

## Unintentional drinking-water contamination events of unknown origin: surrogate for terrorism preparedness

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### ABSTRACT

Drinking-water is a direct conduit to many human receptors. An intentional attack (e.g. terrorism) on drinking-water systems can shock and disrupt elements of national infrastructures. We report on an unintentional drinking-water contamination event that occurred in Tel Aviv, Israel in July, 2001. Initially of unknown origin, this event involved risk management strategies used by the Ministry of Health for abating a potential public health crisis as might be envisaged of water contamination due to terrorism. In an abrupt event of unknown origin, public health officials need to be responsible for the same level of preparedness and risk communication. This is emphasized by comparison of management strategies between the Tel Aviv event and one of dire consequences that occurred in Camelford, England in 1988. From the onset of the Tel Aviv incident, the public health strategy was to employ the precautionary principle by warning residents of the affected region to not drink tap water, even if boiled. This strategy was in contrast to an earlier crisis that occurred in Camelford, England in 1988. An outcome of this event was heightened awareness that a water crisis can occur in peacetime and not only in association with terrorism. No matter how minor the contamination event or short-term the disruption of delivery of safe drinking-water, psychological, medical and public health impact could be significant.

**Key words** | contamination, drinking-water, hazard assessment, public health, risk management, terrorism

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*Ye have seen also the breaches of the city of David, that they are many: and ye gathered together the waters of the lower pool (2 Kings 20:20)*

### INTRODUCTION

Drinking-water and food supplies have been sabotaged throughout recorded history as a military tactic (Eitzen & Takafuji 1997; Kahn *et al.* 2001). The biblical quotation alludes to the historical roots or basis of protecting water resources from enemy invaders who would target drinking water supplies. Many historical events testify to deep cultural roots in the sensibility of Israelis to drinking-water as a target for terrorism; two are highlighted below.

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### Hezekiah's tunnel

The biblical reference refers to the design of a tunnel by Hezekiah for the purpose of protecting ancient Jerusalem's Gihon Spring from the invading Assyrians and dates to 701 BCE. The Gihon Spring lay outside of Jerusalem and presented Hezekiah with a two-fold quandary: to guarantee that safe drinking-water would be available for a beleaguered Jerusalem, and to keep the water source from the Assyrians, who are among the earliest people documented to poison water supplies as a war tactic. From the 6th century BCE the Assyrians poisoned the drinking-water wells of their enemies with rye ergot, a convulsive and potentially lethal fungal toxin (Eitzen & Takafuji 1997). Hezekiah's solution to the dilemma was rather ingenious. He ordered

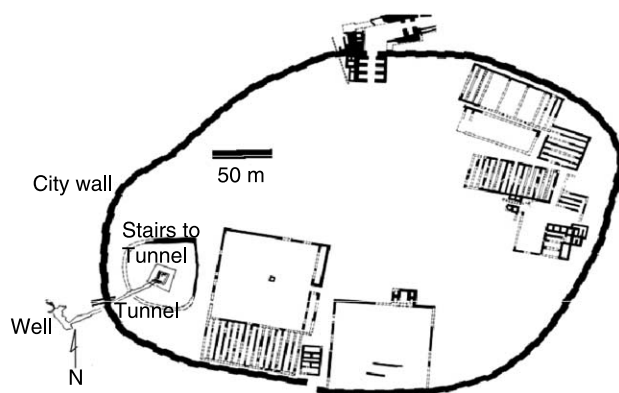
that the Gihon Spring be diverted into the Gai Valley by constructing a tunnel more than 500 m in length; thus, it could be accessed without leaving the city walls and was hidden from enemies who might want to use or poison the water.

### The water tunnel at Megiddo

Megiddo, near to Haifa in the northern part of Israel, was first settled more than 7,000 years ago by cave dwellers. Because of its strategic position on the main road between Egypt and Mesopotamia, Megiddo was coveted by many civilizations. More than twenty cities were built directly on top of each other by continuous conquering armies between 3,000 and 300 BCE. Megiddo appears in the New Testament as Armageddon, location of the apocalyptic battle at the end of times (Revelations 16:16). Armageddon is derived from the Hebrew Har Megiddo (the hill or mount of Megiddo). The communities there were built on high ground so that a low-lying well or spring was usually outside the cities' walls (Figure 1) to provide access to the water supply from inside the city walls and hiding the outside access to keep it from being used or fouled by enemy invaders.

### Drinking water crisis in Tel Aviv

We had previously published details of an unintentional water contamination event of unknown origin (Winston *et al.*



**Figure 1** | Diagram of Tel Megiddo excavation site from the Iron Age (9th–8th century BCE) showing the drinking-water well outside the city wall. Access to the well was through a tunnel that ran from inside the wall beneath the ground and under the wall to the well. Similar systems existed in almost any Iron Age city, and have been located and/or dug at Hazor, Yoqneam, Beth Shemesh, Gezer, Gibeon, and Beer Sheba.

2003). It is not our intention to reproduce what has already been published, rather to illustrate how that contamination event has become a surrogate for dealing with the possibility of a terrorist attack on drinking-water supplies. In particular, we focus on the process of risk communication and management strategies directed toward the impacted public. We compare and contrast this drinking water “crisis” that occurred in the Dan Region of greater Tel Aviv to the principles of risk communication and management with a similar unintentional event that occurred in Camelford, England in 1988 (Table 1; Lawrence 1988; Clayton 1989; Cross 1990). Such a comparison permits the acknowledgment of valuable lessons for improved response to potential similar contamination events in the future.

## CONTAMINATION EVENTS

### Tel Aviv case review

On 9 July, 2001 at approximately 20:00 h, media broadcasts were interrupted by an “urgent” warning from the Israel Ministry of Health of a threatening hazard from contamination of the public water supply in the region of greater metropolitan Tel Aviv. Israel’s national water company, Mekorot, discovered a ten-fold increase in turbidity and a 20- to 40-fold increase in the concentration of ammonia in the core water carrier pipeline. Importantly, the source of ammonia was not known for several days after the beginning of the predicament. In response to this, a directive was issued to the public to not drink tap water until further notice, including boiled water.

The immediate response of the public to the directive was manifest as a crisis – entire bottled water supplies were bought out from Tel Aviv vendors who, in the wake of this spree of panic buying, were reported to have engaged in opportunistic price gouging. Sampling of sections of the water main with high turbidity was promptly carried out by the Mekorot company, the results of which showed the presence of ammonia. This discovery prompted speculation that the source was agricultural fertilizer or industrial liquid ammonia; thus the Dan region was sealed and 150,000 cubic meters of water was drained and flushed with uncontaminated water.

**Table 1** | Comparison of water contamination events that occurred in Tel Aviv, Israel (2001) and Camelford, England (1988)

	Tel Aviv	Camelford
Event	Unintentional	Unintentional
Source	Initially unknown	Initially unknown
Physical cause	Malfunction of ammonia measuring buoy results in 5 tons of ammonia dumped into drinking-water reservoir	Relief driver dumps 20 tons of $\text{Al}_2(\text{SO}_4)_3$ into wrong hopper that directly enters the drinking-water supply
Initial observation	Turbidity spike at monitoring station	Acidic taste, slippery or slimy to the touch
Chemical cause	Ammonia	Aluminum sulfate
Public disclosure	Immediate, full transparency	2–3 d delay
Advice to public	Don't drink even if boiled	Water is safe to drink
Health effects documented	None	Acute and chronic – burning sensation, irritation
Action taken	System flushed	System flushed
Initial toxicological assessment	Precautionary principle invoked, possible tracer of chemical or bacteriological contamination	Precautionary principle not invoked, public assured water was safe
Aftermath of event	Public poll indicated that communication was adequate and situation handled satisfactorily	Event continues to have health, political and legal ramifications today
Lessons learned	Provided opportunity to re-evaluate public health agency's role in drinking-water contamination events	Provided opportunity to re-evaluate public health agency's role in drinking water contamination events

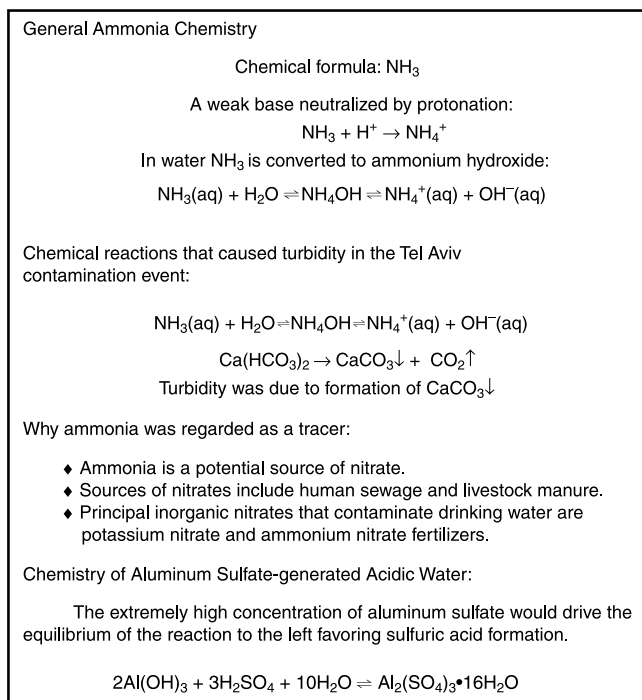
The fact that a source of contamination could not initially be identified led Mekorot to suspect sabotage by terrorists. However, this worst-case situation was ruled out immediately by the Ministry of Health and the Tel Aviv police on the grounds that a terrorist attack would not have caused such a pervasive effect. The location of the turbidity spike and the level of the ammonia contamination made it practically inconceivable that enough ammonia could have been furtively discharged into the drinking water supply.

The management strategy, from the onset, was to invoke the *precautionary principle*. The public was advised not to drink the water until a source of contamination could be substantiated. Once the source of the turbidity wave had been identified as a chemical reaction sequence involving ammonia and calcium carbonate owing to the unique hardness of the drinking water in Israel the source was treated as if the ammonia was a tracer or indicator of contamination from sewage or animal waste along with chemical contamination (Figure 2; Winston *et al.* 2003). In the case of the Tel Aviv incident the depletion of alternative water sources may have created the more serious problem by increasing the potential for panic. This was

certainly the case of the panic buying spree that soon left residents without bottled water in the face of a “no drinking tap water” order.

### Camelford case review

On 6 July, 1988 a serious unintentional drinking water contamination event occurred in Camelford, England at the Lowermoor water treatment facility. This incident shared similarities to that which occurred in Tel Aviv; both began under circumstances in which the source of the contamination was not immediately known. This contamination event arose when 20 tons of aluminum sulfate was inadvertently dumped into the wrong tank at the Lowermoor treatment plant by a relief driver who was not familiar with the plant's layout and delivery measures (Table 1). Aluminum sulfate, at the extremely high concentration that contaminated the drinking-water supply, rendered the water highly acidic, enough so that leaching of some toxic metals and corrosion of pipes and plumbing was considered problematic. Unfortunately, the cause of the Lowermoor problem remained undetermined for two days.



**Figure 2** | A simplified scheme of the chemistry of ammonia and aluminum sulfate that led to the contamination problems associated with the water contamination events of Tel Aviv and Camelford.

Some reports indicate that an egregious error in communication with the public was the assurance by a water authority spokesperson that the water was safe to drink despite complaints of acid taste and irritation (Table 1; Clayton 1989).

The concentration of aluminum in the Camelford drinking water was as high as 620 mg/L and the sulfate concentration 4,500 mg/L. For aluminum, this concentration is 3,100–12,400 times greater than the secondary drinking water standard of the US EPA (2006) and 6,200 times the health-based guideline of the WHO (2004). As in the case of the Tel Aviv contamination event, once the cause of the problem was ascertained the water system was flushed, thereby reducing the aluminum concentration to 1 mg/L.

## RISK MANAGEMENT THROUGH COMMUNICATION

### Dissemination of information

When a contamination event occurs, the public needs information about the nature of the incident, what is being

done to contain or mitigate the release of the contaminant(s), if anybody is threatened, the health effects of exposure to the contaminant, how the public can protect themselves and the availability of further information including when and where it is obtainable, and through what media (WHO 2002). The degree to which such information is made available and how the information is presented is critical and can often make a relatively controllable predicament become a crisis or disaster. An official statement made by a Mekorot representative to the media when the turbidity incident in Tel Aviv was first discovered, and later quoted in Israeli newspapers, was “we’re talking about water that is not fit to drink”. Although the remark was well-intentioned, i.e. with protecting the public in mind, the statement violates a principle of risk communication in its use of emotionally charged words (US Department of Health and Human Services 2002). Such a statement invokes a sense of toxicological risk that exceeds the reality – the risk perception is greater than the actual risk (Winston *et al.* 2003). With that in mind, the words “crisis” and “disaster” were not used in any communication to the press or public by Israeli health officials. A more prudent approach by the Mekorot spokesperson would have been to merely inform the public that, until the cause of the event is established, a no-drinking order is in effect. However, even though the statement by the Mekorot official was inflated, it was in contrast to statements issued by Lowermoor Plant officials at Camelford which, in the face of a similar situation, implied that the water was safe to drink.

### Phases of risk management and comparative strategies

Risk management is comprised of three distinct phases: (1) an *alert* phase, when the problem is first discovered; (2) an *action* or *response* phase, during which the worst-case scenario is considered, risk assessment is conducted and various restrictions are applied accordingly; and (3) a *recovery* phase, in which the cause of the problem is established and corrective action is taken. The recovery phase typically coincides with an easing of the restrictions in accordance with confirmed findings. It is interesting to illustrate these three risk management phases in terms of the strategies employed by the Israel Ministry of Health and to compare and contrast the same with the contamination event that occurred at Camelford (Table 1), because these

strategies underpin the communication processes between the water company, government and health officials with the public.

In the alert phase, officials of the Israel Ministry of Health informed the public immediately via broadcasts through both the radio and television media. During these broadcasts were various interviews with public health officials who, in full transparency, disclosed all that was known throughout every stage of the contamination event. Recognizing that confusion and uncertainty might occur among certain segments of the population, an event crisis hotline was established by Mekorot to address public concerns. Again, implementing the precautionary principle was an essential part of the alert phase. The response by officials at Camelford during the alert phase was a contrariety as compared to the response by Israel health officials and the water company, Mekorot. Presumably, failure on the part of Camelford officials to immediately invoke the precautionary principle resulted in many claims of health problems from the public. According to [Mayon-White \(1993\)](#), “the anxiety and disputes about the effects on health would have been less if the public had been better informed about the incident from the outset”. In the action or response phase (worse-case scenario is considered) Israeli officials considered the presence of ammonia as a likely tracer of point or non-point pollution sources. Thus, microbiological contamination had yet to be ruled out, nor were the possibilities of industrial chemical or fertilizer contamination. Either of these possibilities could have resulted in serious human health consequences ([Ongerth & Pecoraro 1995](#); [Juranek & MacKenzie 1998](#); [Schwartz & Levin 1999](#)). Therefore the main pipeline serving the greater Tel Aviv area was sealed off, drained and flushed with uncontaminated water. The failure to communicate with consumers during the earliest stages of the discovery of water contamination was a flaw in the action phase during the Camelford incident because consumers experienced various effects (skin irritation, burning sensation in the mouth, bad taste) that were contrary to the safe water claims of officials. This obviously resulted in a credibility gap and consumer trust issues. Finally, the recovery phase at Tel Aviv actually began when laboratory data confirmed the lack of microbial contamination. Furthermore, when it was established that the source of ammonia was due to

mechanical failure of the measuring buoy in the ammonia tank, restrictions were eased with confidence. Each hour that passed from the beginning of this contamination incident without reported casualties convinced decision-makers that the contamination was not health-threatening. At Camelford there remains a disparity between emerging research findings and reports indicating a greater incidence of certain health maladies ([McMillan \*et al.\* 1993](#); [Altman \*et al.\* 1999](#)) that potentially could have been caused by the contaminated water. In this regard, there has yet to be a resolute recovery phase for the Camelford water contamination event – especially in terms of consumer satisfaction.

## SURROGATE FOR TERRORISM

As indicated in the title to this paper the Tel Aviv contamination event, albeit unintentional, could serve as a surrogate or proxy in the event of an intentional terrorist attack on a municipal water supply. Security against such a malevolent attack on water systems involves all facets of its planning, design, construction, operation and maintenance. These include system analysis, risk assessment and mitigation procedures to restore the system to partial or full operation. Examination of some of the human errors that happened during the Tel Aviv and Camelford crises helps to reveal areas of vulnerability for terrorism.

## Water system infrastructure

It is worthwhile first exploring the infrastructure of a representative municipal water supply. Drinking-water supply systems typically are comprised of a very large water source, such as a lake, a reservoir, or a catchment tank; a main pipeline to connect the raw drinking-water source to a water-treatment facility where purification processes such as sedimentation, filtration and chlorination are implemented; a transport system to carry drinking-water to storage tanks or towers; and a local piped distribution to residential water tanks and taps or other end-users. This is also typical of the national water carrier water system in Israel. Given the complexity of such water systems it was considered very unlikely that contamination of the magnitude of the turbidity/ammonia event ([Winston \*et al.\* 2003](#)) would

have resulted from terrorism and hence was immediately ruled out. There were no breaches of security barriers and the transport system that carries water from its source at the Sea of Galilee to the various storage facilities is enormous in capacity and would have required tons of ammonia to have produced the level of turbidity that was observed. The Camelford and Tel Aviv contamination events occurred at the level of direct delivery of drinking water to the consumer.

The ultimate goal of a water infrastructure security program is to make it an unattractive target for terrorism (Copeland & Cody 2003). The Camelford incident was the result of a relief driver entering an unguarded facility and dumping 20 tons of a chemical into the drinking-water system. A scenario such as this does not suggest an unattractive target for terrorism. In the treatment of drinking-water, aluminum salts (e.g. aluminum sulfate) are used as coagulants to reduce organic matter, turbidity and microorganism levels (WHO 2004). High residual concentrations cause undesirable color, turbidity and taste. Aluminum sulfate is available and transportable in tonnage quantities and at these extraordinary concentrations presented toxic consequences. Despite the fact that aluminum sulfate is an unlikely choice of chemical contamination for terrorism, that such a mistake could have happened illustrates a potential for a terrorist opportunity to approach and disseminate a large volume of a chemical (or biological) agent into the drinking water supply.

The disruption to the water infrastructure, local government and the public health infrastructure caused by this “accident” qualifies as meeting the objectives of an organized terror attack. It illustrates how such an accident can be a surrogate for an intentional attack by exposing similarities that could be encountered by the various infrastructures mentioned. According to Campbell & Stamp (2004), literature searches that cover many decades show that there have been very few malicious attacks on the water infrastructure in the United States. These authors assert that the available information is not adequate to envisage the kinds of attacks that could potentially ensue in the future. There has never been such an attack on the water system in Israel, albeit preparedness for such is a constant interagency function between government, water companies, military, police and the public. The identification of security weaknesses, what the National Water Resource Association (NWRA)

(Finley 2002) and the National Oceanic and Atmospheric Administration (NOAA) (2002) define as “vulnerability assessment” is of the utmost importance. When security is breached by a breakdown in quality assurance and quality control in unintentional accidents, it reveals vulnerability. Vulnerability was revealed in the Tel Aviv event by an instrument technical failure, and at Camelford by a security breach.

## DISCUSSION

### Communication practices

The public is often guided by a specific mind-set that is characterized by social, psychological, political, economic, legal or historical factors which can affect how an emergency situation is perceived and consequently responded to (Quarantelli 1980, 1984). In this regard, the public response and perception to the Tel Aviv water contamination event was clearly guided by a very different mind-set than that which occurred at Camelford. Everyday life in Israel is under constant threat of terrorism, which is reflected in the psychology and social structure of the people. Historical factors that characterize Israeli sensibility to a terrorist breach of the drinking-water supply system has historical routes dating from biblical times and fueled heavily during the Tel Aviv contamination event by a period of virtually dozens of homicide bus bombings and bombings of public social venues, including restaurants, and celebratory receptions. As stated in this paper, there was a “hot” warning at the Ben-Gurion Airport on the day that the no drinking-water order was broadcast.

As mentioned above, the position of the Israel Ministry of Health from the onset of the contamination event in Tel Aviv was to apply the precautionary principle. It is important to note that application of this principle is neither an arbitrary nor capricious practice. There are three fundamental criteria that risk managers should examine before resorting to the use of the precautionary principle (ILGRA 2002). The first criterion requires identification of a potentially hazardous effect. The second criterion is that the source of contamination is unknown and facts are still being collected. A third criterion, which is of the utmost

importance, is that the worse-case scenario is perceived potentially as having a serious bearing on human health.

Before the source of the turbidity was identified as ammonia, public health officials were confronted with the fact that the source of the contamination had not been identified. Once it was recognized as ammonia, fertilizer, industrial chemicals or microbiological contamination were all considered possibilities and, if this were the case, then the potential for deleterious health effects on the Tel Aviv population was a possibility. Therefore, with all three criteria being met, the precautionary principle could be invoked with confidence.

### Lessons gleaned from the Tel Aviv event

In the final analysis, there was never any real toxicological or health danger to the Tel Aviv public as there was at Camelford from the alarmingly high concentrations of aluminum in the drinking water. Nevertheless, this was a real contamination event, and for the Tel Aviv region had all of the characteristics of a *bona fide* urban environmental crisis. Communication with the public was not any less important than if the event was of more catastrophic proportions. Several factors contributed to the calamity that surrounded the event response. Firstly, the perceived magnitude of the event was reinforced by the abruptness which it was broadcast to the public. Regular programming was suddenly interrupted with “an urgent message”. Obviously such urgency would be at best disconcerting, and at worst, alarming. Under the circumstances there was no way to appeal to the public without creating a certain level of anxiety. In Israel drinking water quality is under the auspices of the Ministry of Health. Within this agency it was well understood that risk communication and perception were important issues to be considered because (1) Israelis are highly sensitized to terrorism, which was commonplace throughout the intifada taking place concomitantly with the present water contamination event. The fact that the event occurred on same day as a “hot” warning of a possible terrorist attack on Ben-Gurion Airport immediately prompted the suspicion that terrorism was involved in the water contamination event presently being related; (2) An event of this type (chemical contamination of unknown origin) was unprecedented in

Israel; (3) initially, neither the cause nor the source of elevated turbidity and ammonia was known; and (4) Israel was already in the midst of a highly publicized water shortage, which added a measure of excess anxiety.

The fact remains that no matter how minor the contamination event or short-term the disruption of the delivery of safe drinking-water, medical, psychological and public health impact can be significant. [Mayon-White \(1993\)](#) warns that an acute incident may be perceived by the public as only the “tip of the iceberg”. In the months that followed the Camelford incident numerous of its residents complained of various symptoms including skin rashes, sore throats, loss of memory and general malaise. Two reports ([Clayton 1989](#); [Lowermoor Health Advisory Group 1990](#)) concluded that there was no compelling evidence to indicate harmful accumulation of aluminum or a greater incidence of health problems associated with the toxic effects of the contaminated water. However, it was recognized that the incident caused genuine suffering in the community, which was attributed to anxiety rather than direct health effects; a conclusion which angered many residents. This result brings to bear the tenet propounded by [Sandman \(2003\)](#) that “risk equals hazard plus outrage”. A member of the British Parliament, who visited Camelford in his post as Environment Minister, called the incident “a most unbelievable scandal” ([Lean 2006](#)).

A post-event telephone survey done by the Israel Center for Disease Control indicated that the Tel Aviv public was very well-informed; the communication during the alert phase was considered to be “highly effective”, with approximately 90% of the affected population receiving the initial warning ([Israel Ministry of National Infrastructures 2001](#)).

### Human errors

Both the Tel Aviv and Camelford incidents involved technical errors with serious consequences. In Tel Aviv, the fact that the spill was not immediately detected at Mekorot resulted from a lack of awareness of the system’s operation. The technical staff at Mekorot had assumed that a flaw in the electronics of the turbidity meter had occurred, which was a serious error in judgment.

Candor versus secrecy or misleading statements  
 Speculation versus refusal to speculate or treating speculation as fact  
     Tentativeness versus confidence  
     Being alarming versus being reassuring  
     Being human versus being professional  
     Being apologetic versus being defensive  
     Decentralization versus centralization  
 Democracy and individual control versus expert decision-making  
 Planning for denial and misery versus planning for panic  
 Erring on the side of caution versus taking chances

**Figure 3** | Ten dilemmas of risk communication that may occur during a public emergency, according to Sandman (2003). The left and right choices of each dilemma represent a continuum of potential communication response positions – the right or first of each choices being favored by Sandman. Under the stress of a crisis, intuitions of politicians and certain officials move toward the latter choices (on the right) of each dilemma.

Moreover, even though there is a fish biomonitoring station in the Mekorot system, there was no effectual alarm system for toxic materials, so toxicity testing was done late in the series of events. Despite having a quality laboratory at Mekorot, only the Ministry of Health's laboratory was used on the night and following morning of the incident, which delayed receiving the results because the analytical staff was inundated with samples. Another criticism was that the public was confused because they had no clear directives. In fact, no directives for such crises existed except for terrorist or wartime water emergencies because, as mentioned above, such an event was unprecedented in Israel. The Ministry of Health proposed that such directives be put into practice by all suitable agencies (Israel Ministry of National Infrastructures 2001). A significant consequence of the crisis was an increase in awareness that a water crisis can occur outside the sphere of terrorism. Gaps in certain "readiness" directives for terrorism events were revealed. For example, in Tel Aviv, trucks that were to deliver drinking-water to the public at strategic locations were never filled because the drivers were not aware of where to have their trucks filled – this was a serious communication gap that was addressed in the final report of the Israel Ministry of National Infrastructures (2001) in their report of the Tel Aviv contamination event.

## CONCLUSIONS

Different strategies employed by officials during the two water contamination events analyzed in this report

(Tel Aviv and Camelford) illustrate how the risk management process can underscore the outcomes and recovery process of such incidents. Lack of openness and transparency in communication with the affected public in the alert phase can lead to failure in bringing about satisfactory recovery and resolution. Furthermore, the events illustrate how lessons obtained from a peacetime water contamination event, especially one in which the source of the contaminant was unknown, can be used for preparedness in the event of a terrorist breach of the public drinking water system. A major emergency can arise during peacetime that requires the same level of preparedness as in the event of terrorism. A communications breakdown in any phase of a public emergency can lead to unnecessary anxiety and even panic. This point was made evident by the communication breakdown in Tel Aviv that prevented emergency water supply trucks from being filled and delivered to the public at designated collection stations. In the final analysis, it is worthwhile to consider the ten dilemmas (Figure 3) posed by Sandman (2003) in a crisis situation. In each of these dilemmas Sandman favors the first of each choice and reminds us that the dilemmas represent a potential continuum of responses. Although Sandman favors the first of each choice (e.g. candor over secrecy), he warns that, under the stress of a crisis, intuitions of politicians and certain officials move toward the latter choices (on the right) of each dilemma. It appears that the handling of the Tel Aviv crisis was more in keeping with that of Sandman (2003).

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