**IRCWD NEWS**

WHO International Reference Centre for Wastes Disposal

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# A Neglected Aspect of Water Pollution

The following is an excerpt from the Paper given by Dr. Max Blumer, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA at the Swiss Federal Institute of Technology, March 1971. Separatum EAWAG No. 398.

## Chemical Persistence Imposes a New Way of Thinking

Oil and chemicals of all kinds pose an ever-increasing threat to our natural waters.

In the oceans a yearly oil accretion of 5 to 10 million tons, i.e. 0.5 per cent of total world production, is reckoned with. This pollution is mainly caused by the fact that oil tankers flush out their tanks during cleaning at sea. However, shipwrecks, such as that of the Torrey Canyon, and the oil drilling losses off Santa Barbara, California, also make a contribution to this catastrophic pollution.

## The Buzzards Bay Disaster

On September 16, 1969 a tanker that had deviated from its course was wrecked on the off-shore rocks of Buzzards Bay near West Falmouth, Massachusetts, USA, spilling 600 tons of diesel oil into the ocean.

This disaster – although modest in comparison to that of the Torrey Canyon where 100 000 tons of crude oil were lost – turned out to be extremely useful, for biologists of the Oceanographic Institute of Woods Hole had been studying the marine ecology of this area for years and could therefore follow and evaluate the influence of the oil spill on marine and coastal life with great accuracy.

## Man – the Ultimate Link in the Food Chain

It is generally believed that oil, being lighter than water, floats and remains on the surface. Here it could, according to popular assumption, be recuperated relatively easily or fought by means of chemical binding agents. Yet as soon as there is suspended sediment in the water (rolled up sand), the oil rapidly falls to the ocean floor and becomes part of it.

Through gas chromatography, an analysis that shows by means of graphs the chemical separation of oil components and how they split up according to the number of carbon atoms, heavy oil pollution was found in the sediments at various research stations near the Buzzards Bay oil spill area.

In some places contamination was noticed only months after the disaster, depending on how the wind and current spread the oil. In June of 1970, that is, nine months after the accident, the first signs of intense biological decomposition were observed. However, the bacteria first attacked the nontoxic substances, while the aromatic and cyclically saturated hydrocarbons, the most toxic components of oil, being considerably more resistant, remain deposited in the sediment of the ocean floor for a long time. These hydrocarbons are either freed and returned to the water or ingested by marine organisms and thus introduced into the food chain.

The oil of Buzzards Bay was also absorbed by shellfish, an important source of income in the area. Surviving, contaminated oysters were kept for months in running, fresh sea water in the Woods Hole laboratories. Yet the oil in the mollusks' fatty tissue could not be "washed away". Still relatively little is known about the biological effect of oil on these organisms; however, findings have revealed that the mussel, also enjoyed in Europe as a food, became sterile as a result.

At one particular research station at Buzzards Bay 65 species were counted before the oil spill: worms, tiny crabs, etc, all important links in the food chain of the fish that live on the ocean floor. The individual count for each species ranged from one to over one hundred per 1/25 m$^2$. Three days after the disaster most of these organisms had been killed off; the few species that did manage to survive remained drastically decimated.

It is characteristic of polluted regions that a few resistant species do "pull through" and then suddenly proliferate profusely. In Buzzards Bay this was the case with the annelid, "Capitella capitata", which sometimes reached a density of 22,700 individuals per 1/25 $m^2$; in the end, however, their numbers were reduced to 1,000 as a result of the toxic oil hydrocarbons that had remained in the ground. Similar conditions can also be found in Lake Constance, where formerly the stickleback and today the mussel dreissena polymorpha Pallas and tubifex have multiplied explosively.

### Buzzards Bay and its Consequences

A revision of the Buzzards Bay findings shows how extraordinarily persistent the oil in the ocean deposits and organisms is. For a long time biologists had believed that chronic oil pollution was biologically more destructive than a single incident. Here, however, we have proof that a single disaster can lead to chronic pollution.

It has been proved that almost all oils are toxic for practically all organisms. Among the hydrocarbons in oil there are a number of cancer-inducing compounds whose structures have unfortunately not yet been clarified. One should therefore be able to expect to have sea food and fresh-water fish analysed for their oil components. Yet systematic checks of this nature, not even for products from obviously contaminated areas, are provided neither in the USA nor in other countries.

Had only the water's hydrocarbon content or biological oxygen demand been measured after the Buzzards Bay accident, one would have been misled to think that all was well. We, in fact, run the risk of letting ourselves be fooled by temporary improvements in water quality, based on the construction of wastewater purification plants, which can obscure possible catastrophic deterioration if systematic investigations of the accumulation of toxic material are not carried out.

In view of the high costs of water purification, authorities should not shy away from spending a minimum sum for the necessary surveillance with modern methods.

In changing our pattern of intervention in the chemistry of nature from the classical conservative approach, which had prevailed throughout the history of man until some 50 years ago, to a strong chemical-industrial orientation, we must also revise our way of thinking. We must recognize the persistence of chemicals and their possible side-effects.

## Model of Organic Wastes Recycling

The following is the excerpt from a speech held by Mr. D. Stickelberger WHO/IRC at the Seminar of the Austrian Association of Water Economy, March 1972.

Most often only the immediate task at hand is considered when waste treatment plants are planned. However, this somewhat too direct approach can easily lead to unsound investments which become noticeable only in the much broader context of environmental problems as a whole. According to the first principle of thermodynamics, energy and thus matter is constant. This means that waste material cannot be destroyed or even removed. The refuse which has seemingly been disposed of always reappears in one form or other, either in the air, water, soil or all three "elements" at once.

The present paper aims at presenting a model for organic matter recycling; the stress is laid on "model", because much research is still necessary before definite conclusions can be drawn. The model may also and specially be useful in developing countries. It may help them avoid some of the mistakes made in industrialized regions.

### Ecological succession

As Stumm and Stumm-Zollinger (2) have shown, an ecosystem develops according to set laws (figure 1). To simplify matters let us examine only the correlations between the soil and plants. Basing his observations on water ecology, Stumm transposed the process of development to the soil and thus to agriculture. The figure below shows the stages of horizontal succession and is qualitative and schematic.

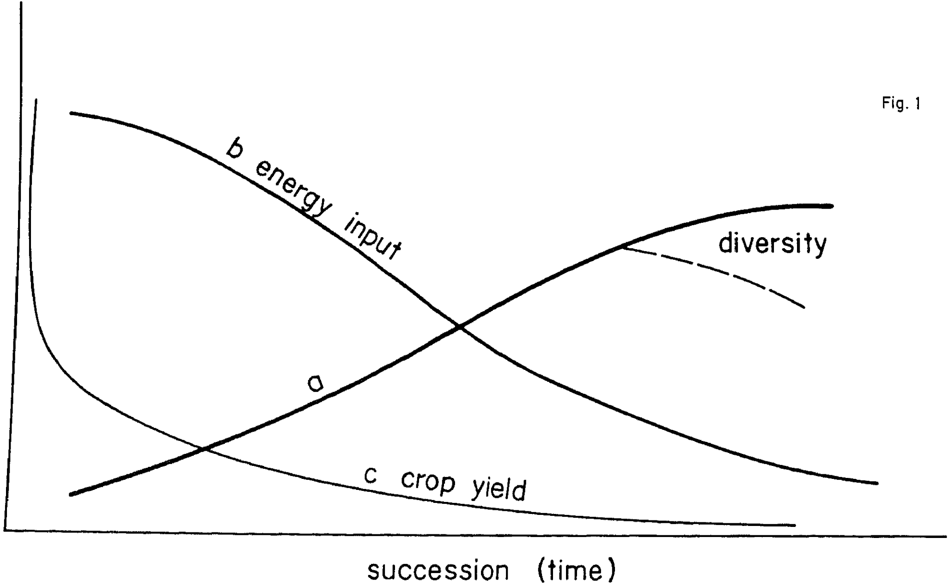


Fig. 1

Three parameters determine the development of this system in time:

a) With the progression of time (succession) the system will strike a stable balance. Ecological succession ultimately leads to a highly diversified population, which can make optimum use of the energy available for its metabolic processes. More and more complex checks and feedback loops are evolved to maintain this biocenosis.

b) While the system is being diversified and stabilized to the highest degree, the nutrient cycles begin to slow down and the energy flow is progressively reduced as it passes through the biomass.

c) As a result of the decrease in the flow of energy and the increase in stability, the yield drops steadily.

Thus we have the following schematic situation (table 1):

| **Unstable** | **Stable** |
|---|---|
| — homogeneous biocenosis | — heterogeneous biocenosis |
| — metabolic waste | — metabolic economy |
| — short, rapid nutrient cycle | — long, slow nutrient cycle |
| — high entropy | — low entropy |
| — high erosion rate | — low erosion rate |
| — high nutrient elutriation | — low nutrient elutriation |
| — eutrophic lakes | — oligotrophic lakes |
| — polluted rivers | — uncontaminated rivers |

Stumm reaches the following conclusion:

"As can be seen from this picture, high net productivity and yield can be attained only if man tries to counter the course of succession by reducing diversity. This is done through the addition of energy (plowing, using fertilizers and insecticides). Tilling the soil is profitable only if man works against the forces of nature. An increase in agricultural production obtained through the addition of mechanical and chemical energy must be purchased with the destruction of the regulatory mechanism and loss of diversity. Land and water are organic systems dependent on each other. If one is endangered the deterioration of the other follows suit. Thus a productive monoculture on land cannot be reconciled with uncontaminated natural waters".

To brighten up this somewhat dismal conclusion Stumm suggests that recreational areas with a stable ecosystem be created.

Thus, on the basis of ecology, it was shown clearly that today's farming methods inevitably lead to the pollution of natural waters.

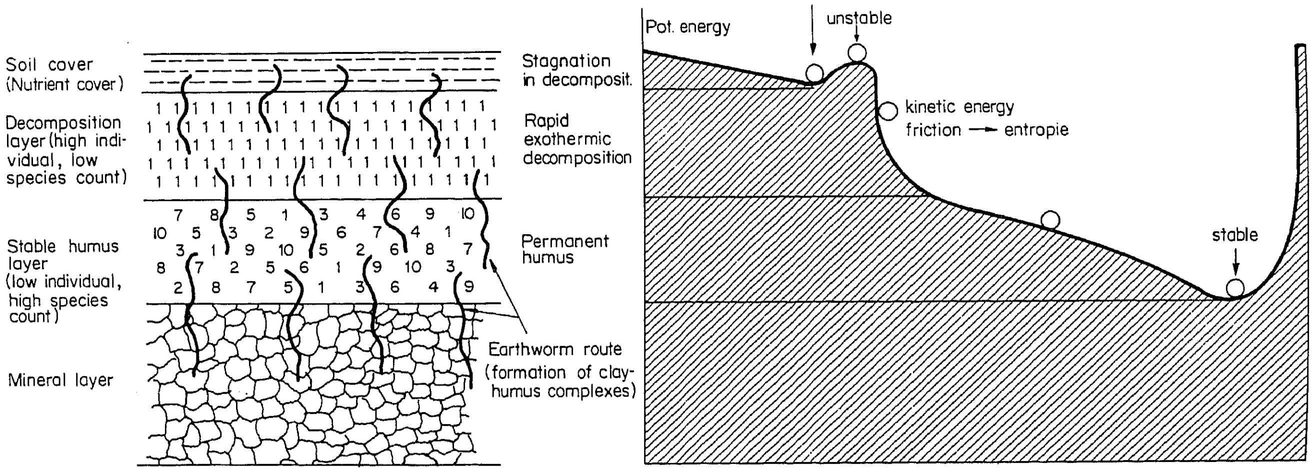
Horizontal succession as described by Stumm can also be interpreted in another sense in the case of agriculture. A forest with a varied vegetation is an example of this. The autumn leaves form layers in the ground (4).

a) The uppermost layer or forest cover consists of leaves and other undecomposed residues. This organic cover, called litter, acts as a protective shield as well as a point of contact between the soil and external influences such as wind, rain and sun. It stores energy for later use.

b) Underneath the litter we find the layer in which decay takes place. Fungi and actinomycetes abound here, serving as agents in the rapid, exothermic decomposition of structured carbohydrates. Entropy production and metabolic waste are proportionately great. The bacteria count is very high while there are few species. Plants forced to grow in such an area will show signs of disease or lower resistance; in fact, they very often die. Budding is prevented or delayed (5). This second, "aggressive" phase of decay in which enzymes, vitamins and antibiotics are formed corresponds to what is known as fresh compost in the field of composting. The dyes that develop here represent a preliminary stage in the production of humic acid.

This layer of decomposition is unstable by nature.

Fig. 2



Comparison between the biological and mechanical process of energy transformation

c) The original forms and structures of leaves, larvae and other edaphon vestiges are no longer recognizable in the stable humus layer. Decomposition here has been completed. A low bacterial count coincides with great diversity and corresponding metabolic economy with low entropy. This final stage can be compared to mature compost, which stimulates plant growth. The edaphon, among which we count the earthworm, mixes the organic material with minerals in the soil and brings about the formation of clay-humus complexes and protein-humus complexes.

The humus layer is stable by its very nature.

Each autumn a new layer of leaves settles on the ground of the model forest described; the previous year's cover thus becomes the layer of decomposition and the decayed layer humifies. Removing the forest cover can cause irremediable damage.

Thus the scheme of ecological succession shown in figure 1 is relevant not only to the "horizontal" development in time but can also be applied "vertically" to layer formation which is determined by the time element during the course of the year. In the decomposition layer the cover layer, with its stored potential energy, is transformed into kinetic energy, ultimately reaching a steady state in the stable humus layer. The three layers described in the above schemes are separated in time (horizontal succession), yet, at the same time, exist side by side (vertical succession).

## Industrial energy input

Like all sectors of production, agriculture, too, needs energy. It was shown that any increase in production had to be purchased with greater energy input. This energy is generated according to industrial principles. The effect is striking, the increase in production great. However, with growing awareness of the need for environmental pollution control, man has begun to realize that there was indeed a hitch to this. Stumm's scheme of ecological succession shows clearly that any increase in production through the direct input of industrial energy was inevitably linked with instability.

The following example can be used to illustrate what this means in concrete terms.

The energy input of the edaphon in the soil is superseded by the plow and mineral fertilizers. Soil porosity which is also dependent on the edaphon is provided for by plastic foam added to increase pore volume. This static, isolated measure to improve soil quality, however, cannot suffice to replace the dynamics of the edaphon in the soil. Of course, air is brought into the soil and water permeability is promoted, but all this is only temporary. The remaining, permanent effects of the edaphon disappear. Soil erosion in general, not only on slopes, becomes more and more of a problem as it contaminates natural waters. Industrial energy input kills off the less resistant species in the soil while the tougher, more adaptable ones take over due to the lack of competition. An example of this is the rapid proliferation of unspecific nematods, small, transparent worms of 0.5 to 2 mm in length (5000 kinds have been observed so far) (6). Basically they feed on the total mass of dead material in the soil. Because there is not enough decaying matter, they turn to the living tissue of plants, thus becoming pests. Pesticides are then used for their extermination. As a result of the unstable conditions in the soil the plant loses its buffer intensity and becomes vulnerable to the attack of individual organism types that behave like pests and as such multiply with great rapidity. Pesticides have a selective effect. DDT, for instance, attacks only insects, leaving arachnids unharmed. The red spider – vermin number one in orchards – has been able to enjoy a veritable population explosion thanks to DDT.

The following succession can be deduced on the basis of this fact. Industrial energy input → metabolic waste → increased yield → homogeneous biocenosis → eutrophication of natural waters → increased vulnerability to disease and pests → increased use of pesticides → increased individual count among pests → heightened toxic situation → aquatic cultures in a sterile environment → high costs and high calorie foods with a low buffer intensity (diseases resulting from modern civilization).

A more radical (utopian) solution for maximum net production with minimum structure is given below:

Without passing any intermediary stages, i.e. plants or animals synthetic nutrients are given directly to man. All metabolisms except that of man are disregarded. The result would be maximum simplification of the food chain accompanied by maximum environmental pollution.

## Biological energy input

Similar to the ecology of the forest, the scheme for incorporating metabolic end products can easily be applied to the nutrient cycle.

If all organic urban wastes were recycled in agriculture, great energy input would be possible, depending on the trophic level, even after deduction of the loss of entropy. Instead of having a rapid energy flow with its inevitable loss of stability and diversity, its entropy and rapid food cycle, energy input would be obtained by recycling metabolic end products. In other words, biological energy replaces mechanical and industrial energy input.

We then have the following trend:

Metabolic end product organic waste → biological energy input → yield corresponds to biomass input → vertical biocenosis ranges from homogeneous to heterogeneous → no run-off reaches natural waters → diversity even with monoculture, high buffer intensity of crops → environmental pollution prevented at source → urban wastes recycling, formerly financially unrewarding, is made economical.

Some one hundred farms and several agricultural enterprises engaged mainly in vegetable growing have been able to make a biological and financial success of "plowless farming" whereby the soil is given only superficial tilling. Admittedly, relatively little composted urban refuse was used. Most often organic animal and vegetal wastes from the farms themselves were applied.

So until there has been more research in this field, the conclusions below can only serve as a model representing an extreme case. Between the unrealistic demand for the total re-use of all organic urban wastes on the one hand and the equally unrealistic possibility of synthesizing all food on the other, an infinite number of reasonable intermediary solutions are conceivable. At present, however, man still seems to be opting for the most rapid food cycle with all the negative effects this has on the environment.

## Conclusions

The aim of this paper is to destroy the concept that farming is profitable only if man works against the forces of nature and to show that satisfactory yields can be obtained by respecting and observing the laws of nature. A cost comparison between the price for a major environmental clean-up and protective, conservationist measures provided for recycling would surely tip the scale in favor of re-use. Ecological succession in its vertical form fulfills the prerequisites for stability and high yield, two principles which seem to exclude each other from the start. Stability also means clean water, and clean water is certainly more economical and desirable than cleaned water.

Based on the correlations exposed we can summarize that

— elimination and destruction are contradictions in themselves
— the disrupted ecological system must be brought into balance and aligned with initial production conditions through buffered feedback loops of end products.

Until this aim can be realized, however, psychological, technological and economic obstacles must be overcome. Industry and technology must participate in evolving model schemes by developing suitable treatment, size reduction, distribution and manufacturing processes as well as providing biochemical agents and additional nutrient compounds based on a slow cycle.

## Definition of terms

**Ecology** The science pertaining to the relation between living organisms and their organic as well as inorganic environment.

**Biocenosis** The balanced relation between the plant and animal species of a biotop under given external conditions.

**Biotop** Part of the environment populated by a characteristic and constant community of plant and animal life.

**Ecosystem** Together the biocenosis and the biotop constitute a functional unit in which organisms and the environment influence each other alternatively. Examples are lakes, meadows, forests, ponds, puddles. The ecosystem is an organism on a higher level in which organic and inorganic components mutually determine each other's existence.

**Metabolism** The physical and chemical processes that take place continuously in living organisms.

**Catabolism** The process by which an organism decomposes and, with the concomitant release of energy, turns to waste, the end product.

**Entropy** Theoretical value measuring the mass of energy in a thermodynamic system that cannot be transformed into mechanical work.

**Stable** A system is termed stable if it remains more or less unchanged despite external influences such as climatic variations, over-fertilization and the use of pesticides. According to Thienemann's second law (1), a biotop is stable, that is, optimum conditions have been attained when there are a great number of different species but relatively few individuals within each species. The more varied the ecosystem and the more diverse the organisms (heterogeneous biocenosis), the longer the food cycle becomes. This is accompanied by a decrease in entropy production (metabolic economy).

**Unstable** An ecosystem is considered unstable when there are few different species and one becomes predominant through the overabundance of its individuals. The few existing species are, ecologically speaking, very similar (homogeneous biocenosis). The nutrient cycle is short and changes very rapidly, with an increase in entropy production (metabolic waste).

**Nutrient cycle — short** The shortest and most rapid cycle excludes its living organisms. An extreme example is the production of synthetic foods for human consumption. Less extreme and more feasible is hydroponics, soilless crop-raising with the help of solutions containing plant nutrients.

**Nutrient cycle — long** Decaying plants in the soil are eaten and excreted; these excrements are, in turn, eaten and excreted by other animals. A succession of subsequent links which play a part in decomposition follows, until the nutrients are finally absorbed by plants (vegetables, fruit, then indirectly by pastureland to go into milk and meat, all foods eaten by man). During the passage through the organism's intestines, only one to ten per cent of the food is digested; thus enough remains for its successor in the food chain.

**Buffer intensity** In the ecological sense, this term expresses the constance of a state of equilibrium in relation to external influences. Under stable conditions, the buffer intensity in an ecosystem is very high; in an unstable, precarious system it is low. There is very little resistance against disease and pests. The various degrees of metastability lie between the stable and unstable poles.

**Biomass** The total mass of living organisms found in an environment.

**Edaphon** Collective term for all organisms living in the soil.

**Crumb structure** Biologically-formed soil aggregates that have a stabilizing effect as a result of the slimy material produced by the edaphon.

**Hydrocultures** (Hydroponics, water cultures) Plants grown in a water solution containing all necessary nutrients, which are absorbed through root-fibres.

**Eutrophication** Growth and spread of nutrients.

**Trophic:** connected with nutrition.

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# Abstracts

The subsequent abstracts have been taken from our documentation on solid wastes which contains at the present moment 800 publications.

We intend to send to all our Collaborating Institutions and other interested parties in a few months the Thesaurus which is the key to our documentation. In the following IRC-News we plan to publish selected abstracts.

*Braun, R.:* Problem of disposal of inorganic industrial sludge (Problem der Beseitigung anorganischer Industrieschlämme)

DECHEMA, Monogr., Jg. 64 (1970), 1144–1167

Industrial sludges, particularly from electrochem. industries, contain toxic substances, soluble in water, or which become soluble upon prolonged exposure. The insoluble sludge is filtered, and dried for disposal, but should not be burned in conventional incinerators. The solvability of the slag formed on heating alone or with 10–30% waste glass was found to vary, depending on the source of the sludge, with max. solvability at 700° and 400°, (30 and 20% solvability), and decreasing solvability at 1000–1200° (5–< 1%). The solvability of slags with glass is not always lower than without glass, but the material is smooth, and nonporous, and thus more readily disposed. Other methods tested included solidification, by adding sand and cement or gypsum, and biological decomposition, by composting with organic waste and sludge. The composts so obtained have not been extensively tested, but considerable amounts of industrial waste components in composts have been found harmless to plant growth and germination.

*Hämmerli, H.:* Calculation of refuse firing (Berechnung von Müllfeuerungen)

Maschinenmarkt, Jg. 75 (1969) No. 41, May 23

Planning and operating of refuse incineration plants most correspond to population growth in order to cope with the constantly increasing generation of refuse. Plastic wastes heighten the danger of corrosion. Refuse weight and volume after loading are important factors in collection. The throughput capacity of the incinerator depends on the wastes' calorific value, which is constantly on the rise. To reach the guaranteed throughput capacity of a furnace the grate width and length, combustion chamber volume as well as operating hours are decisive. The above-mentioned critera can be calculated on the basis of the admissible heat load for the grate, the quantitative grate load and the thermal load of the combustion chamber. The possible operating capacity of a furnace can be represented graphically by means of a nomogram showing grate performance and firing.

*Anonymous:* Burn refuse without oxygen
The American City, March 1969, p. 44

Pyrolysis may be the answer to solid-waste disposal problems in some cities if the methods being developed by the City of San Diego, Calif., continue to show promise. Pyrolysis (destructive distillation in the absence of oxygen) has been studied by the San Diego City Utilities Department as a method of reducing the volume of solid wastes which must ultimately be disposed of by sanitary landfill.
Combustible materials fed into the pyrolysis chamber are heated to 1,200 °F to 1,500 °F. Gaseous end products include large quantities of condensible organic substances and several noncondensible gases, including $CO_2$, $H_2$, and CO. The small amount of residual organic char produced has a potentially significant commercial value. The volatile condensible end products can be employed as fuel to provide heat for the pyrolysis operation. Using typical samples of municipal solid wastes, researchers have found the operation to be self-sustaining. Estimates indicate that the useful life of existing landfill areas could be increased sevenfold by pyrolysing the combustible fraction of the waste, burying the noncombustibles in the landfill, and either burying or selling the organic char residual.

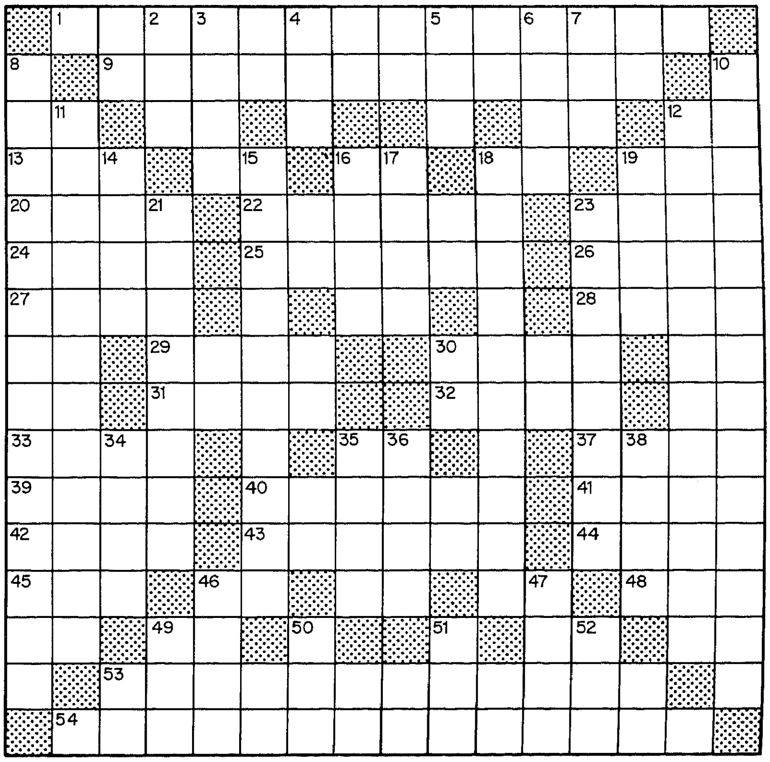
Across:

1. Nutrient spread in water
9. Stage in hygienization
13. License plate of Canada
19. Metal
20. Precipitation
22. Interval of notes in music
23. To assume a certain attitude
24. German fem. name
25. 2/3 of all chemical elements (pl.)
26. Teller of untruth
27. Musical composition (German)
28. The disturbed biological balance of a water body causes its blooming (sing.)
29. Dissolute person
30. Indication
31. Village in the Eastern Pyrenees
32. International Red Cross Committee (German, abb.) first K = C
33. Help in wrongdoing
37. Part of the human body (pl.)
39. Color shade (Ital., pl.)
40. No man is an...
41. Name of a Swiss agricultural exposition
42. Noun-forming suffix meaning inflammatory disease
43. Hydrocarbon
44. Denial (Russian)
45. Such (dial.)
48. Village in the Caucasus, USSR
53. Waste processing method
54. The price we pay for affluent

Down:

2. To join in marriage (colloq.)
3. Please reply (abb.)
4. Port Authority of a City in Virginia USA (abb.)
5. International Chamber of Commerce (abb.)
6. Rhythmical movement caused by the attraction of the sun and the moon
7. Electrically charged particle
8. Invisible to the human eye (pl.)
10. Chemical process
11. Underprivileged
12. Differ in opinion
14. ...stion, biological decomposition
15. Consumed by fire
16. German masc. name
17. Phoenician God
18. Bane (pl.)
19. Working laboriously on a task
21. Relating a story (3rd person)
23. Aquatic flotsam
34. Masc. name
35. Lowest fem. voice
36. River in Styria
38. South American spicy dish
46. 12 (Spanish)
47. Material allowing percolation
49. Insect
50. National Theatre of Paris (French, abb.)
51. Lowland enclosed by hills (German)
52. Unquestioning belief (French)

Answers appear in next issue
Puzzle Editor, B. Krummet



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