Mishna

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Abstract: This study presents the integration between the social and cultural values of the Shabbat and the technical tools and burning materials utilized to light the Shabbat at a Jewish home. It describes the means by which a comfortable home environment is achieved by maintaining a burning fire and lamp light to expel the darkness and the coldness of the night. It is mainly based on the second chapter of Mishna Shabbat, Seder Moed, entitled "Bameh Madlikin". Earthenware oil lamps, their materials, fuels, wicks and uses are described, and the lamp and candle and their flame mechanisms are illustrated by their chemical reactions. This work is the result of a joint effort of chemists and engineers.

Introduction

This article describes the integration between the social and cultural values of the Shabbat and the technical tools and materials employed in Jewish homes to illuminate the Shabbat during the period of the Mishna epoch. It is based on the "Bameh Madlikin" ("With what may we light?") chapter of Mishna Shabbat [1] and on the Sages' commentaries and rules that permit or forbid the use of the oil lamps [2]. The concept of Shabbat appears in several books of the Bible. Its observance

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South Africa and France. During the IMRS Congress in August 2010, Mexico he received a "Distinguished Service Award" from NACE International and the NACE Central Mexico Section. He is a member of the National System of Researchers in Mexico. His particular interests are culture, art, education and history. He has been a NACE International member for 26 years. mschorr2000@yahoo.com affects the socioeconomic aspects of the Jews as individuals and the Jewish people as a nation, as well as many different communities throughout the world [3].

The Shabbat laws and customs derive from two central events in Jewish history:

• The universal day of rest: God finished his work of creation, then He rested on the seventh day and blessed this day (Genesis 2: 2-3).

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professor at the University of Baja California. His activities include corrosion research, consultancy, and control in industrial plants and environments. During the IMRS Congress, in August 2013, Mexico, he received a "Distinguished Service Award" from NACE International and the NACE Central Mexico Section. He has been a NACE International member for 26 years. benval@uabc.edu.mx • The Fourth Commandment, which commands "Six days thou shalt do thy work but on the seventh day thou shalt rest (Exodus, 23:12). This was interpreted by Rabbinic teaching in subsequent generations.

The Shabbat has the status of a joyous holy day, being the most significant day in the Jewish week.

The Shabbat meal

The Shabbat meals are considered to be festive since they include the whole family and contain the three components of a rich, satisfying meal: grain, wine and oil [4]. The Bible contains numerous references to food and meals. On the eve of the Shabbat, the family had their dinner together at the table. The family members worked hard in the preparation of the food, which might have included bread, meat, grains and dried and fresh fruits. Non-alcoholic grape juice was served to children and adolescents. Fine herbs and aromatic species were added to the wine, to make it taste better, including sometimes anise seeds, raisins, honey or some other fruit juice as a sweetening agent [4].

Bread, the staff of life (Isaiah 3:1, Ezekiel 4:16), was baked in ovens made of clay or mud and straw, located in the courtyard of the family house. Many homes had pottery jars for grains, wine, oil and water storage. Food was also the prime means of showing hospitality. A bowl for washing hands, before eating, would be offered to each guest.

Households for extended families were built from stone and wood, and contained cisterns for the collection of rainwater, with walls coated with mortar made from local limestone rock [5].

In ancient times, including the Biblical and Mishna periods, wood was the available fuel. Fires were used for cooking food, for generating heat and light for the home environment, for processing earthenware jars and dishes, for distilling wine

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converting it into an alcoholic drink, called "shechar" (related to "shikor"- drunkard") and for refining and purifying silver and gold.

The "Bameh Madlikin" chapter of the Mishna [1]

"Bameh Madlikin" is a chapter in Tractate Shabbat (Order Moed) of the Mishna. It discusses the laws that permit or forbid lighting in a Jewish home during the Shabbat. Three commandments that enhance the feeling of peace within the family household are mentioned: light, eruv and tithes. The Mishna was compiled in the first and second centuries CE in the town of Zeppori (Sepphoris in Greek) in the Galilee.

In some ancient Jewish communities, for example, those from North African countries and Yemen and also in their synagogues in Israel, and also in many Ashkenazi synagogues, this chapter of the Mishna is recited and/or sung by the cantor (chazan) between the "Kabbalat Shabbat" service and the evening service on Friday night [6,7]. For readers' convenience, the full text is presented in Appendix A [1]. A detailed commentary on the oil lamps, their combustible materials, wicks and procedures for maintaining the clean burning of the oil lamp, appropriate for Sabbath observance, can be found in Ref. [2].

Combustible materials

The classification of the numerous combustible materials reported in "Bameh Madlikin" (Appendix A) and in the commentaries [2] is based on the sources of the combustibles, their nature, chemical composition and combustion properties and behavior [8,9]. They are categorized into three groups, as follows:

- Vegetable oils extracted from seeds, nuts and fruits
- Animal fats obtained from sheep tails, tallow and fish.
- Mineral petroleum derivatives e.g. tar, naphtha.

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Brown flax seeds



Pistachios



Hazelnuts



Sunflower seeds



Almonds



Pine nuts



Peanuts



Sesame seeds



Wheat germ



Poppy seeds



Walnuts



Ground flax seeds

Figure 1. Seeds suitable for oil production.

Oil is extracted primarily from seeds by crushing, grinding and pressing, followed by refining. Many plant oils are liquids at room temperature and so burn easily. The main chemical component of the vegetable oils and animal fats is glycerol: $C_3H_8O_3$. The fuel most recommended for lamps is olive oil [10]. The Sages were not concerned with the bad odor of other fuels as long as they burn well, and keep the Shabbat light burning (Figure 1).

It is worthwhile noting that many additional oils are mentioned in the Bible as edible oils for cooking and flavoring foods, for health and beauty care, for holy incense, for religious rites such as anointing the heads of kings, princes, governors, priests and army commanders. Nowadays, many books are devoted to essential biblical oils, used for healing. Not only books are produced: a commercial company sells a collection of 10 oils and perfumes (all cited in the Bible) contained in beautiful, transparent glass bottles for many purposes, as described by the company owners.

Earthenware oil lamps

Before the invention of electric light, oil lamps and candles were the dominant means of illumination in many parts of the world.

The terracotta oil lamp consists of three central components, utilized during the lighting: the fuel, the wick and the flame. These materials are converted into light energy and are consumed during the lamp operation. This lamp has a double aim: to keep the Shabbat laws rules and to maintain the comfort of the home dwellers [11,12]. The lamp has several functional parts: the handle to move it, the central hole to pour the oil and the nozzle to insert the wick, to keep it burning (Figure 2).

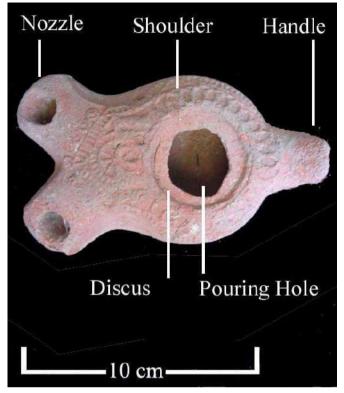


Figure 2. Components of an earthenware oil lamp found in Samaria.

The oil lamp and its light became significant household items, and constituted a vital symbol in the development of Jewish culture and religion. In this connection, the lamp appears in the Bible, for example, Psalms 119: 105, 132:16; Proverbs 6:23, 20:27. The lamps were produced by pottery artisans, using local clay, a silicate mineral. The potters' work and products are described in several places, for example, Isaiah 29:16, 30:14, 41:25. The shapes and sizes of the lamps evolved during the generations and according to the artisans' place of residence. Archeologists have found many lamps during their excavations in Jerusalem, Samaria, and Jerash (Jordan).

It is interesting to note that sheep's wool is not considered suitable for making wicks, even although wool was abundant in biblical times (Deuteronomy 18:3-4, Judges 6:38). Since wool is composed of proteins and fats, its combustion generates bad smells similar to flesh burning and, probably, grey smoke and fine black soot particles.

Candle illumination

A candle, in the past and nowadays, consists of a cylindrical body manufactured from solid, combustible materials, with an embedded wick that provides light after ignition [13]. In the Land of Israel (Eretz Israel) the candles were made from beeswax that ensured clean burning. The candle wick functions by a capillary mechanism, drawing the melted wax up to the flame, where it vaporizes and burns. The wicks were made of linen (from the flax plant) or from old clothes, singed into a wick, to facilitate its burning [2]. Modern candles are produced from paraffin, a heavy hydrocarbon fraction obtained from crude petroleum refining, and most commercial wicks are fabricated from braided cotton (Figure 3).



Figure 3. Paraffin candle with its burning flame.

In a modern Jewish home, two candles are lit on Sabbath evening, inserted into the sockets of candle-holders made of silver, bronze, glass or ceramic. In the Shabbat ceremony, the candles are set on the table together with the Challah (ritual bread) and a cup of wine, for the blessing (Figure 4). This tradition originates from rabbinic/halachic laws set down during the long European Medieval Period by community rabbis in the Jewish Diaspora, in countries around the Mediterranean Sea.



Figure 4. Kabbalat Shabbat table: candles in candle holders, challah and a cup of wine for the blessing.

Combustion and flame chemistry

Combustion is the oxidation process, by molecular oxygen (O_2) from the surrounding air, of a carbon-containing material, by an exothermic chemical reaction releasing carbon dioxide (CO_2) , water (H_2O) and energy as heat and light. After the wick ignition, flames are formed as the visible part of the fire.

Glycerol $C_3H_8O_3$ is the main component of vegetable oils; its combustion in an oil lamp is written as

$$C_3H_8O_3 + 3.5O_2 \rightarrow 3CO_2 + 4H_2O + energy.$$
(1)

The flame of a candle is a mixture of reacting and evolving gases and solids, emitting visible light, for the ambient illumination.

The luminous yellow color of the flame, provided by incandescent carbon particles within the flame, lighten the surroundings. During poor combustion, uncombusted particles are dispersed as black smoke and soot, imparting a bad odor to the home environment. The Sages created their rules to maintain adequate hygiene and to avoid these inconveniences.

The combustion of modern candles produced from paraffin is written as

$$C_{25}H_{52} + 38 O_2 \rightarrow 25 CO_2 + 26 H_2O + energy.$$
 (2)

Conclusion

The Sages established a body of laws, rules and commandments to ensure the household's spiritual peace and material cleanliness in keeping with Shabbat observance [14].

The Sages were preoccupied with achieving two primary aims: to maintain the light provided by the oil lamps, and to ensure a pure home atmosphere, free of smelly and smoky contaminants. These healthy Shabbat practices were maintained by the Jewish people, throughout the generations, in many countries.

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Appendix A.

- 1. With what wicks may we light the Sabbath lamp and with what may we not light? We may not use a wick of cedar bast, or uncombed flax, or raw silk, or a wick made of willow bast or desert weed, or seawood. [For oil] we may not use pitch, or wax, or cotton-seed oil or [contaminated consecrated] oil that must be destroyed by burning, or fat from sheeps' tails, or tallow. Nahum the Mede: We may use boiled tallow. But the Sages say: Whether boiled or not boiled, we may not use it.
- 2. [Contaminated consecrated] oil that must be destroyed by burning may not be used for a festival lamp. Rabbi Ishmael says: We may not use tar out of respect for the honour due to the Sabbath. But the Sages permit all these oils: sesame oil, nut oil, radish oil, fish oil, gourd oil, tar or naphtha. Rabbi Tarfon, however, says: We may only use olive oil.
- 3. No product from a tree may be used as a wick for the Sabbath lamp, except flax. Also no product of a tree can contract "tent" uncleanliness, except flax. If a wick was made from a cloth that has been twisted but not singed, Rabbi Eliezer declares, it is susceptible to contamination and may not be used for a Sabbath lamp; but Rabbi Akiva says, it is not susceptible to contamination, and may be used for the Sabbath lamp.
- 4. One may not pierce an eggshell, fill it with oil, and put it over the mouth of a lamp so that the oil may drip from

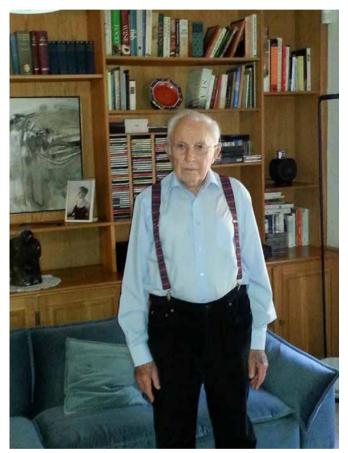
it into the lamp, even if the vessel is of earthenware, but Rabbi Judah permits it. If, however, the potter had originally attached it to the lamp, it is permitted because it constitutes a single vessel. One may not fill a bowl with oil, put it beside a lamp, and put the end of the wick in it so that it draws oil from the bowl; but Rabbi Judah permits this.

- 5. One who extinguishes a lamp because he is afraid of heathens, robbers, or depression, or to enable a sick person to sleep, is not liable [for violating the Sabbath). If he did it spare the lamp, or the oil, or the wick, he is liable. Rabbi Yose absolves him in all these cases except that of sparing the wick, because he thereby turns it into charcoal.
- 6. For three transgressions women may die in childbirth: for being careless in observing the laws of menstruation, separating the challah [dough-offering), and lighting the Sabbath light.
- 7. One should say three things at home on the eve of the Sabbath just before dark: Have you tithed? Have you prepared the Eruv? Light the Sabbath lamp. If there is any doubt whether or not darkness has fallen, we may not tithe definitely untithed food, nor immerse [unclean] vessels, nor light the Sabbath lamp. We may tithe produce about which there is doubt whether it has been tithed or not, we may prepare an Eruv, and insulate hot food.

Profile of Avraham Baniel: applied chemist and entrepreneur

by Arlene Wilson-Gordon

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Avraham Baniel

On a sunny winter's day, I visited Prof. Avraham Baniel in his beautiful home in the German Colony of Jerusalem. I had heard that he was already 98 years old and so didn't know what to expect. When I rang the bell on the gate surrounding his eclectic garden, I was surprised to be greeted by someone who looks much younger than his chronological age. Prof. Baniel is a charming man, full of stories about his long career as an applied chemist and entrepreneur. He was born in Lodz, Poland in 1918 but came to Israel with his parents when he was only three years old. He was the youngest child with two older sisters. Apparently he was a handful because after some years of study at the Gymnasium in Tel Aviv, his parents sent him away to be educated at the Ben Shemen Youth Village, an agricultural boarding school established by a German Jew, Sigfried Lehman, to educate Jewish children who survived the pogroms in Ukraine. He had advanced ideas about education in general such as allowing the pupils to choose the subjects and teachers that appealed to them.

Already as a schoolboy, Baniel developed his love of chemistry. In common with many successful chemists, he experimented at home with explosives, and was strongly influenced by a French chemistry teacher who gave him a chemistry book in French. At the suggestion of his father, a polymath, Baniel learnt the language in order to read the book. Later, as a student, he also learnt German in order to read the chemical literature.

His knowledge of French proved to be very useful when he went to France in 1937 to study chemistry at Montpellier University, one of the world's oldest universities. He would have preferred to study in England but it was prohibitively expensive. The method of education in France made a lasting effect on him. This method, Cartesianism, was based on the work of René Descartes who was the first thinker to emphasize the use of reason to develop the natural sciences. In France, Baniel learned to think through a problem analytically before tackling it experimentally, a skill that he has used to good effect in his long career. He also learned to respect his fellow human beings and to have a deep appreciation for knowledge in all its forms. He enjoys relating a story about an analytical exam in which he was given two hours to identify unknown compounds. He solved the problem in just ten minutes after noticing which bottles had been removed from the rather dusty cupboards that lined the long corridor leading to the laboratory. Fortunately for him, his examiner thought that a scientist should use all the available methods to solve a problem. From this experience, Baniel learnt never to waste an observation. His stay in France also taught him to appreciate wine and, to this day, he enjoys a glass of wine with his meals. After his return from France, he studied for the master's degree in chemistry at the Hebrew University of Jerusalem. During the British Mandate, he and his colleagues established two chemical factories from scratch and while working in a paint factory in Kiryat Ata, he

applied his chemical knowledge to supply the British Army with seawater-resistant paints for maintenance of its frigates, while also supplying the Hagana and Lehi with explosives made of nitrocellulose derived from old films. Later, after the Second World War, he returned to France to do his doctorate at the Sorbonne.

After the establishment of the State of Israel in 1948, he helped to found the Israel Mining Institute (now IMI TAMI, part of Israel Chemical Industries) whose role was to exploit Israel's few natural resources. Early on, he realized that, rather than just selling the raw materials, they should concentrate on developing technology which could be patented. He and his colleagues were surely pioneers in the field of selling knowledge, an approach that, in recent years, has led Israel to be called the "startup nation." He proudly told me that he never shared the anti-feminist prejudice so prevalent in those days and appointed a South African woman chemist, Dr. Ruth Bloomberg, as his deputy: "I chose her to be my No.2 purely on merit. Excluding women from top jobs was, in my thinking, the acme of foolishness. This eventually translated to her position as second-in-command of TAMI."

He had hoped to spend the rest of his career in TAMI. However, his tenure as director ended abruptly in 1973 when the "Arad project for manufacturing HCl" failed. Despite his explicit warnings that the process designed by the American company, Allied Chemicals, was unviable and destined for failure, and his good relations with the Minister of Finance Sapir, the government had already invested \$100 million in the project and someone had to pay the price.

However, Baniel was never one to be overcome by setbacks. He rapidly established himself as scientific consultant to a host of American and European companies, using some of the proceeds to buy his home in Jerusalem. Eventually, the focus of his activities returned to Israel and he was appointed director of the Casali Institute of Applied Chemistry at the Hebrew University. The Casali Institute was founded in 1970 at the suggestion of Prof. Zvi Enrico Jolles and funded by the Italian industrialist Alberto Casali who realized that although Israel had many excellent scientists, few were involved in applied chemistry. After his retirement and appointment as Professor Emeritus in 1987, Baniel did not rest on his laurels. He continued as a consultant and, later, together with his son Eran (formerly an actor and theatre director), formed a string of startups. One of these was HCL Clean Tech (founded in 2007 with Aharon Eyal, later called Virdia) which used HCl to convert the cellulose in chips into high-value feedstock for biofuels and the plastics and chemicals industries. The company was eventually sold in 2014 to a Finnish company. However, the Israeli inventors did not benefit financially.

The most recent of the Baniels' startups is called Doux Matok (doubly sweet) and is based on an idea that Avraham Baniel has been playing with for many years since the time he worked in the paint factory in Haifa. At that time, during the British Mandate, everything was scarce and he was asked to obtain edible starch that could be used to thicken pudding for school children. The idea was that this would increase the sweetness of the pudding so that less of the scarce sugar would be required. Although Avraham Baniel has wide experience in the field of sugar substitutes, he is convinced that the best way to reduce the amount of sugar in food, now a global imperative, is to coat silicate particles with sugar thereby producing the same sweetness with less actual sugar. The company is already in advanced negotiations, led by Eran Baniel, with international food producers.

Avraham Baniel is truly an inspirational figure who enjoys his children, Eran and Anat, grandchildren and greatgrandchildren, his daily walks in Jerusalem and meeting interesting, especially young, people. He regards each day as a gift. When asked what advice he would give to young people beginning their careers, he replies without hesitation, "Do what interests you."

Arlene Wilson-Gordon was born in Glasgow, Scotland. She completed her BSc (Hons) at Glasgow University and her DPhil at Oxford University under the supervision of Peter Atkins. After a postdoc at the Hebrew University with Raphy Levine, she joined the faculty at the Department of Chemistry, Barllan University, where she rose to the rank of Professor and in 2015, Professor Emerita. Her research interests lie in the field of theoretical quantum and nonlinear optics. She is the editor of the Israel Chemist and Engineer, an



online magazine for all who are interested in chemistry and chemical engineering.

Profile of Major Dr. Moshe Rabaev: Recipient of the 2016 Decoration of Excellence in Technology from the Commander-in-Chief of the Israel Defense Forces

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Moshe Rabaev

Moshe Rabaev was born in the former Soviet Union, in the Kavkaz region, in 1976. He was raised in the then flourishing Jewish community, composed mainly of merchants, by a family who specialized in leather tanning and crusting – processes that involve lots of chemical reactions. "My grandfather always told his children that he would like at least one member of the family to study chemistry, so they could gain a better understanding and perfect the family's leather processing methods," Rabaev says.

As a smart teenager, Moshe finished his schooling early at the age of 16, too early to serve in the Soviet army, and began working in the family business. The business did not prevent him from fulfilling his grandfather's wish: Moshe was sent to study Biology and Chemistry at the local university. During these years, members of his family decided to immigrate to Israel. One day he received a letter from his aunt, inviting him to come and live with her in Israel and continue his studies at Ben-Gurion University. Moshe, who grew up on Zionist ideology, felt that it was the perfect time to leave the USSR and start his adult life in the Promised Land. He decided to immigrate to Israel all by himself, leaving his parents and siblings behind.

Moshe enlisted in the Israeli Defense Forces (IDF) as an academic reserve officer, which allowed him to continue his studies and later use his new skills in the army. He enrolled in the Department of Biology at Ben-Gurion University, but very soon his passion for chemical engineering took over, and he decided to change direction and enroll in the School of Chemical Engineering at the Sami Shamoon College of Engineering and finished with the first graduates in engineering of the college. He obtained the BTech degree earlier than expected, after only three years instead of four. During his studies, he worked at the Israeli Bromine Industries and took part in a project on flame retardant materials in plastics.

In 1999, Moshe joined the Israeli Air Force as a young officer in chemical engineering, at the Fuel and Chemistry Department at Engineering unit Yahav 230 and then at the Central Aircraft Maintenance Depot Unit (Depot 22). Moshe embarked on his scientific career right there and then. He was involved in studying the effects of different impurities in fuels on engine performance, and on the effect of jet-fuel-consuming bacterial growth in fighter jets. "In this very unique environment, we can study everything from a process in a small lab beaker to dismantling a jet to pieces and seeing the impact on the various systems inside," Moshe says. As he describes it, "Jets are one big fuel tank and the effect of any impurity or bacteria could be detrimental to the mission." Hence, understanding the cause of these impurities and how to mitigate them is of great importance, especially in the Israeli jet fighter jets, which are being modified according to the Israel Air Force specifications. He also uses his methods for detection of impurities to monitor

the maintenance level of the Air Force jets: "The cleaner the fuel in the tanks, the better the quality of jet maintenance." During this work he completed an MSc degree in environmental engineering on the "Biodegradation of jet fuel", a project which inspired him to open an Air Force lab dedicated specifically to this subject.

Moshe's keen interest in research and his valuable contribution to the IDF created an opportunity for him to complete his PhD studies. The Air Force was willing to give him almost two years' leave in order to work on his PhD. As on previous occasions, Moshe managed to condense time and conduct a study on the "Development of catalysts for the production of jet fuel from vegetable oil" in the Blechner Center for Industrial Catalysis and Process Development under the guidance of Prof. Moti Herskowitz and Prof. Miron Landau, both from the prestigious Chemical Engineering Department at Ben-Gurion University. He completed the main part of his work during the time allocated by the IDF and finalized his degree in the next couple of years. Rabaev's PhD work granted him a patent and generated interest in the scientific community. Dr. Rabaev then returned to the Air Force to take the position of Head of the Fuel and Chemistry Department, the department where he started his career. In order to put the Israeli Air Force at the forefront of fuel and non-metallic materials technologies, new programs were developed on composite materials for the Israeli Air Force, new green jet-fuel development, green sustainable approach to materials in aviation, corrosion resistance, polymer degradation and the shelf life of materials and fuels, the investigation of failure mechanisms in nonmetallic materials, cooling liquids in air-defense systems such as the Iron Dome, and others.

One of the biggest challenges he had to face in his career is building a strong cohesive team to tackle all these very critical issues. This is one of Moshe's biggest prides: commanding a professional team made up of young soldiers and officers and pushing them to excel! For all of his contributions to the IDF, most of them classified, Dr. Rabaev was recently awarded the 2016 Decoration of Excellence in Technology from the commander-in-chief of the IDF.

Beyond his formal job, on a volunteer basis, he takes a modest part in the activities of the <u>Israeli Society of Chemical Engineers</u> and <u>Chemists</u> and other frameworks. He enjoys writing and editing books on his passion: engineering and science. So far, he has led the editing process of three books: "Crude oil and its products," "Topics in tribology and lubricants," and the recently published book, "Natural gas." All three were written with the cooperation of leading professionals from Israeli academia and industry and were published by the <u>Israeli Institute of Energy and Environment</u>. In the future he is planning to promote international cooperation and publish a new book by consolidating a group of leading professionals in the field of "Aviation fuel problems and its solutions".

Apart from his work, Moshe enjoys spending time with his wife Dr. Irina Rabaev and three daughters, likes to cook in his kitchen and he is in the course of inventing several new dishes.

Dr. Lior Elbaz has a B.Sc., M.Sc. and Ph.D. in chemical engineering, all from the Ben-Gurion University, Israel. During his graduate studies, he became an expert in electrochemistry and electrocatalysis. He used his expertise to develop alternative energy technologies. After finishing his Ph.D. he joined the MPA11 group, at the Materials Physics & Applications Division at the Los Alamos National Laboratory, a world leader in the development of fuel cell technology, where he developed new catalysts,



and materials for fuel cells, in order to reduce their price and increase their durability. After almost four years at Los Alamos, Lior came back to Israel to take a faculty position at the Department of Chemistry, Bar-Ilan University, where he heads the alternative Energy Lab.

Profile of Prof. Daniella Goldfarb: recipient of the 2016 ICS outstanding scientist prize

by Jordan H. Chill and Sharon Ruthstein

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Daniella Goldfarb

While other students were taking their break at Blich Highschool in Ramat Gan, Prof. Daniella Goldfarb, winner of the 2016 ICS outstanding prize, was asking the chemistry lab technician to give her one more unknown ionic solution to identify. "I was fascinated by the idea that I could find out the content of a series of transparent and colorless solutions and which ions were 'hiding' in an unknown sample." This driving force of 'discovering what is there that cannot be seen' has been the motto of her impressive academic career, leading her to investigating molecular structures, coordination of metal ions, and developing new and novel methods and theories that shed light upon the properties of a mysterious solution or solid.

As a top chemistry undergraduate at Hebrew University Daniella had the opportunity to work as a summer student in the lab of Prof. Haim Levanon. Though her role was limited to purifying chlorophyll samples for others, this experience did introduce her to the powers of spectroscopy, and the excitement of solving and obtaining molecular information from a spectrum was a motivating force throughout her scientific career. She followed her husband Arnon to the US in 1976 and completed her MSc degree at University of Rhode Island, and upon returning to Israel two years later accepted a research assistant position in the lab of clinical toxicology at the Sheba Medical Center. It took her only six months to realize that her place was in research.

"With no internet at my disposal, my search for a PhD position took place in the library reviewing publications from different groups" recalls Prof. Goldfarb. Her interest in spectroscopy and physical chemistry led her to the institution housing a couple of the few NMR spectrometers in Israel at the time - the Weizmann institute. While considering pursuing a project working on NMR on biological systems, prospective supervisor Prof. Hadassah Degani suggested that she take a few months to learn NMR theory with pioneer in NMR Prof. Zeev Luz; as it turned out, a few months turned into a full and productive PhD program with Prof. Luz. This reflects an emerging pattern - rather than being guided by a clear plan for her scientific career, Prof. Goldfarb found circumstances dictating her career decisions, and it was her passion for science, her 'give-it-all' approach to her work and good advisors along the way (for which she considers herself fortunate) that brought her eventually to success. Daniella remembers working with Zeev Luz as a real adventure filled with excitement. Sundays with Prof. Shlomo Alexander studying the theory of liquid crystals and meeting with several luminaries such as Hans Wolfgang Spiess, and Nobel Laureate Pierre-Gilles de Gennes, and collaborating with the synthesis wizard, Herbert Zimmermann, were some of the highlights

of this period. On one occasion, Daniella had voiced to Prof. Luz her concern that her collaborations with a sabbatical guest in the lab were too time-consuming and she was anxious to complete her degree. Luz paused, then informed her that, after publishing 13 papers in under 4 years, indeed she had.

Characteristically, post-doctoral plans were out of her hands. While she had her heart set on a position in the Griffin group at MIT where she was readily accepted, her husband landed an exciting job in distant Houston, and the sky seemed to fall upon her. Things, however, are not always how they seem. In what turned out to be an excellent decision Daniella joined the lab of Prof. Larry Kevan, a pioneer of pulsed EPR, allowing her to master two new fields - zeolites and pulse EPR. At the University of Houston she learned how to build a pulsed EPR spectrometer, to synthesize metal grafted zeolites materials, and with this new and exciting field she had no problem obtaining an academic position in Weizmann institute. Once again life had taken her down the right path for her. Daniella spent her first Weizmann year setting a wet lab and building her spectrometer and, and later also the a high field EPR spectrometer, one of the few worldwide. She embarked on a fruitful research program featuring developments in pulsed high field EPR techniques and their applications to materials and biological research. Another turning point was her Sabbatical at Exxon in the lab of Hans Thomann, where she mastered electron-nuclear double resonance (ENDOR). This time Arnon followed her. Her contributions include method development, advances in understanding of the physical concepts in complex pulsed EPR experiments and several novel applications of these techniques to interesting problems in catalysis and life sciences.

Another turning point in her career was when she realized that EPR was a valuable tool for studying biological systems as reflected in work with the groups of Profs. Avi Shanzer and Israel Pecht (both from Weizmann) and a long term collaboration with Prof. Shimon Vega helped her "see what the spins are doing". Now she shares a decade-long prolific

Sharon Ruthstein gained her BSc in Chemical Engineering from the Technion. She did her MSc and PhD at the Weizmann Institute under the supervision of Daniella Goldfarb. In 2008, she became an EMBO Postdoctoral Fellow at the University of Pittsburgh, where she worked under the supervision of Prof. Sunil Saxene. Sharon joined the Department of Chemistry at Barllan University in October 2011. Her research is aimed at exploiting biological pathways in human and bacteria cells, which involve metal ions, using pulsed



Electron Paramagnetic Resonance Spectroscopy (EPR).

collaboration with Prof. Gottfried Otting (National Australian University) – a pioneer in the field of paramagnetic NMR on proteins - who serendipitously joined the "EPR table" at an conference after Daniella's first presentation on distance measurements using Gd(III)-tags (which he did not attend). "This is one of my most successful collaborations, of which I am very proud and honored to take part in", reflects Prof. Goldfarb. A fitting culmination of this approach is her recent work using Gd(III) tags to obtain structural information on proteins in cells, another field in which Daniella plays a pioneering role. All in all Daniella has supervised 8 MSc students, 19 PhD students, and 22 post-doctoral fellows, and published more than 200 scientific publications in distinguished journals. " I have been very fortunate to have had the chance to work with excellent young coworkers, and having Dr. Akiva Feintuch in the lab for the last 10 years, sharing our research with me," she says. She has also received several important awards, among them the international EPR society silver medal for chemistry (2002), Fellow of the International Society of Magnetic Resonance (2008), The International Zavoisky award (2009), the Kolthoff Prize (2011), and Fellow of the Royal Society of Chemistry (2013).

Beyond her scientific achievements, her academic path has led her to positions of leadership as one of the most recognized scientists in her community. Daniella has been instrumental in making EPR visible in the broader field of magnetic resonance and beyond, efforts rewarded by an impressive list of public positions she has held. After terms as Vice President of the AMPERE, and president of the European Federation of EPR groups (EFEPR), she is currently the president of the International Society of Magnetic Resonance (ISMAR). She derived particular pleasure from her role on the editorial board of the Physical Chemistry & Chemical Physics journal.

Jordan Chill received his BSc in Chemistry summa cum laude from Tel Aviv University, and his PhD (with distinction) from the Weizmann Institute under supervision of Prof. Jacob Anglister (Structural Biology). His PhD work was awarded the Ester Helinger Excellence Prize. Chill conducted his post-doctoral studies as an EMBO fellow in the laboratory of Dr. Adriaan Bax at the National Institutes of Health (Bethesda, MD, USA) where he studied the structure and function of the KcsA potassium channel using



nuclear magnetic resonance (NMR) methods. Since 2007 Chill heads the Biomolecular NMR group at Bar Ilan University, and in 2014 he was appointed Associate Professor. The Chill group employs sophisticated NMR methods complemented by other biophysical approaches to investigate protein structure, protein-protein interactions, membraneassociated proteins and intrinsically disordered proteins, all in the context of biological function, health and disease. "I never pursued such positions, but being Israeli and a woman it always seemed that it was important for me to be at those social and scientific junctions." Back at home she has assumed leadership positions in various important committees, but perhaps closest to heart is her work in promoting women in science. "I tell all my students - it is not enough to be just a good scientist it is important to be also a human being." Prof. Goldfarb believes that world-wide gender imbalance in science can be alleviated by shifting both female scientists and maledominated administrations from current paradigms. Over the past several years she is championing a new social thinking on both sides about promoting more women in science, accepting and embracing the differences between men and women, thereby helping women find their natural position in the scientific academic world.

"I have been very fortunate in my career, and, given the chance, would do it all over again," summarizes Prof. Goldfarb. But it was not only luck. During her scientific career Daniella never chose the short or easy path; instead she took on challenges, never allowed them to discourage her, and fought for what she loves and believes in – excellent science. In a way, her seminal contributions to the fields of material and biological EPR created her own 'luck' and paved the way for future developments in these exciting fields for the benefit of scientists around the world.

פתרונות מתקדמים לתחום הכימיה האנליטית



אגנטק מציעה מגוון רחב של מכשור מדעי ומתכלים של חברות מובילות בעולם בתחום המדעי, האנליטי והרפואי.



אגנטק

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Review of the book "Corrosion Problems and Solutions in Oil Refining and Petrochemical Industry" by Alec Groysman, Springer 2016

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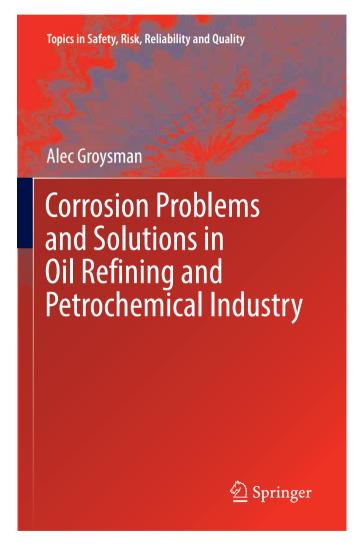
Alec Groysman

Recently, the third book of the wellknown chemist, corrosion engineer and scholar, Dr. Alec Groysman, has been published by Springer. The book summarizes the author's 40-year experience in the corrosion protection of oil refining and petrochemical facilities. It is logically organised, providing a systematic overview of process units of oil refineries and petrochemical plants with a precise description of the chemistry involved and the relevant types of corrosion

problems, classified by their mechanisms. Separate chapters focus on methods of controlling corrosion and the means of corrosion monitoring.

The principal audience of the book consists of corrosion, maintenance and chemical engineers. Accordingly, the book concentrates on a description of the main sources of corrosion problems and their optimal solutions. The core strength of the book is the focus on practical aspects of corrosion prevention. General knowledge is supported by a large number of case studies. They are very well documented, including descriptions of conditions leading to failures, location and material composition of failed parts, service time, appearance, additional examinations or analyses, failure mechanisms and recommended solutions. The case studies are accompanied by photographs, metallographic assessments and records of corrosion monitoring when needed. They represent a valuable source of data that will help to prevent similar problems in other refineries.

Since the book is focused on the practical side of corrosion control in oil refining and petrochemical industry, the author avoids lengthy discussions of fundamental aspects of described failure modes. These are indeed explained but in a condensed form useful for operational engineers. In any case, each chapter is accompanied by a short list of resources for further reading to assist those who require more details.



The appendices treating specific aspects of corrosion prevention in the oil and refining industries are also very useful. For example, the properties of crude oils, physicochemical properties of sulphur compounds, data on relevant metal alloys and procedures for cleaning and passivation of metal surfaces are given. The book has a good glossary and index. A nice idea was to include a dictionary of American and British English terms used in the industry.

The book is well written and easy to read. It is a great compendium of practical knowledge with briefly described underlying mechanisms, representing an irreplaceable source of data and knowledge for corrosion engineers and consultants active in oil refining. It can also be recommended to academics seeking trustworthy industry-relevant information. Obviously, it is the right step in the lifetime pursuit of the author to fight corrosion by spreading knowledge as he estimates that missing information and human errors are responsible for up to 65–85 % of corrosion cases, dealt with in the oil and petrochemical industries. Tomas Prosek graduated at the University of Chemistry and Technology in Prague in 1996. From 2001 until 2015, he worked at Swedish Corrosion Institute in Stockholm, Sweden and at Institut de la Corrosion in Brest, France. Since January 2016, he is leading the Department of Metallic Construction Materials in Technopark Kralupy of the University of Chemistry and Technology in Prague. His primary research interests are atmospheric corrosion, protection by metallic and organic coatings, outdoor and



accelerated corrosion testing and corrosion monitoring. He is the president of the Czech Association of Corrosion Engineers.

An executive summary of the Professors' Report

Ehud Keinan

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In October 2013, the Israeli government issued a tender to establish an ammonia production plant at Mishor Rotem in order to move the risky operation from Haifa Bay to the Negev. Unfortunately, in November 14, 2016, realizing that nobody has responded to the call, the Ministry of Environmental Protection (MEP) announced its failure. Frustrated by the government failure, Haifa Mayor Yona Yahav appointed a professional committee of scientists and engineers of diverse background to examine all aspects of the ammonia activities in Haifa Bay. The committee was requested to prepare a comprehensive expert report that included the ammonia ship, ammonia tank, land transportation of ammonia, ways to satisfy the essential needs of the domestic and export markets, etc. Mayor Yahav intended to use the report as a factual basis for legal proceedings and public discussions. To ensure objectivity and total independence, all ten committee members who are

listed below (Figure 1) agreed to work voluntarily, receiving neither compensation nor any other benefit.

- Prof. Ehud Keinan, the Schulich Faculty of Chemistry, Technion (Chairman)
- Prof. Noam Eliaz, Dept. of Materials Science and Engineering, Tel Aviv University.
- Clinical Prof. Yedidia Bentur, the Rappaport Faculty of Medicine, Technion
- Dr. Alec Groysman, Faculty of Chemical Engineering, Technion
- Prof. Amos Notea, Faculty of Technology Management, Technion
- Prof. Asher Tishler, the Coller School of Management, Tel Aviv University



Prof. Ehud Keinan



Prof. Noam Eliaz



Prof. Yedidia Bentur



Dr. Alec Groysman



Prof. Amos Notea









Prof. Yoel Sasson

Prof. Asher Tishler Prof. Amnon Stanger Prof. Dan Shechtman Prof. Israel Schechter Figure 1. Members of the Ammonia Committee.

- Prof. Amnon Stanger, the Schulich Faculty of Chemistry, Technion
- Distinguished Prof. Dan Shechtman, Dept. of Materials Science and Engineering, Technion
- Prof. Israel Schechter, the Schulich Faculty of Chemistry, Technion
- Prof. Yoel Sasson, Institute of Chemistry, the Hebrew University of Jerusalem

The report is organized in ten chapters, which are summarized below.

Chapter 1. Ammonia – properties and toxicity

Ammonia is a very toxic gas. Exposure to a concentration of 0.5% in air causes death within 5-10 minutes. Those who are exposed to lower concentrations may not die immediately but become paralyzed and, therefore, cannot rescue themselves. Rupture of the ammonia ship would create a deadly cloud of ammonia, which could reach the entire metropolitan area of Haifa and beyond. The event could create havoc of a magnitude that has never occurred in Israel's history, with hundreds of thousands of casualties. It would be impossible to reach the victims and rescue them because only rescuers equipped with autonomous breathing systems can safely enter a contaminated area. Furthermore, all the roads would be clogged with vehicles with asphyxiated or unconscious drivers. Those who would stay in closed buildings could possibly do better, but may not survive, and the event could last for more than 8 hours.

Unlike the experience gained in the Second Lebanon War, where rescue teams arrived at rocket-damaged areas immediately after the attack, in the case of ammonia contamination, rescuers would not be able to arrive in time to help the victims. Under such chaotic circumstances of unbelievable scale, people will have to take care of themselves. If the event lasts for many hours, the damage would be quite independent of the direction of the wind.

Chapter 2. The ammonia tank has never been a strategic asset of Israel

Authoritative, yet false, statements by senior officials have created the myth that the ammonia tank and related activities in Haifa represent a national strategic asset. These statements sought to support the claim of Haifa Chemicals Ltd. (HCL) that the ammonia tank is unique and irreplaceable, a vital national infrastructure. Furthermore, HCL managed to market itself as the guardian of this asset for the State of Israel in both routine and emergency situations. This position has won the overwhelming support of state officials, including the MEP, the Council of National Security (CNS), the army and even the State Comptroller, all accepting this myth as an absolute truth. However, this assumption has never been verified and is simply incorrect. The ammonia tank has never been a national strategic asset. Various business entities other than the fertilizer producers need tiny quantities, less than 3% of the excessive amounts of liquid ammonia entering the Kishon port every month. Approximately 97% of that is exported in the form of chemical fertilizers, mainly to customers in China and India. This is quite a profitable industry, but has nothing to do with national interests. Anyone interested can produce ammonia and fertilizers, preferably in the Negev. Importing huge quantities of liquid ammonia (120,000 tons per year), stockpiling it in a densely populated area, and transporting it across the country from Haifa to the Negev, a distance of 260 km, is a major strategic threat, certainly not a strategic asset.

The report commissioned by the MEP in 2011, which describes the Israeli ammonia market, is a poorly written document, riddled with erroneous data, poor analysis and, in particular, false conclusions. This is a historically important report because it was fully adopted by the MEP, as if it were a professional and objective document. Furthermore, the report and its conclusions were fully endorsed by the government and served as the basis for the problematic resolution 766 and the above-mentioned tender, which resulted in loss of valuable time and public resources and left a huge population of one million people at high risk.

Moreover, this report contradicts an earlier report by the Committee of the National Emergency Authority (NEA), which examined the need to maintain strategic stocks of hazardous materials. The NEA stated that the domestic Israeli economy does not need more than 2,250 tons per year, certainly not the current imports of 120,000 tons. Such small amounts can be imported and stored in the form of iso-tanks, which are well protected, or in other forms, such as urea, which can be distributed and stored in various sites around the country in safe sites, without risking the population. The NEA stated clearly that there is no reason to stockpile strategic inventory of ammonia and, therefore, no reason to maintain a large ammonia tank in either Haifa or anywhere else. It is a disturbing mystery why the commissioned report of the MEP, which contradicts the earlier report of NEA, has become the sole policy-determining document.

The government resolution 766 of October 6, 2013, declared the establishment of an ammonia production plant at Mishor Rotem as a national interest of vital importance and urgency, and instructed all ministries, government bodies and regulators, to promote and prioritize the project, including all aspects of infrastructure, regulation and supply of natural gas, in order to complete the project in the shortest possible time. To date, nearly four years after that dramatic announcement, there is no facility in the Negev, no ammonia production plant in the Negev, no tender for establishing one, and no probability of having such a plant in the foreseeable future. It is likely that if any business would like to produce ammonia in the Negev, it will do so without resorting to the aid and initiatives of the government of Israel. In any case, it is not the task of the Israeli government to take care of supplying raw materials for an American private company that has chosen to produce fertilizers for export on Israeli territory.

Chapter 3. Refrigerated ammonia tanks - maintenance and inspection

Recognized international organizations, such as the European Fertilizer Manufacturers Association (EFMA), and the National Association of Corrosion Engineers (NACE), have formulated detailed guidelines and standards for the maintenance of storage tanks of refrigerated ammonia at atmospheric pressure. These documents testify to the great importance the chemical industry in Europe gives to safety issues. The guidelines detail how and why to perform periodic inspections of the tanks, what is the recommended frequency of testing, what test method should be used, and how continuous monitoring should be performed between inspections. All of these reflect the considerable probability of failure and the high risk to the population and environment.

Ammonia tanks are built according to international standards that require radiographic testing (RT) and magnetic testing (MT) methods to ensure the quality and integrity of welds, which are of critical importance throughout the life of the container. The main cause of metal aging is the phenomenon of stress corrosion cracking (SCC). Any material under a corrosive environment develops cracks that can cause sudden and unexpected failure. These microscopic cracks undergo gradual branching and eventually unite to form macroscopic cracks, which may lead to sudden collapse of the metal structure with catastrophic results. Metal surfaces may look fine and shiny and, yet, may contain multiple microscopic cracks. The SCC phenomena vary greatly with the toughness and strength of the metal plates, quality of welds, internal stress, external pressures and function of the tank. Thus, decisions on the planning and execution of internal inspection programs are of crucial importance.

Another risk factor is metal fatigue, which stems from periodical fluctuations in stress of temperature and pressure over time. This phenomenon is manifested by tiny microscopic cracks, which penetrate deep into the material, weakening its ability to resist the load until it breaks down abruptly. Metal fatigue is one reason why the average life span of a refrigerated ammonia tank is limited to about 40 years. Consequently, according to the European standards, the 31-year old tank in Haifa is rapidly approaching the end of its life.

The EFMA Guidelines repeatedly emphasize the requirements for very high levels of skill and experience in managing and conducting the periodic inspections. Reliability of data is critical for making decisions on how often the tank should be examined. Risk-based inspection frequency is linked to two factors: the probability of failure and the expected consequences. In light of these guidelines, the fact that the tank in the Haifa Bay has never been inspected internally over its 31 years of operation raises serious questions. Even if the tank were perfectly built using the best possible materials, and even if it were located in the heart of the Sahara Desert, hundreds of kilometers away from any settlement, the final inspection date already passed six years ago. Obviously, the construction technology of 30 years ago was not perfect, and the tank is not located in the Sahara desert. Using the risk matrix of the EFMA guidelines, the Haifa tank had to undergo an internal examination, at least three times during its lifetime. This negligence could result in a heavy toll of human life. The tank is already in the "red area" of the risk matrix, namely the highest possible risk, which requires immediate cessation of all activities, emptying the tank and immediate inspection from inside.

The most highly recommended technique for internal inspection is wet fluorescent magnetic testing (WFMT), which is the most sensitive way for detecting SCC. The test is also very useful for repeated testing after welding repair and after heat treatment. There are other methods, such as the introduction of dyes, radiography, ultrasound and acoustic emission, some of which can be done on the outside of the tank with no need to stop its activity, but these are less sensitive and cannot detect cracks below a certain threshold. For example, the method of acoustic emission is relatively easy to perform from outside, but its sensitivity is very low. EFMA guidelines stipulate that non-invasive tests can be conducted only if at least one internal testing and external testing have been performed where the internal inspection revealed no significant SCC, general corrosion or intrinsic inborn defects. In other words, the single test, which was carried out in the Haifa tank by the acoustic emission method in February 2015, is meaningless and unacceptable according to European standards.

Chapter 4. The inspection results of the ammonia tank in Haifa Bay

The statements made by HCL officials, claiming that the ammonia tank has been tested and that the test fully confirms its integrity and credibility, is false, has no factual basis, and

is misleading, irresponsible and dangerous. Furthermore, the statement made by HCL that the expected lifetime of the tank has been extended for additional 55 years, is unprecedented and outrageous. The test was carried out in an amateurish way, contrary to international standards and guidelines, ignoring the key principles of risk-based inspection. It is very disturbing that the severest environmental risks in the State of Israel, which may affect hundreds of thousands lives, is ignored by the regulator. The absence of the MEP at all phases of the fake inspection is glaring. HCL decided by itself when to test, what to test, how to test, who will perform the inspection, how to report, to whom to report, and the Ministry gave an automatic approval stamp after the fact. Since an internal inspection has never been performed over the entire 31 years of the tank, which is unprecedented by any international standard, and because the acoustic emission report indicates the possibility of the existence of serious cracks in the tank wall that could lead to collapse within a few months, it is essential to decommission the tank immediately and prepare it for a true inspection.

Chapter 5. Analysis of world accidents involving ammonia tanks

All accidents described in this chapter are relevant to the ammonia tank in Haifa Bay, especially the accident that occurred near the town of Jonova, Lithuania. The ammonia tank of Jonova was built under the supervision of a reliable Japanese company. That tank is highly relevant to the Haifa one because it was of a similar size and was constructed by a similar method. When that tank collapsed due to metal failure, which can occur anytime in Haifa, it was only 11 years old, i.e., 20 years younger than the Israeli tank. It was an insulated steel tank with external steel casing, tightly fasten to its concrete foundations by 36 massive steel strips. In addition, the tank was surrounded by a protective wall of 40 cm reinforced concrete, like the one in Haifa. All of these features did not prevent the tank from bursting powerfully and flying 40 meters away, uprooted from its foundation, tearing all the welded steel bands and taking the concrete wall on its flight. Although, fortunately, most of the gaseous ammonia cloud flared and burned, yet the clouds of ammonia reached 32 km and created a contaminated area of 400 square kilometers.

In Soviet times it was possible to quickly evacuate 32,000 people from the disaster area. In Israel today, nobody can evacuate 600,000 residents from the area near the tank or to offer them any kind of help. In addition, one should keep in mind that the Jonova area of Lithuania is not tectonically active and is not prone to earthquakes, as opposed to the Haifa Bay area. Furthermore, Jonova is not threatened by terrorist organizations like our region.

Chapter 6. Risks involving the ammonia ship

Hezbollah Secretary General declared that he considers the ammonia tank to be an "atomic bomb" at his disposal. This statement sounds boastful, unrealistic and baseless. The two atomic bombs that were dropped on Hiroshima and Nagasaki at the end of the Second World War claimed 246,000 human lives. A similar toll of 230,000 deaths resulted from the tsunami in the Indian Ocean in 2004. Both of these events are remembered as traumatic events worldwide, mainly because they occurred as a complete surprise, within a terribly short period of time, and because the victims were innocent and helpless against tremendously powerful phenomena. Hezbollah Secretary General was absolutely right about the destructive potential inherent in the tank, and even more importantly, in the ammonia ship.

Despite the fact that the threat posed by the ammonia ship is far larger and more significant than the one associated with the ammonia tank on the beach, it had never been part of the public agenda. The Shafir Committee, which was established after the Second Lebanon War, intended to examine all aspects of preparedness and defense with regard to hazardous materials in the Haifa Bay in both peaceful and war times. Their report, as well as the 2011 report of the MEP, never mentioned the risks posed by the ship. Only recently, after bringing this issue to the Supreme Court in July 2016, the MEP admitted that damage to the ship would actually create a cloud of ammonia gas with a lethal range of 6 km. These estimates were established with more details, although referring to the ammonia tank, by the Haz-Mat report of 2007.

Once a month, for already 30 years, the ammonia ship enters the Kishon port, carrying a tremendous amount of 16,700 tons of liquid ammonia within 5 containers. Usually, it stays at the port for two days, and during that time pushes about 10,000 tons of ammonia into the tank on the beach, to renew the maximum allowable capacity of 12,000 tons. A detailed study, published in 1974 by the US Coast Guard, assessed the risks of marine transportation of liquefied ammonia. It was found that the contact between liquid ammonia and seawater causes a spontaneous exothermic reaction that has catastrophic consequences. Their experiments demonstrated that approximately half of the liquid ammonia dissolves in water, but the other half evaporates immediately, creating a cloud of ammonia gas. One can compare this phenomenon to the familiar event of pouring water on hot metal surface or into a pot of boiling oil.

Rupture of the five tanks in the ship would result in a cloud of ammonia weighing over 8,000 tons and the initial height would be 600-800 meters. Although ammonia gas is lighter than air, it reacts with moisture in the air, forming an equilibrium with water crystallites thereby keeping the ammonia near the surface for many hours. Videotaped leak events at various locations around the world show that the ammonia contamination looks like a thick white fog creeping close to the ground. In the accident occurred on the Jonova site in Lithuania, clouds of ammonia reached as far as 32-35 km, contaminating an area of 400 square kilometers. The free software ALOHA is widely used by the US Environmental Protection Agency (EPA) and by the MEP, Ministry of Defense and the chemical industry. The ALOHA predicts that on a fair weather, partly cloudy, when the wind speed is 10 miles per hour, which is very common in Haifa, the area of the deadly cloud of ammonia could reach a diameter of more than 20 kilometers, depending on the wind direction, and could travel a distance of tens of kilometers, until gradually dissipating and being absorbed in the ground. The event will last for at least 8 hours and, during this time, all those trapped within the danger zone and not equipped with autonomous breathing system with oxygen tanks, will choke to death within 5-60 minutes.

All the metropolitan areas of Haifa and its suburbs are within the range of this deadly cloud, even if the attack occurred when the ship was within the waiting area in the center of the bay, away from the port. Technion City is just 4 km away from the port and Haifa University, 5.5 km away. According to the known wind directions in the Haifa area, the chances of survival in these campuses would be very slim. The effect on the Haifa hospitals would also be a fatal blow. Even if someone would trigger an alert signal, it would not be possible to evacuate the hospitals and their medical teams in a timely manner. This would effectively neutralize the entire health system in the metropolitan area, including Rambam Hospital, the Italian Hospital, hospitals in the Carmel and Bnei Zion. Over 600,000 people would be at high risk. Such numbers are inconceivable in any apocalyptic scenario that has been considered by any security officials in Israel. This means hundreds of thousands of casualties, blocked roads and a chaotic situation that this country had never experienced. There is no rescue organization that can control disasters of this magnitude. Nobody can collect real data in real time, analyze, make decisions and initiate any action.

The ammonia ship cannot be protected against a terrorist act. Planning, scheduling and execution of a terrorist act on the ammonia ship entering Haifa is much simpler than many recent terrorist attacks in Israel and abroad. The arrival times of the ship are known for at least one week in advance with an accurate day and hour. Anyone can easily follow the ship route using any smartphone with the free app MarineTraffic. The ability to prevent an attack on the ship is essentially impossible. A multinational team of multiple citizenships operates the ship. These sailors are replaced frequently at various ports along the ship's route from Ukraine, through various ports, including the ports of the black sea, Turkey and North Africa. It should be remembered that the ammonia ship has a standard steel envelope of 19 mm thickness, and this is also the thickness of the ammonia containers. The distance between the envelope of the ship and the containers is usually 20 cm. In military terms the ship and its containers are only slightly stronger than a tin can. Any terrorist can consider a wide range of weapons, devices and scenarios that could rupture the ship and containers. Even a machine gun positioned outside the port can do it. The damage can be done by various explosives placed inside the ship, shoulder-fired missiles, magnetic bombs, marine mines, as well as a direct hit by a surface-sea missile, such as the one that hit the IDF combat ship in 2006. Hezbollah may prefer the scenario of a hit by an accurate missile, because it would be very easy to target a large stationary ship. Moreover, it is possible to accurately plan the time of attack for optimal meteorological conditions in terms of damage efficiency.

Chapter 7. Risks of tanker trucks: analysis of accidents around the world

HCL consumes 85,000 tons of ammonia out of the annually imported 120,000 tons. The company operates two production sites, each consuming about 40,000 tons annually. Thus, 40,000 tons ammonia are transported using road tankers from Haifa to the Negev. The average transportation rate is 10 trips a day, through densely populated areas, from northern Haifa Bay to the southern site at Mishor Rotem, south of Arad, a distance of 260 km. Fortunately, during nearly three decades of activity there were only few of road accidents involving tankers ammonia, and none of them breached the tanker itself. Fortunately, to date, terrorists have not targeted these tankers, despite the fact that the release of 20 tons of ammonia gas in urban area can be disastrous. The potential damage following either a mechanical failure or a terrorist attack can be assessed on the basis of accidents involving road tankers, which occurred worldwide. In one case where an ordinary road tanker collapsed, it ended with 129 dead and 1,150 wounded. The level of risk that Israel imposes on its citizens to enable business activity of a private company is unreasonable and intolerable. The business model of importing liquid ammonia to Haifa, for use in Mishor Rotem, is not acceptable in a modern country.

Chapter 8. Risks associated with the regulator's weakness: Bhopal and Seveso

Industrial activity is very expensive in developed countries due to the intricate regulatory track and procedures in terms of time and money. Therefore, it is quite tempting for developed industries to conduct their dangerous activities in places where safety requirements and enforcement capabilities do not exist, or are relatively weak. In this way they can bypass the expensive routes of licensing and continuous supervision and avoid the need for approval by the local population. This is a way to increase profits by saving on quality and security arrangements at the production facilities. Increased profitability comes at the expense of the local population, which cannot be protected by the political leadership. Since the activity usually involves cheap products and low technology and because safety standards and insurance coverage in developed countries are expensive, the advantages to the foreign company are obvious. International organizations, such as the United Nations, have already considered such scenarios and the risks posed to vulnerable populations whose politicians are unable or unwilling to protect them. Still, there is no mechanism in which international organizations can protect these populations.

Understanding the parameters that led to the disasters in the city of Bhopal, India, and in Seveso, Italy, can prevent a disaster of similar magnitude in Haifa Bay. In all cases, there was a company from a developed country, which would have good reasons to set up factories in a weaker country. The Swiss company Givaudan chose to build a plant in Italy, the American company Union Carbide chose to build a plant in India, and the American company HCL has chosen to operate in Israel. In all three cases, if the company would have been operating either in the US or in Switzerland, its profitability would be much lower because the product is cheap and the technology is relatively low, whereas safety standards in these countries are rigid and costly, and insurance coverage is very expensive for such activities. In all three cases, there is a company that takes advantage of cheap labor in another country, where safety barriers are low and the regulator is absent, careless and toothless. The big difference is that in India and Italy the disaster has already happened, whereas in Israel it has not yet.

Chapter 9. Risk management

According to the theory of risk management, the seriousness of a given risk is expressed mathematically as the product of two parameters: probability of the event and severity of the consequences. Security officials, not only in Israel, tend to ignore this basic principle, especially when exposed to public debate, or even when presenting an expert opinion in court. Phrases such as "an event of very low probability" are meaningless, and their use reflects irresponsibility. We all remember the complacency and smugness of security officials in the US with respect to feasibility of the attack on the Twin Towers in New York, not to mention the estimates of Israeli intelligence and the political leadership on the eve of the Yom Kippur War. Whoever treats only the likelihood parameter and ignores the severity of the incident, is wrong and misleading, because it converts a two-dimensional surface into a onedimensional statement, which is meaningless. Converting a

serious discussion that is based on quantitative logic into a populist debate, based on qualitative terms, is inexcusable, because it harms not only the subject of discussion, but also the level of discussion.

The ammonia risks may be discussed in the context of earthquakes. First, there is a very likely chance that an earthquake at the Yagur Fault would lead to fracture of the ammonia tank. The MEP has recently predicted that the lethal range of the ammonia cloud, which will be created by the collapse of the tank, would be 4 km, and a terrorist attack on the ammonia ship would create a lethal zone of 6 km. Our estimates, based on the ALOHA program, are larger than 10 km. Given the population density at these ranges, the number of casualties, especially fatalities, could reach hundreds of thousands.

Secondly, there is an unjustified difference between the way the State of Israel evaluates the risks of major earthquakes (probability is low, and the potential for damage is relatively low) and the way it manages the risks associated with the ammonia activities (probability is high, and the potential for damage is relatively high). The expected loss of lives is 10 times higher than the expected toll of a major earthquake. This difference may be attributed to incorrect risk management and the fact that earthquakes are familiar phenomena. The scenario of mass poisoning by an ammonia cloud is an unknown disaster and is therefore transparent to the public and political eyes, resulting in ignorance and complacency.

The public commission report of Major-General Herzl Shafir considered only risk scenarios that were easy to handle but of marginal insignificance. They referred only to the ammonia tank, but not the ship. They referred only to top-attack of the tank, only by high-trajectory weapons, only to damage during a declared war, etc. This is, of course, only one disaster scenario out of countless scenarios, all being ignored, including the dire scenario that would involve the collapse of the tank as a result of metal fatigue, earthquake, terrorist attack, strike by flat track weapon, not to mention an attack on a ship of ammonia, which is the worst scenario. The Committee acknowledged that "in the routine, the situation of a hazardous event, fault, terrorist event, it is not the responsibility of the IDF, so we do not know how to deal with those ... in principle, according to our instructions and in accordance with our mandate, the tank is protected to our satisfaction." And yet, the commission transmits a tranquilizing message for all other scenarios not even discussed by them. This complacency of the committee makes the lines of separation between risk factors vague. Because there is no entity willing to take a comprehensive responsibility, the situation is difficult and complex, allowing for continuing "business as usual" and ignoring the actual risks.

Chapter 10. Alternative ways to match the Israeli demand for ammonia

There is no need to import liquid ammonia to Israel by ship and there is no need to risk hundreds of thousands of people during this operation. There are several reasonable alternatives to this activity. None of these alternatives requires huge tanks of the kind found in Haifa Bay. Other industries that need small or medium size quantities can import ammonia using well-secured iso-tanks, which come in size of 20 feet long (12.5 tons of ammonia), 30 feet (18 tons) and 40 feet 23 tons). Such containers are locked up in a steel cage with dimensions identical to those of standard marine containers. Their transportation is safe and effective, is not expensive and handling is similar to that of regular containers. All needs of the Israeli economy, except for the fertilizer industry for export, is merely 3,000 tons of ammonia per year. This amount can be imported using 150 iso-tanks. There is no need to bring in all that amount at one time, and it can be imported sporadically through container ships transactions, which reach all Israel's ports, without special safety requirements.

Ammonia can also be produced on site from urea, a solid, granular material, which is easy and very safe to import and store indefinitely. There are effective technologies to hydrolyze urea to ammonia, so that all the ammonia produced is consumed immediately and therefore there is no need to store it in a container of any sort. The Israel Electric Company produces all the ammonia it needs for neutralization of nitrogen oxides in the Orot Rabin power station. They plan to reach an annual consumption of 200,000 tons of urea, which enables the production of 113,000 tons of ammonia, almost equivalent to the liquid ammonia imported to Israel by HCL. It is also possible to produce ammonia from natural gas in small quantities, as can be seen all around the world in the last 20 years.



קורסים מוכרים לגמול השתלמות

להיות מנהל פרויקט

קהל היעד: מהנדסים והנדסאים בעלי תואר ראשון, לפחות, בתחומי הנדסה ואשר עוסקים במקום עבודתם במשרת ניהול ונדרשים מדי פעם לנהל פרויקטים ("נוסף על תפקיד").

הקורס להיות מנהל פרויקט מבוסס על הספר "להיות מנהל פרויקט" ועל יסודות הליבה של המקצוע: תכנון הפרויקט, בקרת הפרויקט והתקשורת בפרויקט, והוא מתווה דרך ומסביר בגובה העיניים כיצד להיות מנהלי פרויקט הלכה למעשה. כל פרויקט שהוא, בכל גודל ובכל עולם תוכן. נתמקד בליבה, נעסוק בַעיקר ובפרקטיקה ונציע שלל כלים מלווים, ייחודים ופשוטים לשימוש קל ומידי וכן, נלמד כיצד לנהל את הזמן העומד לרשותנו בצורה אפקטיבית וכיצד להיות מנהלים-מנהיגים

בסיום הקורס המשתתפים יבינו את תפקידו של מנהל פרויקטים מזדמנים, ידעו את יסודות המקצוע ויקבלו סט של כלים יישומיים לניהול של פרויקט קטן.

בין הנדסה לקיימות – פיתוח מוצר מקיים

קהל היעד: מהנדסים/הנדסאים ומנהלים בעלי תואר ראשון, לפחות, בתחומי הנדסה, ניהול או כלכלה.

פיתוח מקיים מתמקד בפיתוח מוצרים העונים על צרכי ההווה תוך התחשבות בצרכי הדורות הבאים. במציאות הנוכחית, שיקולים סביבתיים אינם עוד מותרות, אלא חלק בלתי נפרד מליבת הניהול, הייצור והפיתוח בתעשיות השונות. ארגון אשר אינו מטמיע שיקולים סביבתיים כבר בשלבי התכנון הראשונים, נתקל לעיתים בחסמי כניסה בשווקים ובעלויות בלתי צפויות. הקורס מעניק ארגז כלים לפיתוח מוצרים העונים על קריטריונים של סביבה וקיימות, תוך התייחסות למוצר לאורך מחזור חייו המלא, החל משלב כריית חומרי הגלם ועד סוף חיי המוצר בפן הטכנולוגי כלכלי וניהולי.

בסיום הקורס המשתתפים יבינו את משמעותם העסקית טכנולוגית של האתגרים הגלובליים הנוכחים. המשתתפים, ידעו להתמודד עם השלכות האתגרים הסביבתיים ויפנימו את עקרונות הפיתוח המקיים כך שיוטמעו בעבודתם השוטפת ובחיי היום יום. המשתתפים יפתחו חשיבה ביקורתית מקיימת, וימנפו הזדמנויות לפיתוח מוצרים מקיימים בעלי ערך טכנולוגי כלכלי וסביבתי.

ביומימקרי

קהל היעד: מתכננים, מהנדסים, אדריכלים, מעצבים, ביולוגים, יזמים, אנשי ניהול והוראה המעוניינים לשלב חשיבה ביומימטית וכלים ביומימטיים בעבודתם.

ביומימיקרי (Biomimicry) הוא תחום דעת רב - תחומי המתפתח בקצב מואץ בעולם העסקי ובעולם האקדמי ומזוהה כמנוע חדשנות. הנחת היסוד הביומימיקרית היא שהפתרונות למרבית הבעיות שבהן נתקל האדם כבר נפתרו בטבע. שילוב הידע האנושי עם הידע שבמערכות הטבעיות מאפשר פתרונות חדשניים ומקיימים.

הקורס "מבוא לביומימיקרי" מוצע לכל מי שסקרן להכיר את הטבע כמחולל רעיונות, לפתח חשיבה אחרת המזהה בטבע פתרונות לאתגרים, לרכוש כלים לחדשנות מן הטבע, וליהנות ממפגש בינתחומי מפרה עם אנשים מדיסציפלינות שונות. אנו מזמינים אתכם ללמוד כיצד לעצב את עתידנו בדמותו של הטבע.

הקורס יתמקד בבסיסים התיאורטיים של דיסיפלינת הביומימיקרי לצד מיטב הכלים והמתודולוגיות הקיימים, וישלב התנסות מעשית וחווייתית בפיתוח אתגר ביומימטי בצוותים רב תחומיים.

קורוזיה, ציפויי הגנה ובקרת איכות

"צבע" (ציפוי) הנו האמצעי הנפוץ ביותר למניעת קורוזיה על-ידי בידוד הפלדה מהלחות ומתנאי הסביבה הקורוזיביים. משך חיי הצבע תלוי מאד באופן הכנת השטח ובאיכות תהליך הצביעה.

משאבים רבים מושקעים בצביעה איכותית למניעת קורוזיה, מתוך כוונה להאריך את חיי הצבע ולהימנע מהוצאות אחזקה מוקדם מהצפוי.

מטרת הקורס הקניית ידע בסיסי בקורוזיה; רכישת ידע מקצועי בצבע וצביעה– הכנת שטח, יישום, בקרת איכות ופיקוח; יושם דגש על הכרת שיטות, ציוד ותקנים לבקרת איכות לתהליך הצביעה ובדיקות איכות למוצר הסופי.

ICS panel discussion: How can we raise the next generation of Israeli Nobel Laureates in chemistry?

Ehud Keinan

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This is a transcript of the Panel Discussion held during the 82nd Annual Meeting of the ICS, February 13-14, 2017, at the David Intercontinental Hotel, Tel-Aviv, Israel. Prof. Chaim Sukenik of Bar-Ilan University and the Lev Academic Center moderated the discussion with three panelists: Nobel Prize Laureate Prof. Aaron Ciechanover of the Rappaport Faculty of Medicine, Technion, Prof. Lia Addadi of the Department of Structural Biology, Weizmann Institute of Science, and ICS President Prof. Ehud Keinan of the Schulich Faculty of Chemistry, Technion.



Left to right: Profs. Chaim Sukenik, Aaron Ciechanover, Lia Addadi, Ehud Keinan

Prof. Chaim Sukenik opened with the following remarks: "The Nobel Prize has always been viewed as the ultimate mark of excellence and academic distinction. Israelis (people of the book), have always been proud of academic achievements and so even before the Startup Nation phenomenon we've attributed great value to intellect, innovation and accomplishment. In fact, even in the early days of the State of Israel there was a major emphasis placed on education at all levels. One of the major concerns of most Israeli parents has always been how to give their children the best education and the best training possible, either at school or by various supplementary programs.

There is a sense that the quality of Israeli education may have changed a bit over the last decades. There have been significant national discussions surrounding our educational system and whether or not we will be able to remain competitive in the international arena. As recently as this past November, there were reports that Israel's standing in international math and science exams was not what it should be and there is genuine concern about all this.

As to Nobel prizes, some of you may recall that for the first 50 years or so after the founding of the State of Israel, while there was a lot to be proud of, some people were expressing consternation and asking why is it we have no Nobel prizes? As if it was assumed that if we were really any good that was to be expected. There was Agnon's prize in literature, which was largely awarded for work he did during pre-state times, and there were the peace prizes that Menahem Begin, Yitzhak Rabin and Shimon Peres received. Nevertheless, the expectations were for something more.

That all changed about 15 years ago. In 2002 and 2005, Daniel Kahneman and Robert Aumann received Nobel prizes in economics. In the decade starting with 2004, chemistry in Israel stepped into the center stage, as there were six Nobel prizes awarded to Israeli chemists. In 2004, Aaron Ciechanover and Avram Hershko were awarded a Nobel Prize for their work with ubiquitin. Then, in short order, Ada Yonath was awarded a Nobel Prize for her work on the structure of ribosomes, Dan Shechtman was awarded a Nobel Prize in 2011 for his work in quasi-crystals and, in 2013, Arieh Warshel and Michael Levitt were awarded a Nobel Prize for their computational work. These prizes are certainly a source of tremendous national pride and inspiration that reflects our respect and admiration for the prizewinners. But the question that we'd like to address today is where do we go from here? What does this mean for us today in the State of Israel? How does one try to maintain or even enhance this moment, and how does one raise the next generation of Israeli Nobel laureates in chemistry and other sciences?

We're honored to have with us a diverse panel, each of whom brings their own perspective to this question. I will not go into long introductions of any of the panelists. If there are aspects of their background that they would like to mention in terms of how their personal history has led to their developing the perspective they are going to share with us, they're free to do so. Prof. Ehud Keinan, is ICS President and Chairman of the Advisory Council of High School Chemistry Education. He also plays a very important public role in defining Israeli policy with respect to chemistry in the environment today. Prof. Lia Addadi came to Israel from Italy, where she did her first degree. Lia did additional training and her PhD at the Weizmann institute and ultimately came back to Weizmann as a professor. She is now involved in several leadership positions at the Weizmann Institute. Prof. Aaron Ciechanover was trained here in Israel, primarily in medicine. I encourage all of you to take a look at the biographical essay that Aaron has on the Nobel Prize site. I must tell you that I regard it as a source of pride as a Jew and an Israeli citizen, to see how he has so strongly identified with his Israeli and Jewish background, and developed from that to the international standing that he has achieved today.

What I ask our panelists to do, is that each of them should take 5-7 minutes to share with us their own take, their own flavor, their own perspective, on the question of how can we raise the next generation of Israeli Nobel laureates in chemistry. I will then ask 1 or 2 follow-up questions of each of them and open up a couple of questions where we'd like to hear from more than one of them. If we have time, we'll open up the discussion to questions from the floor."

Prof. Ehud Keinan: "First of all, I would like to point out that Nobel Prizes are not the goal, they are just an indication that we're in the right direction, but they are not themselves the goal. We are all scientists here and I would like to talk in quantitative terms and cool down a little bit the enthusiasm about being the Startup Nation and about the current situation in the State of Israel. We have to remember that the people who are responsible for being a Startup Nation are not the 8.5 million people who live in this country. A mere 120,000 people, only 1.4% of the population, are responsible for the glory of the Startup Nation. I am not very happy with the education level the other 98.6% have.

I want to make another quantitative comment. Half of the Jewish people live in Israel, and the other half reside outside the country. If you consider the large number of Nobel prizes awarded to Jewish scientists, you realize that the chances for Jewish scientists to win Nobel prizes are 10-fold higher if they live outside the State of Israel.

I think that the main problem is our formal education system and our failure to identify and encourage the excellent pupils. Albert Einstein already mentioned that the formal education system is a perfect killer of curiosity, saying, "it is a miracle that curiosity survives formal education". He also said, "I have no special talent, I am only passionately curious." Most teachers deliver the wrong message that for every question there's only one answer, and even worse, the correct answer is that of the teacher. In order to become excellent, our kids need to have not only curiosity, but also critical thinking and skepticism. And most of the teachers in the formal education system, as well as parents, kill both curiosity and critical thinking. By doing so, they kill the chances for these kids to win future Nobel Prizes. The enemy of excellence is perfection. In order to achieve a perfectly smooth surface one has to polish the rough surface, to cut off anything that sticks out of it. In other words, making something perfect means killing those very features crucial to achieving excellence. Those unusual things that stick out of the surface are the excellent pupils and students, the gemstones we are looking for. It is very interesting that human beings do not differ much in their anatomical properties, such as body weight, height, size of the skull, brain weight etc. The range is probably not more than 30%. However, the differences in intellectual capacity may span a spectrum of several orders of magnitude. Thus, finding the pupil who is 10,000 times above the average is an extremely challenging but important and rewarding task, like finding a hidden goldmine. In most cases those potential goldmines finish their high school unnoticed. Most of these excellent people develop their talents outside the formal education system. If we could only double the thin layer of excellent students in Israel from 1.5% to 3%, this would be a different country."

Prof. Lia Addadi: "I don't believe that the title question sets the right tone: we should not educate students to get Nobel prizes. We should educate them to become good scientists, in this case good chemists. The Nobel Prize might be a possible consequence of being good scientists; it cannot come as a pre-condition.

Good scientists are broad-minded and forward-thinking scholars, the accent being on the depth as much as on the breadth. Chemistry is not a definition of a specific area of activity, it is a definition of the order of magnitude at which we deal with the subject: chemists are those who think at the level of molecules, their interactions and their structures, whether this is applied in the area of physics, materials, biology or chemical synthesis.

I am a chemist who has been applying my chemical understanding to biological systems for more than 30 years, doing research that ranges from physics to biology through chemistry. This did not make me a biologist and I'll never think as a biologist, no matter what I have learnt about biology. I believe that I'm not a unique example. So what should we teach young chemists? I believe that we must give them a strong basis of understanding of what occurs at the molecular level, including providing them with the tools, such as spectroscopy, imaging, microscopy or structural methods, which are needed to unravel new things at the molecular level. Armed with this strong basis, they will then be able to apply their approach to any system and any problem they wish to investigate." **Prof. Aaron Ciechanover**: "We must change our educational attitude in order to attract young people to science. I interact a great deal with young people. Actually, 30-40% of the time I devote to volunteer activities goes to the educational system. I just gave a talk last week in a high school in Kiryat-Haim and a week before I gave a talk in Tirat Hacarmel. I insist on developing conversations with school kids, not giving them lectures. They present to me their view of chemistry and I try to present to them a different view, mostly my own perspective, going from chemistry to medicine.

For many of them it is a discovery because many of them want to be physicians, others want to be researchers in other areas and I tell them that it is all the same. A pill is a drug and any drug is a molecule and the molecule enters the body and acts based on a certain mechanism. I tell them how a drug is developed, I tell them about screening, about animal models, and clinical trials. I found that they are completely blind to these basic things. For them a drug is something that they buy in the pharmacy. I hope that my efforts will eventually trigger their curiosity. I think that we need to change our departmental structures. If you look at the departments of chemistry in Princeton and in Harvard, half of them are pure biologists in one way or another and the situation in our chemistry departments is very different.

I wish to share with you something objective, and that's the fact that we're closing ourselves in ivory towers away from the public. Part of the war against us is a war against science. People tell me from time to time that they believe in God but they don't believe in science and I have to tell them that science is not a faith. Science is a method of testable experiments that at the end leads to progress and improvement of our lives. They compare religion to science, claiming that if I believe in one, I don't believe in the other. I would like to briefly discuss with you two big wars that are being conducted these days:

One is about genetically modified organisms (GMO), which is all about chemistry. What do we do? We equip organisms or plants with the ability to resist extreme climate changes, herbicides, or increase yield in crops in the field in arid areas. So there is a big war against GMOs, in which I'm deeply involved. Another one is about climate change, which is also about chemistry. Many people around the world mix these issues with religious argumentation. People believe that the creator will not harm his people, and that we shouldn't tamper with God. Changing climate is harmful so are GMOs. That's how God created nature and we shouldn't tamper with it. When I interact with the public I ask a simple question. Do you eat DNA? And they answer: Me? I never eat DNA - God forbid.

I ask if they eat tomatoes, and they say yes. So, I ask what do you think a tomato is made of? Or cucumbers? Or cheese? It's all DNA. You're eating grams and grams of DNA. And then what happens to it? It's all being digested in the intestinal tract. People don't believe me when I tell them that they eat DNA. But that's the only way to educate them, or at least bring them to ask and answer simple questions.

The same is true for politicians. We need to educate them just as we need to go out and educate the public. We think that the only role of the public and the politicians is to provide us with money for our research and we need to tell them how we do the job. We must talk to the public and educate the public. We need to convince the politicians that science is not a kind of faith, it's a method that has been developed along the years: a testable, proven system, an international language. These are two complementary efforts with a common goal.

Science is all around us. A cellphone is science, a fridge is science, communication is science, everything is science, and it's all chemistry. There's nothing around us that isn't science. We must convey these messages to the general public. We must reach out to the public. It's much easier to brain-wash the public about all kinds of nonsense about GMOs and climate change and so on, but the work at the end will penetrate our homes and laboratories and we are going to lose if we're not going to do something about it."

Prof. Chaim Sukenik: "Thank you all very much. I'd like to take the prerogative and ask one follow-up question of each of you, then, perhaps, we can open things up for further questions. Ehud, I'd like to go back to you. I heard a talk by Dan Shechtman a couple of years ago, where he argued that the place to really convince people about science, to educate them, is starting at kindergarten. He has actually launched a program in the city of Haifa that tries to promote science education at that early stage. More broadly, we see an initiative now, from the ministry of education, pushing 5 bagrut units in mathematics and advancing English education. How does one get the public to buy into this? What's the secret of achieving this turn-around in public perception? How do we get both young and old to realize that science is all around us? How do we stimulate interest in science?"

Prof. Ehud Keinan: "I'm sorry to sound pessimistic about the formal education system everywhere, all around the world, including Israel, or particularly in Israel. If you look around and you see the excellent people, those who really made it, you find out that they got their education that made them so special outside the formal education system. The found it in some extracurricular activities, clubs and opportunities outside the schools.

The formal education system is a commodity. If they succeed, they provide the perfect education system, but not the education for excellence. If they're successful, they kill curiosity. If you look at every 5 years old child, you see that they are extremely curious about everything. They make us tired just to follow what they do, because they're so curious. When they go to school, you put them in a place that starts changing them. They go into a mental cage, where they learn to become perfect. We need to find ways to promote curiosity and bring them to see experiments and ask questions and be critical. That's what Dan Shechtman is trying to do in kindergartens and elementary schools around Haifa.

We keep talking about other people, but I want to make a statement here and approach the people in this audience. We all want to have excellent people. We all want to have people breaking away from the pack, or thinking outside the box. Of course, all six Israeli Nobel Prize laureates in chemistry are of this sort. The entire world has been going in one direction, and these people chose to go in the opposite direction. They all broke away from the pack, investigating protein destruction, for example, when everybody was studying protein construction. It's not something that we can teach. However, I think that we have a huge responsibility, and this is because the politicians are not going to make it happen. Don't expect that the politicians will make it happen. They don't even understand why curiosity and critical thinking are so important. Most of the teachers are not going to make it work either. An average teacher on a minimal salary is not going to make it happen. We need very special people to be able to bring about this revolution. And if we talk about excellent people, there are probably not more than 2-3% of excellent teachers.

So, who is going to do it? I believe that the people in this room can do it and it is our responsibility to make it happen. I feel that we must recognize the responsibility to promote excellence in science. I am doing as much as I can. It is very clear to us what should be done and we are the only people who can fully understand what should be done. Everyone in this room understands what I'm talking about and you know that you can do it. And if you don't, please don't complain that things go wrong in this country, simply because everything starts with education and everything is related to the quality of education. You can devote part of your time. We are all very busy, but even if you give it as little as 1% of your time, you'll see results. Keep in mind that nobody else will do the job.

Now about science, we talked about chemistry. Of course, nobody will disagree with me that everything in science except theoretical mathematics is chemistry. Simply because everything involves materials and every material is composed of molecules and everything depends on the way molecules talk to one another. Isaac Newton said that men build too many walls and not enough bridges. This is correct even in the physical world, as we build more walls than bridges. All of this is part of the story, and Ciechanover has already mentioned this. Part of the inhibition to excellence, or to the growth of excellent scientists, is the internal politics within the academic institutions. The whole idea of scientific disciplines is wrong. Scientific problems don't have boundaries. The scientific disciplines as we know them are nothing more than convenient teaching packages; they have nothing to do with scientific research. Consequently, the common buzzwords: multidisciplinary, interdisciplinary etc., are meaningless, because the notion of disciplines is meaningless.

Again, my main message to you is that promoting the next generation of creative scientists is our responsibility. Nobody else will do our job and nobody else can do this job."

Prof. Chaim Sukenik: "Lia, I'm very curious. You talked about the importance of getting people interested, and stimulating interest at a variety of levels.

There's always been a kind of tension between things that are more applied and things that are more basic. What I've seen over the years that I've been taking graduate students is that they have become much more interested in the question 'what is it good for?', 'what is it going to do at the back end?'. Both in terms of 'what kind of job it will get for me?', and in terms of 'OK, what tool will I be creating for doing something practical?'

Talking about advances in basic science it's quite clear that if you're going to allow the practical side and the side of 'what is it good for' to be your only guide, you're not going to go off into the brand-new directions that you referred to before.

How would you suggest that people balance those two? We want to stimulate the interest, that perhaps includes a relevance component, but we still want to make sure that people are going to strike out in new directions?"

Prof. Lia Addadi: "That's a tricky question. I would like first to relate to something about what Ehud said before. This something is getting stronger and stronger, I think all over the world, and it is both the fact of 'what is it good for', and the fact of providing everybody with equal opportunities.

Now, when I came to Israel, I didn't know what a multiplechoice test was. I just didn't know it. I never had anything of the kind. At first, I asked what it is. Then I failed in multiplechoice exams. We weren't used to exams of two hours. Now, of course oral exams are problematic because of their high variability and because they depend on how the teacher woke up that morning. But, on the other hand, they still provide a basis for the discussion that stimulates the thinking. You can test not what answer is right out of 3, but what kind of thinking there is behind it. The students who come to our lab very often tell me with surprise 'you know, to go your way of thinking, I have to forget all of what I have been taught until now, and of course they exaggerate. They don't have to forget all of what they've been taught, but they have to forget the type of 'answering the right questions' that Ehud mentioned. So maybe, one of the things that we have to do at the level of undergraduate students is to forget about multiplechoice tests. We need to go back to a way of thinking, and to stimulate thinking among the students.

Going to your question: 'Applied as against fundamental'. I don't think that there is a clear-cut answer. Because there are those who will prefer an applied type of approach and those who will prefer fundamental approaches. But I think where we can make a difference is in the way to get there.

So, my students and my collaborators often laugh at me, because I say that when I'm looking at a product of evolution and examine how it's made, I've learned never to ask why. Why did this organism evolve in this particular way? Or why is this biological material built in a certain manner? Because "why" implies that we are looking just to find our goal and we know where we want to go. The organisms never asked 'oh how am I going to get there?' This is not the way. But what you can ask, what I try to ask, is "how?".

It's the same with applied research. If you look at the purely applications driven researcher, the only thing that is important is the final product. So, you test thousands of "possible final products" without asking how. I think that's not my way. That's not what I would recommend. If you're asking how and thinking mechanistically as to how to get to a certain point, I think it doesn't matter if the problem at hand is fundamental or applied."

Prof. Chaim Sukenik: "Perhaps one point to follow-up on your remarks. I was intrigued by your not so subtle criticism of the current university infrastructure in terms of how well it draws lines. At the end of the day the questions remain as to how a university should allocate scarce resources within the organization and to what extent should the university, or some form of higher management, direct choices in research topics and/or structures within research centers. To what extent can/ should the scientists themselves generate these things and at the end of the day: how do we simulate the most productive environment within our institutions of higher education? That's really what we want."

Prof. Aaron Ciechanover: "If you think about the history of universities, the first universities and early scientists never considered disciplines of physics, chemistry, biology, medicine, etc. These scientists defined themselves as natural philosophers. And they all used mathematics as a language, sort of a theoretical tool. Nature has always been a continuum

and the various disciplines were created later. In nature all problems involve materials, and materials don't have any identity. For example, the amazing story of Yuri Oganessian and the discovery of the super-heavy elements cannot be defined exclusively within physics or chemistry.

So when we talk about particles, they have no identity. People call it physics. When molecules start to react its chemistry, when they go into membranes and separate from the outside environment it is biology. And if something goes wrong with our biology, then it's medicine. But it's all sitting on a continuum, and Nature doesn't know about our artificial disciplines. This division into disciplines has become the Holy Grail and we stick to it. I don't want to criticize my own university, but the president has to deal with 22 different deans and chairpersons, each of them has their own demands and requests and so on. We need to think of a way to change this structure.

On the other hand, the demand for interdisciplinary research creates the opposite problem that is difficult to solve. Science has become so specific in each discipline, and each field is so loaded with huge amounts of knowledge. So how can we create a renaissance man who would be a physicist, a chemist, a biologist and also knows much about medicine. That's obviously impossible. So, the solution would be something in-between, perhaps encouraging free movement of people. If we put an engineer, a chemist and a physicist in one room, we cannot guarantee that something good would come out of it. Nevertheless, we need to encourage free exchange, which is indeed coming.

We are using now so many different techniques. I'm using mathematicians for my own science, and I cannot make any progress without a bioinformaticist because I don't have the tools to read the data myself. We need to encourage interactions among scientists of different disciplines who can learn from one another and develop new ideas. There is no doubt that we should change our administrative structures and remove the boundaries to allow free movement of people without formal appointments. Think about all this structure that we built to control the movement of people from one place to another. You belong here and you belong there and every department has so and so positions. This is all really pathetic and it doesn't belong to the current world.

We should think about education. It's not only our own structure, but also its broader implications. We're thinking about it a lot in the medical school at the Technion. How should we be creating a new generation of physicians or bioinformaticists? Processing of data and big data must be part of our professional tool-kit. We are limited by the time allowed to us. We have so little time in which to educate the physicians, 6 years is long enough anyway. Nevertheless, we are dynamically changing the program all the time, and I'm not sure that what we're doing is right. The product will tell us how right we are. But I think we need to really brainstorm both our structure and the education system that we are using to educate future generations."

Prof. Chaim Sukenik: "Thank you. I would just add one comment. I was part of the project in establishing the Nano-Center at Bar Ilan. One of the rules that was applied to the allocation of laboratories was that on every floor of the building there should a biology, chemistry and physics faculty member. Just that simple trick has led to numerous collaborations between disciplines. I think people that are more involved in university administration should seriously think about it.

I have more questions but I'd like to devote the last five minutes to questions from our audience. Please stand up, speak as loud as you can and address your question to a specific panel member."

Question 1: "What is the Strategic approach of the ICS, which will enable scientists to have more influence in high schools?"

Prof. Ehud Keinan: "First of all I would like to emphasize how important this is. We are proud of being a Startup Nation. Israel has about 5,000 startup companies, meaning that for every 16,000 citizens we have one startup. There is nothing similar worldwide. Remembering that the people who are responsible for this achievement make only 1.4% of the population, we could do much better. Imagine that we could double this thin layer and make it 3% of the population, so we could have 10,000 companies in this country. Such a dream would change the country on every front, including security. It would be more significant than buying stupid submarines or stupid airplanes for \$100 million each. Think of the consequences of doubling the thickness of the layer of excellent people. It would certainly be a different country. Remember that our education system

exposes only a small percentage of all pupils to science, perhaps not more than 20-25%. This means that almost 80% of our kids are not even aware of the great opportunities offered by a career in science.

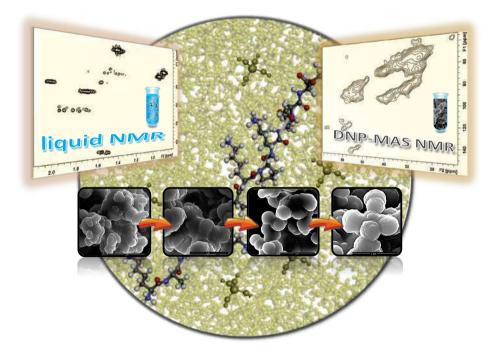
As for the question, how to do it? There are many ways. In my capacity as Chairman of the Advisory Council of High School Chemistry Education at the Ministry of Education and at the ICS, we've initiated various programs in order to improve science education and chemistry education in particular. There are several programs to which scientists can volunteer at various levels. Please feel free to approach me by email or communicate in other ways and I'll be happy to give you more details and explore together programs that could fit your preferences.

There is a broad spectrum of potential involvement. You can join forces with a science teacher in the class, you can do something to encourage curiosity and interest in science, promote critical thinking. If you can save a few souls among potential scientists, you'll do a great service to the country."

Question 2: "I have two questions: 1) Should we have first year or more than the first year of general science, and 2) What are the other skills, softer skills, beyond science that you can identify as important? "

Prof. Lia Addadi: "To answer both questions in a short way, as a matter of fact I think that we have to establish a strong basis in one area. I think that the work of teaching general science should be done during the high school years. That's the task of the high school: to expose kids to science, and then let them find where they feel most comfortable."

Prof. Chaim Sukenik: "I want to thank our panelists, who have left us with a lot of food for thought. Thank you all for participating."





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