in the later stages of spring growth." We also lack data to ascertain the effects of antimetabolites on the diatom populations.

The circulation patterns of the major water masses that affect this region may be responsible for the long-term fluctuations in diatom biomass. Excluding deeper circulation, Reid *et al.* (*7*) recognized four water masses distinguishable by their temperature, salinity, oxygen content, and phosphate content in the California Current. These come from the north, west, south, and below (due to upwelling). Namias and Huang (*10*) and Huang (*11*) concluded that, because of climatic fluctuations, a lessening of north-to-south wind stress results in more eastward oceanic flow from the subtropics and less flow from the California Current system which in turn results in positive sea level anomalies.

Cold and low-salinity water masses brought down by the California Current from the higher latitudes are rich in nutrients (*7*) and consequently support a large phytoplankton population. On the other hand, water masses originating in the west are warmer and more saline and the nutrients in their surface layers are nearly exhausted (*7*). Thus, when the upwelling follows a large influx of nutrient-poor water, the resultant diatom blooms are smaller than those observed when the flow of the California Current is strong.

Several parameters shown in Fig. 2 support this conclusion. Diatom blooms are considerably smaller when large positive salinity and temperature values prevail (*12*). A strong southerly flow, combined with upwelling, further cools the water and results in a lowering of the sea level through isostatic adjustment to changes in the specific volume of the water column (*13*). Thus large diatom blooms would be expected to take place when the sea level is relatively low. Indeed, there is a significant correlation between diatom biomass and sea level values (*14*).

Since diatoms are hydrodynamically passive organisms, the influx of water masses and the consequent mixing processes should result in changes in the total diatom biomass and in the species composition as well. Balech (*15*) reexamined the species composition from Allen's samples collected during the cold periods from 1938 through 1939 and compared those with his own collection sampled from 1957 through 1958 when anomalously high temperatures prevailed. His findings indicate that an abundance of warm-water and tropical species prevailed during the warmer period; however, during the colder period these species were largely absent. He concluded that warm-water species in 1957 through 1958 were not generated locally but were transported from a center of subtropical or even tropical water. My limited analysis of species composition confirms his findings. For example, Balech reported the presence of the warm-water species *Chaetoceros peruvianus* during the period 1957 through 1958. According to Allen's records, this species first appeared during week 28 of 1930, was found only occasionally before week 52 of 1932, and was not seen again during the remaining observation period.

SARGUN A. TONT

Scripps Institution of Oceanography, University of California, San Diego, La Jolla 92093

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Risk of Communicable Disease Infection Associated with Wastewater Irrigation in Agricultural Settlements

Abstract. *The incidence of enteric communicable diseases in 77 kibbutzim (agricultural communal settlements) practicing wastewater spray irrigation with partially treated nondisinfected oxidation pond effluent is compared with that in 130 kibbutzim practicing no form of wastewater irrigation. The incidence of shigellosis, salmonellosis, typhoid fever, and infectious hepatitis is two to four times higher in communities practicing wastewater irrigation. No significant differences are found for the incidence of streptococcal infections, tuberculosis, and laboratory-confirmed cases of influenza. Nor are differences found for enteric disease rates during the winter nonirrigation season. Strong wastewater treatment measures, including effective bacterial and viral inactivation through disinfection, are recommended for all cases of sewage irrigation or land disposal near residential areas in light of the potential public health risks involved.*

The subject of airborne microorganisms from wastewater and their health significance was recently investigated by Hickey and Reist (*1*). They reviewed the relevant literature extensively and concluded that aerosols that contain a variety of virulent pathogenic bacteria are emitted and spread from aerated wastewater processes to nearby areas that may be populated. They pointed out, however, that "present evidence does not conclusively confirm or negate the existence of health risk from viable wastewater aerosols," and they stress the need for further investigation. More recently, the lack of conclusive epidemiologic research on disease risks of occupational exposure to sewage was emphasized (*2*).

Wastewater aerosols are formed not only during treatment processes, but also during irrigation with sewage effluents, in particular where the spray or sprinkler system is used. Agricultural irrigation with wastewater is practiced extensively in a number of countries that suffer from water shortage, but the increasing rate of wastewater pollution of natural surface water sources in the majority of countries leads to indirect irriga-

tion with highly contaminated water. In the few reports concerned with wastewater irrigation (*3*, *4*) the spread of pathogenic microorganisms in the air in the vicinity of wastewater spray irrigation systems was demonstrated and the health hazards to the nearby population discussed.

Since water is in short supply in Israel, domestic wastewater effluents have been used extensively for agricultural irrigation for more than 20 years. About 250 agricultural settlements use this mode of irrigation, mainly by the sprinkler system. The level of enteric microorganisms in these partially treated nondisinfected oxidation pond effluents (mean detention time, 3 to 7 days) often approaches that found in raw domestic sewage (*4*). The Ministry of Health has therefore issued regulations limiting wastewater irrigation to crops that are not consumed by humans. These regulations do not take into account, however, the dispersion of pathogenic microorganisms as aerosols and the potential risks to farmers and adjacent residential areas.

Among the settlements that use sewage effluent for irrigation, kibbutzim (communal settlements) take an important place. Not all kibbutzim, however, use this method of irrigation. Kibbutzim are known for their highly developed health consciousness and generally good health services. They regularly report communicable disease cases to the district health offices of the Ministry of Health, which forward the reports to the Department of Epidemiology of the Ministry of Health, where they can be obtained by the public. This encouraged us to collect data for a retrospective study of the incidence of enteric diseases among the kibbutz populations, comparing morbidity rates between the users and nonusers of wastewater for irrigation.

Our study encompasses 77 kibbutzim (population 36,465) that are registered with the Ministry of Agriculture as using wastewater for irrigation, and 130 kibbutzim (population 46,360) that do not utilize wastewater for any purpose. Nineteen kibbutzim (population about 10,000) that use sewage in their fishponds were excluded from this study. The population numbers are averages for the years with which this study is concerned. However, only minor changes in population took place. The distribution of ages in both groups is similar (Table 1), although the kibbutzim utilizing wastewater tend to have a slightly older population, since this group includes a number of larger and older settlements.

Table 1. Age distribution in kibbutzim that use wastewater for irrigation and in kibbutzim that do not use wastewater.

Age (years)	Wastewater users (%)	Nonusers (%)
0 to 14	28.4	28.7
15 to 44	50.5	55.0
45+	21.1	16.3

The data were mainly collected for enteric diseases that could be waterborne, including shigellosis, salmonellosis (apart from typhoid fever, for which separate data were obtained), and infectious hepatitis. Influenza, an airborne disease, was also included. Streptococcal infections (including scarlet fever) and tuberculosis, both not considered to be associated with sewage, were selected as controls.

The data were obtained from the Ministry of Health's Department of Epidemiology, Central Laboratories (Jerusalem), and Virus Laboratory (Jaffa). All cases of bacterial infections were confirmed in the laboratory. Infectious hepatitis was diagnosed clinically only, as were most cases of influenza. The influenza cases that were confirmed in the laboratory are presented separately. The data for typhoid fever cover the years 1963 to 1975; for salmonellosis, 1969 to 1974; for influenza, 1973 to 1974; and for the remaining diseases, 1971 to 1974. Irrigation in Israel is carried out during the dry summer season from April to November, and this period was examined.

The results are given as mean seasonal incidence per 100,000 people (Fig. 1, summer). There is a clear difference (significant at 0.1 percent) in morbidity between the settlements that use sewage effluent for irrigation and those that do not, the disease incidence being from two to four times higher in settlements utilizing sewage for spray irrigation. Interestingly, the ratio for clinical influenza in the sewage-irrigated settlements is also twice that in the "clean water" settlements. This agrees with the findings of Ledbetter *et al.* (*5*), who showed an increase in influenza cases among sewage treatment plant workers. On the other hand, no difference was found between both groups of settlements in laboratory-diagnosed influenza cases. This may be ascribed to the fact that the symptoms of influenza may also be caused by adenoviruses or enteric viruses, both often found in sewage. Concerning the diseases not

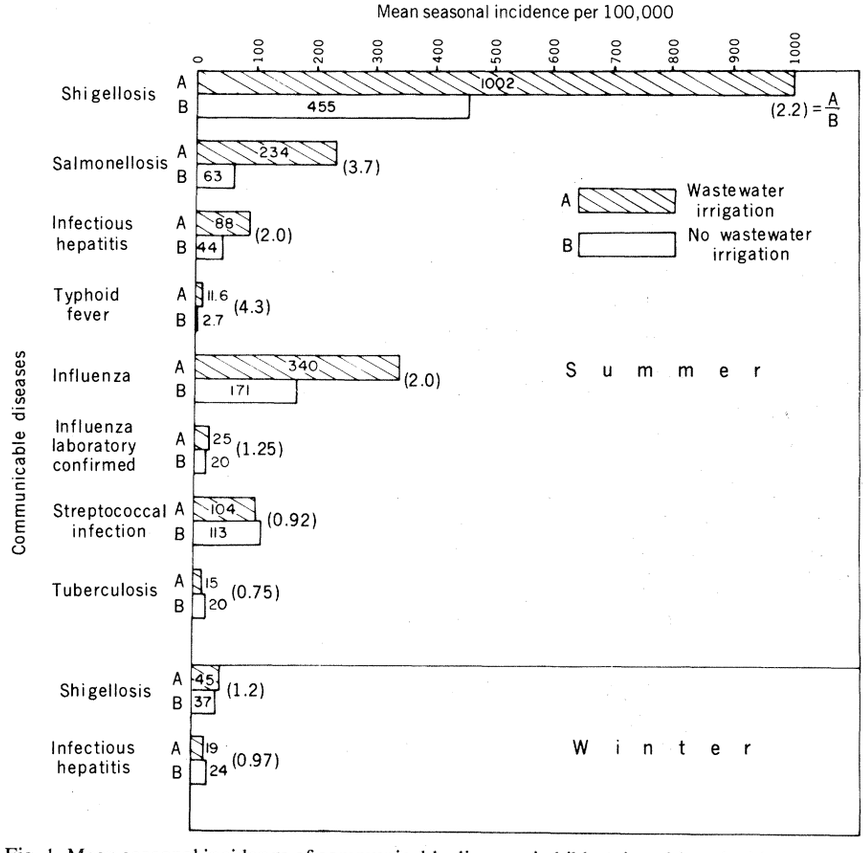

Fig. 1. Mean seasonal incidence of communicable diseases in kibbutzim with and without wastewater spray irrigation.

associated with sewage (streptococcal infections and tuberculosis), no significant differences in disease incidence were seen. This observation tends to rule out biased reporting by the settlements, since faulty reporting should have brought to light a distinct difference in the morbidity ratio of these diseases.

During the winter months (December to March) sewage irrigation is not practiced. If there is a connection between sewage irrigation and an increased incidence of enteric disease, the winter period should show no difference between the sewage and tap-water users. We also collected the data for the winter months, but because of the low morbidity rate, information could be obtained only for shigellosis and infectious hepatitis (Fig. 1, winter). No significant differences were found in disease rate between both groups of kibbutzim. This strengthens the hypothesis that there is a relationship between irrigation with sewage effluent and enteric disease incidence.

This retrospective study provides some epidemiologic evidence for an increased risk of enteric communicable diseases among the utilizers of wastewater. The fact that no significant differences are reported for diseases not considered to be associated with sewage or for enteric diseases during the nonirrigation period supports the assumption that reporting is essentially uniform for both groups.

The quality of the drinking water in all communities studied is good and is monitored routinely both by the water supply company and the Ministry of Health. The possibility of pathogen transmission by sewage-irrigated crops has been discounted since Ministry of Health regulations do not allow the use of sewage for the irrigation of vegetables or other crops consumed raw. Geographic factors have been discounted since settlements in both groups are distributed more or less uniformly in all areas of the country.

These findings indicate that the health hazards associated with partially treated nondisinfected wastewater irrigation may be greater than previously assumed. In the case of the kibbutzim studied, the areas spray-irrigated with wastewater were 100 to 3000 m from the residential areas. No direct evidence is available at this time concerning the actual concentration of pathogens in the air at the residential areas, although studies have shown that enteric bacteria of sewage origin could be detected as far as 1200 m from the site of a sewage trickling filter plant (*6*). It is also possible that the pathogens from the wastewater irrigation areas can reach the kibbutz populations by an alternate pathway, on the bodies and clothes of the irrigation workers who live in the community and return from the fields at mealtime and at the end of the day.

The introduction of a high degree of wastewater treatment, including effective inactivation of bacterial and viral pathogens by disinfection of all wastewater utilized for any purpose in the vicinity of settlements or residential areas, would appear to be a reasonable precaution in light of these findings.

ELIYAHU KATZENELSON
ITZHACK BUIUM
HILLEL I. SHUVAL
Environmental Health Laboratory, Hebrew University–Hadassah Medical School, Jerusalem, Israel

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Ovum Aging and *p*H Imbalance as a Cause of Chromosomal Anomalies in the Hamster

Abstract. *Using female hamsters mated in estrus, we have produced triploid embryos as manifestations of pregnancy wastage by combining delays of 3 to 4 hours in fertilization with exposure of the animals to hypoxia. Among the triploid embryos only XXX and XXY karyotypes occurred, indicating derivation from XX-containing ova. These findings have relevance to human reproduction.*

Experiments conducted in the 20-year period 1935 to 1955 documenting the adverse effects of fertilization delays on reproduction in rats, mice, guinea pigs, and rabbits were summarized by Chang and Fernandez-Cano (*1*). Shortly before this study appeared, Tjio and Levan had demonstrated 46 chromosomes in man (*2*), in a study that initiated a decade of investigations aimed at adapting tissue culture techniques to the demonstration of animal karyotypes (*3*) including human aneuploidies.

In hamsters it has been found that hypoxia (*4*), delayed fertilization (*5*), maternal aging (*6*), and *p*H equilibrium (*6, 7*) may each, acting alone or interdependently, have a decisive influence on the occurrence of chromosomal polyploidies and aneuploidies (*6*). Female hamsters exposed to hypoxic atmospheres in the postcoital period conceive many embryos with triploid and tetraploid karyotypes (*4*). Chromosomal aneuploidies and other manifestations of pregnancy wastage are evident in the fetuses of mothers subjected to delays of fertilization. Nine hours after the estimated time of ovulation, sexual activity of the female hamster markedly diminishes, and mating, even when it takes place, seldom results in fertilization. Even a delay as short as 3 hours beyond the estimated time of ovulation results in measurable increases of pregnancy wastage, that is, in decreased yields of normal embryos, increased embryonic mortality, and in aneuploid karyotypes of surviving embryos examined after 9 days of intrauterine development (*5*).

The importance of *p*H balance (7.1 to 7.3) for normal mitosis, and the mutagenic effect of *p*H disturbances on cell division, has been demonstrated in vitro with human blood cultures (*7*). More recently, by using critical *p*H disturbances accompanying hypoxia as a mutagenic agent, an interdependent action of maternal aging and *p*H disturbances on chromosomal patterns of 9-day-old embryos was demonstrated (*6*). This last finding led us to examine the possibility of there being a similar interdependency between postovulatory aging and *p*H imbalance.

Healthy female Syrian hamsters (*Mesocricetus auratus*) aged 3 to 6 months were used in these experiments. They were housed in separate cages, kept under conditions of reversed lighting (6:00 p.m. to 5:59 a.m.) (*1*), and darkness (6:00 a.m. to 5:59 p.m.) for 3 weeks so that es-