# Technology and Development Aid

## The Case of Ganga Action Plan

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*Technical aid programmes constitute an important part of bilateral and multilateral international development programmes and are an important conduit for the import of technology. These programmes have as one of their objectives the transfer of technology. Yet they are normally carried out by technology suppliers who work on, commercial lines and whose interests are opposed to that of upgrading the technical level in the underdeveloped country.*

*The Ganga Action Plan is financed by 'development aid'. Foreign aid in the actual execution is confined to two projects, the integrated sanitation project at Kanpur and the low-cost treatment and conveyance system at Mirzapur, , both under Dutch development aid. What has been the impact of this on technical upgradation?*

DURING the last decades, there has been an increasing realisation that technological change has played a crucial role in economic development. In the context of underdeveloped countries too there is some realisation that long-term growth requires not merely the utilisation of underutilised resources or more investment, but changes in the technical conditions of production. In the perceived context of the need for upgradation of the technical level in an underdeveloped country, the import of higher, more advanced technology from the developed countries is seen by many as the realistic option.

The upgrading effect of the imported technology can be considered to consist of two components. On the one hand, the import of technology makes it possible to undertake production which is more efficient than what would be normally possible in the existing situation. In case the imported technology introduces a more efficient process (product) than what could have been possible with the existing technology in the host country itself, then we can consider the technology to have a positive additive effect. In case the imported technology is less efficient or of comparable efficiency, it can be considered as having a negative additive effect and a non-additive effect respectively. What needs to be made clear is that the additive effect does not refer to the efficiency of the imported technology as compared to the existing practice in the underdeveloped country, but to an alternative solution which can be adopted on the basis of existing know-how in the country.

But what is more important in upgrading the technical level in a country is not so much the positive additive effect, but the propensity for diffusion of the technology throughout the particular industrial branch. This propensity depends not only on demand factors but also on technical factors. As significant as the impact within an industry, or even more important is the inter-industry impact of a new technology.[1] One of the most important inter-industry impacts is the inter-industry diffusion of technology, which has been captured by Rosenberg by the term 'technological convergence' (Rosenberg, 1963).

What is important for us to consider is the effect of the method of import of technology on the subsequent intra- industry and inter-industry diffusion of technology. The asssumption is that the more active the links with and within the indigenous innovation chain[2] during the import of technology, the greater will be the propensity for diffusion. In practice, the crucial link is that between invention and innovation.

Any process which bridges the invention-innovation gap can be considered to promote diffusion, and therefore upgradation of techniques and ultimately development. The disjunction between science and technology on the one hand and production on the other hand, is a characteristic of underdevelopment.[3]

In this context we propose that apart from the additive effect it is also important to consider the connecting/disconnecting effect of technology imports. In considering the connecting effect, it is necessary to take into consideration the utilisation of different technologies during the import of a new technology. Given the potential for inter-industry diffusion of processes, the technologies to which the links have to be established are at different 'technological distances'[4] from the imported technology. The links which are established between the imported technology and existing indigenous technologies would have a dual function—application of indigenous know-how to the problem being tackled, as well as the absorption of the new experience by the local technological structure. A similar diffusion also takes place through links with the education and training sector.

Such an incorporation of an advanced technology, with positive connecting effects has various other consequences other than a mere diffusion of the technology. This connection with the local know-how base makes it possible for the new innovation to follow another 'technological trajectory'[5] different from that followed in the developed country, and brings it more in tune with the resource bases and needs of the underdeveloped country. It will then be possible to develop technologies appropriate to the host country. Without the positive connecting effect the imported technology remains an island without significant long-term effect, and we cannot consider such an import as transfer of technology.

Technical aid programmes constitute an important part of bilateral and multilateral international development programmes and are an important conduit for the import of technology. Hence it is important to consider the impact of the technology imported under technical aid programmes—both the additive and connecting effects. These programmes have as one of the objectives the transfer of technology. Yet they are normally carried out by technology suppliers who work on commercial lines and whose interests are opposed to that of upgrading the technical level in the underdeveloped country.

### I

### Ganga Action Plan

Given this background, it is interesting to consider the possible impact of the technology imported under the Ganga Action Plan (GAP), taking into consideration both the additive and connecting effects. The Ganga Action Plan is an important project, being the first widely publicised technology mission[6] undertaken by the present political leadership, whose emphasis on the role of technology has been seen by many as a new era in India's development strategy. The Ganga Action Plan has a significant component of foreign inputs, financed by 'development aid'.

The setting up of waste water treatment plants is the focus of the plan to clean up the Ganga river. "The principal thrust of the Ganga Action Plan in the first phase is immediate reduction of the pollution load on the river Ganga and establishment of financially self-sustaining treatment systems" (Ministry of Environment, 1985 p 4). Foreign aid in the actual execution of the Ganga Action Plan is confined to two projects. The integrated sanitation project at Jajmau, Kanpur and the low-cost treatment and conveyance system at Mirzapur both under Dutch development aid. The total cost of the Dutch project is Rs 16 crore (*GAP-present status*, May/June 1987, p 14) as compared to the Rs 290 crore earmarked for the first phase of the whole Ganga Action Plan. The specific demand of the GAP to formulate projects which will produce methane from sewage treatment is to be taken care of in the Dutch project by the utilisation of anaerobic treatment of the effluent.[7] In the words of the Ganga project directorate (GPD), this Dutch project is to supplement the Indian know-how, because "the Dutch technology relates to anaerobic processes as distinct from the aerobic processes generally followed in India" (GPD, no date (June 1987?), p 14). The heart of the Dutch project is the utilisation of the Upflow Anaerobic Sludge Blanket (UASB) system[8], for the treatment of the waste water at Jajmau, Kanpur (and later also at Mirzapur).

Before we analyse the possible impact of Dutch development aid on technical upgradation, it is important to situate the development aid within the Ganga Action Plan. A perusal of the developments shows that the foreign inputs were not invited on the basis of any technology plan. Indeed, no detailed assessment was made on the basis of which a rational decision to import technology could be taken. Related to the absence of a plan, is the fact that the participation of the Dutch in the GAP and the effort for the cleaning of the Ganga took place on the basis of two independent processes.

The decision to clean up the Ganga on a mission basis[9] was taken up immediately after Rajiv Gandhi won the 1984 elections. The action plan for the prevention of pollution of the Ganga was prepared by the department of environment in December 1984, and the Central Ganga Authority with the prime minister as chairman was set up in February 1985. A high level interdepartmental steering committee was set up to plan, administer and monitor the action programme, and the steering committee held its first meeting on June 28, 1985. The revised action plan prepared by the authority in July 1985 has become the authoritative document as far the plan is concerned.

In the meanwhile, during the bilateral consultations between the government of India and the government of the Netherlands in February 1985 it was decided that environmental protection would be a field for 'co-operation'. The areas identified included "general assistance in the field of water pollution control in specific river basins and notably in the Ganga river basin and transfer of know-how of 'clean' production technologies and waste water treatment technologies". Or in other words, the principal decision to import waste water treatment technology was taken quite early, even before the first meeting of the steering committee of the Ganga Action Plan in June 1985.

As a part of Dutch involvement in the environmental sector in India, an identification mission for development co-operation between India and the Netherlands visited India during August and September 1985.[10] It was this mission which identified Kanpur and Mirzapur as the sites where Dutch project were to be set up. Formally the decision to use a particular type of technology was taken by the fact-finding mission which visited India from January 13 to February 9, 1986 for assistance in the field of environmental and sanitary engineering. This mission identified the UASB process as the process to be used in Kanpur. But in fact we can assume that the decision to use this process was taken when the identification mission was constituted, since the leader of the mission belonged to the consultancy firm Haskoning, that was involved in the development of the UASB process for sewage treatment in (semi) tropical conditions, by putting up a pilot plant in Colombia.

## II

## Additive Effect

In order to consider whether there is an additive effect due to the Dutch technology introduced for waste water treatement, we need to make a comparison between the imported Dutch technology and the technologies which would have been applied with the existing knowledge in India. In case, the Dutch system is more efficient in the given concrete conditions, than what would have been applied on the basis of existing Indian technology, then we can consider that the imported Dutch technology has had a positive additive effect on the Indian technological level.

The waste water treatment technology to be introduced by the Dutch in India has two components. It was originally proposed (DGIS, 1986) that the waste water from the tanneries and sewage in Jajmau, Kanpur, be combined and treated. therefore we are comparing the utilisation of UASB technique for combined treatment with the treatment alternatives suggested both for sewage and for tannery effluents.

### Sewage

In order to assess whether the Dutch technology to be applied in Kanpur is more efficient in the given concrete conditions, that is whether it is more 'appropriate',[11] a detailed assessment of the different alternatives have to be made. In the absence of the availability of any other studies, we are basing our judgment on the comparison made by the Dutch fact-finding mission (DGIS, 1986). This is further validated by the fact that the choice of UASB technology as the most appropriate for upgrading the sanitary and environmental conditions in Jajmau, was taken on the basis of the assessment made by the Dutch fact-finding mission.

The mission report does not consider the advantages of its proposal as compared to the original proposal of the Ganga Action Plan[12] but with three other options of its own choice, which are well known and for which the technology exists in India. Therefore the comparison made by the report is too narrow and inappropriate to conclude whether the Dutch technology can have an additive effect. Yet as we shall argue even within these narrow confines there are enough indications to show that there is no additive effect or that the technology is 'inappropriate'.

The validity of the comparisons made in the Dutch report between the Dutch UASB alternative and the other alternatives itself needs to be questioned. Table 1 gives comparison of the Dutch alternative (option D) with the next best of the alternatives considered which is somewhat similar to the option of the GAP (option B). In the report, the comparison is made as if the UASB alternative is a full-fledged treatment system, and on this basis the Dutch alternative is presented as a superior technology. The use of UASB reactor to treat sewage is normally considered only as a form of pre-treatment, due to its inefficiency in the removal of pathogens in the sewage and because of lower efficiency of the removal of BOD and COD.[13]

The inefficiency in the removal of pathogens works against the rational use of the wastewater in areas around Kanpur which is to use the water for irrigation and not for release into the river Ganga. The investigations in Colombia conducted by the Dutch company Haskoning shows that UASB treatment removes only 50 per cent of the pathogens (Van Velsen, A F M and J A W Maas, p 4). On the contrary, normal treatment methods using maturation ponds achieve pathogen removal of 99.9 per cent measured in terms of the removal of faecal coliform, as well as the removal of cysts and ova of intestinal parasites. Even the other anaerobic method tried out in India, the anaerobic filter has a higher efficiency in the removal of pathogens than the UASB alternative.[14] Therefore, in case the sewage farm workers are not to be exposed to infection, maturation ponds or other methods

Table 1: Comparative Features of Wastewater Treatment Methods for Kanpur

| | Option B | Option D |
|---|---|---|
| Investment costs without land (106 Dfl) | 7.5 | 6 |
| Construction area (ha) | 22 | 3.5 |
| Operation/maintenance costs (Dfl/year) | 95,000 | 80,000 |
| Operational skill | high | low |
| Energy consumption (106 kWh/year) | 1 | 0.7 |
| Energy production (106 kWh/year) | 1.1 | 1 |
| Treatment efficiency (per cent BOD) | 85-90 | 80-90 |
| Effect of industrial discharges | – | + |

*Notes:* B = high rate aerobic treatment, including anaerobic digestion of the excess sludge, followed by maturation ponds. D = anaerobic treatment in an UASB reactor followed by a post-sedimentation unit. Dfl = Dutch florins.

*Sources:* *DGIS*, 1986, Table 8.

of removal of the pathogens will have to be utilised. But the costs involved for this are not included in the comparison made with the other alternative, which includes maturation ponds. In case maturation ponds are to be included in the Dutch scheme, it would naturally have its impact on the investment and maintenance costs as well as on the construction area required, and the superiority of the Dutch alternative will have to be argued afresh. Further, the assumption made in the report that the skill required is low cannot be justified.

The treatment efficiencies used in the report also need to be questioned. Table 1 gives a BOD removal efficiency of 80-90 per cent which seems comparable with that of the B option which has an efficiency of 85-90 per cent. The paper by two engineers of Haskoning, the firm which conducted the pilot plant studies in Colombia (Van Velsen, A F M and J A W Maas, p 5) conclude that "a BOD reduction efficiency of 80-90 per cent has to be considered as the maximum for anaerobic treatment of domestic sewage". A perusal of the data provided in the same paper shows that the value of 89 per cent which was achieved for 6 hours retention time, referred to raw influent and filtered effluent which cannot be applied for the UASB plant, where what is envisaged after the UASB treatment is only a post-sedimentation. The highest value which can be achieved is not 89 per cent but 84 per cent, which was obtained in Colombia for raw influent and settled effluent (DGIS, 1985, 8-5). This value is also subject to lowering in case the settlability of the suspended solids is less than that in Colombia.

The lower efficiency in the removal of BOD would mean that this treatment will not be sufficient to release the effluent into the Ganga. This would mean that even in case the highest efficiency is met the BOD in the effluent would exceed 30 mg/l which is the limit set by UP Water Pollution Control Board.[15] In case the water is to be used for irrigation, there is no need to treat it at all, since the BOD of the influent is below 500 mg/l the limit for agriculture. But due to the low efficiency in the treatment of pathogens, the effluent from the UASB plant would still need post-treatment. Indeed the pilot plant studies in Colombia were done along with various post-treatment facilities.

It is also significant that the COD reduction values (which are not used for comparison in the DGIS report) are substantially lower for the UASB treatment of domestic sewage, ranging from 73 to 78 per cent for HRTS ranging from 2, 4 to 8 hours. But what is even more important is that these are based on the figures for raw influent and filtered effluent. Due to the comparative inefficiency of the UASB reactor to degrade suspended solids, the efficiency of the system to degrade total COD is much less. The data available for raw influent and raw effluent shows that a maximum efficiency of about 68 per cent was achieved for HRTs of 6 hours (Lettinga, G et al, 1987 p 27, Fig 4). The performance obtained from the pilot studies at the Netherlands at 20° C has been even more unsatisfactory. According to the researchers, "clear evidence was obtained that the system was fairly ineffective in removing finely dispersed solids". Since in many months in Kanpur the sewage temperature is 20° C or even less unlike in Columbia where it was around 25° C, the poor results obtained in the Netherlands are also of significance. Unlike what the Dutch technologists appear to consider, the higher temperatures at Kanpur can also pose a problem for the treatment efficiency of the unit, since with temperatures in the forties the mesophilic bacteria would be operating at a range of lower efficiency. The problem of treatment of suspended solids appear even more important, when we consider that the suspended solids in Kanpur is about three times higher than even the high values in Cali.[16] Therefore, it appears likely that COD reduction of the UASB plant in Kanpur might be even less than the 68 per cent obtained in Cali. This has to be compared with the COD removals of >90 per cent achieved by the normal treatment systems. Yet, the Dutch comparison does not use COD reduction as a parameter for comparing the performance of the different technologies.

At the same time, even among the anaerobic systems there are systems with better efficiency in the removal of suspended solids. Anaerobic filters which have been tested out in India, have shown better efficiency in the removal of suspended solids. An efficiency of almost 88.5 per cent has been reported for the removal of suspended solids, the efficiency for BOD removal was 80 per cent (Raman, V et al, 1982 p 77).

Indeed the researchers from Wageningen recommend the UASB process only as pre-treatment, "all these investigations revealed that sludge blanket concepts provide a satisfactory pre-treatment in terms of COD and BOD reduction at higher ambient temperature" (Lettinga et al, 1987, p 29). Yet the report of the Dutch technical mission (DGIS, 1986) which visited India does not consider the UASB plant as a pre-treatment facility but as a full-fledged treatment facility in enumerating its advantages over the other alternatives.

On account of these factors the additive effect of the UASB technology considered as an alternative for sewage treatment needs to be questioned.

## TANNERIES

The assessment of the additive effect regarding the treatment of tannery effluents is crucial in the case of the Dutch project, since it is the *raison d'etre* of the project. Given this, it is strange that the mission report does not even use COD values to compare the performances of the different technological options. This indicator is more crucial in assessing the efficiency of treating industrial effluents. The lower efficiency of the process in treating suspended solids and COD, discussed in the earlier section can be expected to have a more negative effect in the case of treating tannery effluents. Apart from this, the fact that the Dutch have much less experience, either at the lab level or otherwise, in dealing with vegetable tannery effluents, casts doubts at the possible additive effect of the Dutch alternative.

The additive effect with reference to the utilisation of UASB reactor for the treatment of tannery effluents has to be assessed by comparing with the alternatives put forward in India.

Most of the important work on the treatment of tannery effluents in India has been done by the Central Leather Research Institute (CLRI), Madras and by the National Environmental Engineering Research Institute (NEERI), Nagpur. In this paper we have confined ourselves to the contribution of NEERI on which information is available.

On the basis of the survey of 11 tanneries conducted by NEERI, the method suggested is the removal and recovery of chromium followed by treatment with anaerobic upflow contact filter and aerobic treatment. The proposal by the Dutch to utilise UASB to treat tannery wastes is made on the argument that the sewage treatment system can easily handle a higher load of organic matter,[17] with the added advantage of increased gas production.

Unlike the process route suggested by NEERI, the Dutch alternative does not include any aerobic component. There has been a discussion in India about the advisability of using anaerobic methods to treat effluents containing tannins. One of the studies which compared aerobic and anaerobic methods concluded that aerobic methods are much more efficient in dealing with tannins. Since the Dutch method does not make use of any aerobic component, it cannot be expected to remove the tannins adequately, or in other words, the alternative can be considered at best as a form of pre-treatment even when considering the process as a method of treating tannery effluents.

Some of the lab level work conducted at the Water Pollution Control Laboratory at Wageningen in the Netherlands, show some of the problems, apparently of a more serious nature, associated with the utilisation of the sludge blanket process for the treatment of waste water containing vegetable tannins. "This study indicates that tannins are potent inhibitors of methanogenesis. Therefore their presence in wastewater should be considered when evaluating the feasibility of anaerobic waste treatment processes" (Field, J A and G Lettinga, 1987, p 373). Of course, the extent to which the tannins and their derivatives present in the wastewater will affect the production of methane depends on the type of tannins and their derivatives present in the wastewater. But the effect of one of the tannins studied shows that the toxicity of this chemical for the methane producing bacteria and subsequent reduction of the production of methane is significant (about 45 per cent), even at the concentrations of tannic acid present in the wastewaters of Jajmau.[18] What is important to note is that this toxicity is also persistent in the case of one of the tannins(gallotannic acid) studied. Given this background it is also important to be cautious about the serious problems that might arise during the start up of the UASB plant. The starting up of the UASB plant and the formation of a good granular sludge is a very sensitive and skilled operation in the running of the UASB plant. In case the chemical patented at the University of Wageningen, to precipitate these tannins, is to be used in Jajmau for the pre-treatment of the wastewater, then the advantages of the UASB process would have to be reassessed.

Chromium is another component in the effluent at Jajmau with toxic effect on the methanogenic bacteria. The effect of this chromium is also considered to be insignificant due to the great dilution with sewage. Yet, this has to be taken into consideration as one of the possible drawbacks of the UASB technique. A further undesirable aspect of the Dutch proposal is the presence of chromium in the sludge produced, which would make the sludge unsuitable for agricultural purposes.[19] The problem of chromium in the sludge is dismissed as rather unimportant by the Dutch because of the fact that the chromium is present as trivalent chromium and not as the toxic hexavalent chromium. Since we cannot rule out the possibility of conversion of trivalent chromium to hexavalent chromium, it would be quite irresponsible to dismiss the problem of sludge disposal as the Dutch report does. Even if the sludge is not used for agricultural purposes with the resulting effect on income, the problem of chromium toxicity is not solved since the sludge would anyway have to be disposed and most likely it would only result in the chromium laden sludge being illegally used for agriculture.

In the evaluation unertaken in India of the different types of anaerobic reactors, (NEERI, 1987 b) preference was given to anaerobic filters rather than to sludge blanket reactors. One of the reasons is that, the UASB reactor is less resilient to shocks than the anaerobic filter reactor.

In the opinion of four of the Indian scientists who have been working on anaerobic digestion, located in three different institutions, the preference under Indian condition would be for the application of anaerobic filter rather than for the UASB reactor. Their reason is not so much the possible inference due to the toxins present, but the greater skill required in operating and maintaining the UASB plant as compared to the filter. On the contrary the opinion of experts in the Netherlands seems to be that they both require equally skilled operators.

The above discussion, questions the additive effect of the new technology introduced under Dutch Development Aid. Table 2 enumerates the problems on account of which the superiority of the Dutch technical package put forward in the mission report *(See Table 1) needs to be questioned.*

With the avilable information, there appears to be enough basis to assume that there is no additive effect from the technology, considered both as a treatment method for tannery effluents and for sewage. A more quantitative assessment including that of the Ganga Action Plan alternative and the NEERI manual would make it possible to take a more definite position.

## Elimination of Local Alternatives

What is important is not so much the technical validity of the criticisms of the Dutch option for the environmental programme at Jajmau, but the fact that the 'technical evaluation' was not an objective assessment of the different technological options available in India as compared to the technology considered for importing. The technology assessment was done by the Dutch mission in which eventual contractors already had a dominant role. The mission basically compared the conventional aerobic methods of treatment with only one types of anaerobic treatment—the UASB technique. The other method, the anaerobic filter treatment of sewage which was developed in India was not really compared (DGIS,1986, 5.1.3.b and 5.1.3.c). In my discussions with Haskoning, the anaerobic filter was basically dismissed due to the problems of clogging which the filter faces. Yet, according to earlier Indian experience, the anaerobic filter worked for 1.5 years without clogging and by flushing water from the top and desludging the filter could work indefinitely (Raman et al, 1982, p 75). The NEERI study on vegetable tannins with anaerobic filter also noticed that filters were not choked (Arora, H C, 1980, p 506). A recent survey of the different anaerobic systems has also identified the utilisation of anaerobic filter for the treatment of municipal wastewater as one with great potential especially in the developing countries (Vigneswaran, S et al, 1986, p 33).

From a study of the problems associated with the treatment of the effluent in Kanpur, one conclusion emerges. Considering the fact that UASB is a good process which has great potential for application in India for dealing with water pollution, the Jajmau sewage mixed with tannins appears to be the least suitable for it. The UASB process is ideally suitable for dealing with soluble wastes for which it was developed. The best would be to apply it first to one of the easier wastewaters and later try out on more difficult wastewaters such as sewage.

## Connecting Effect

*Even if the technology imported under* technical aid has positive additive effect, it can still take place in a manner that the connecting or disconnecting effect dominates with very different consequences for long-term development. In order to assess the connecting effect, we need to inventarise the relevant technologies available in the country and the extent to which they have been utilised in the project. The 'relevant' technologies can be ranked according to the 'technological distance' they have from the specific technology being introduced. Thus for example, the knowledge available in the country about the UASB process can be considered to be at the same distance or negligible distance from the technology being imported. But what is relevant is not merely the knowledge about the specific UASB process but also of other anaerobic processes such as anaerobic filter process. The distance from the specific technology can be measured by the amount of time required to train those practising that technology in the practice of the specific, in our case the UASB technology. At a further distance than the anaerobic wastewater treatment processes, but still close enough to be important is anaerobic digestion in general. Apart from the introduction of anaerobic processes, what is of relevance is the knowledge of the treatment of sewage and tannery wastes and more generally wastewater treatment in general.

The importance of these related technologies arises from the importance of inter-industry diffusion of techniques. Thus for example, the UASB technique is not a process to be used for only sewage but also for various other wasterwaters such as pulp and paper industry, sugar industry, starch industry, etc. The diffusion of the UASB technique will not take place directly from one industry to another. But only through the medium of laboratory and pilot scale research and development, where the necessary experiments can be conducted on the different types of wastewater. Thus the absorption of the new technology introduced in the production system, by the research system is a necessary condition for the successful diffusion of the UASB technology throughout the relevant sectors of the economy. Or the connecting effect deals with a crucial component of the process of absorption and assimilation of an imported technology.

Rationally it can be assumed that, lesser the technological distance of the imported technology from the indigenous technology, the easier it would be to connect the im-

Table 2: Factors Affecting Efficiency of Dutch Alternative

| | |
|---|---|
| 1 Presence of tannins in wastewaters in Jajmau | Toxic to methane producing bacteria |
| 2 Presence of Cr in the wastewater | Possible negative effect for agriculture and health |
| 3 Inefficient in removal of pathogens | Health hazards for farm workers |
| 4 Inefficient in the removal of tannins | Tannins in the effluent |
| 5 Inefficient in removal of suspended solids | High COD and SS in effluent |
| 6 Skilled labour for maintenance necessary | Higher possibility of breakdown |

ported technology with the existing R and D system in the country. In the case of the Ganga Action Plan in spite of the existence of considerable amount of know-how the Dutch project did not connect up with the existing R and D basis in the country.

### Indigenous Technology

Considerable amount of expertise on wastewater treatment is available in India. The National Environmental Engineering Research Institute (NEERI), Nagpur, established in 1958-59 is the premier research organisation in the field of wastewater treatment. NEERI has so far developed 300 flow sheets for industrial wastewater treatment plants of which two hundred have been already erected. Yet, the Dutch project does not in anyway make use of the expertise available at NEERI. Specifically in the case of sewage and tannery effluents a large body of expertise exists within this organisation.

For sewage treatment, NEERI has opted for the non-conventional methods of treatment since they make use of the higher temperatures and abundant sunshine available in India, and because they are more appropriate for the skills available in India. Twenty studies by NEERI have shown that up to a population limit of one million, these methods compete effectively with the conventional sewage treatment plants. The biological rope contactor for sewage treatment which has been developed by NEERI has already received acclamation for the tremendous energy saving made possible.[21] Yet the Dutch project is not in any way linked to the expertise available with this premier public health research organisation.

Along with Central Leather Research Institute, NEERI has also been a centre for work on tannery effluents, having played a pioneering role in the study of the treatment of vegetable tanning effluents. The main work of NEERI on tannery effluents was concentrated at the zonal laboratory in Kanpur, which was established in 1962. Since the inception of this laboratory, considerable work has been undertaken by the laboratory in the survey of tanneries in the state of Uttar Pradesh, and in characterising and treatment of tannery effluents (NEERI, 1986a, pp 10-11). In 1965 laboratory investigations were carried out on primary treatment of tannery effluents. The performance of the facilities provided at one of the tanneries in Jajmau, showed that these primary treatment plants achieved a BOD reduction of 38 per cent after a detention time of 24 hours. As reported in the annual report of 1980-81, the main activity of this zonal laboratory was the treatment of the tannery waste from small units. Yet the expertise of this Kanpur laboratory is not utilised in the development of the scheme for the treatment of tannery effluents in Kanpur itself.

Surprisingly enough research on anaerobic digestion of solids and wastewater is not new in India. The following research areas at increasing distance from the technology employed in the Dutch project existed in India. (1) UASb bioreactor; (2) other anaerobic bioreactors for wastewater treatment, especially those dealing with the treatment of sewage and tannery wastes; (3) anaerobic digestion of solid wastes. Significantly, research on the specific bioreactor, the UASB reactor was also conducted in India. Research on anaerobic treatment of wastewater using other types of bioreactors, started in India at the same time as in Holland if not earlier (see Table 3). The details of the research work in India is given below. The information is confined to the work done at NEERI. This information which is not by any means exhaustive gives ample evidence of the considerable amount of research conducted.

### Research in India

*Anaerobic treatment:* Research on anaerobic treatment of wastewater began in NEERI in 1969.[22] The studies dealt with both the substrates of interest to us namely sewage and tannery wastes. The success of these anaerobic studies on sewage were reported in 1969 by NEERI[23] and at an international conference in 1970. The results of the field trials conducted using anaerobic filter were published in an international journal in 1972.[24] The bioreactor on which maximum amount of work has been done at NEERI is the anaerobic filter also called contact filter. The utilisation of this bioreactor to treat tannery effluents has been carried out at the zonal laboratory at Kanpur, which is considered later.

By 1980 not only were the laboratory-scale studies on the utilisation of anaerobic filter to treat sewage completed at NEERI, but also the pilot plant studies were completed (AR 1980-81, p 43). By 1980, these studies had generated enough design criteria for the erection of a full-scale treatment plant. The influent had a BOD level varying from 100 mg/l to 250 mg/l and the method succeeded in removing 80-85 per cent BOD. Later this process was extended to the treatment of dairy wastes. Modifications on the existing reactors, such as the rotating biological drum reactors were also employed (AR 1983-84, p 19; AR 1984-85, p 56). Some modifications on the design of moving bed reactors have also been made (NEERI, 1987a). In 1983, a new lab was started which concentrated on anaerobic treatment of wastewater.[25] The work on anaerobic treatment at NEERI got a major fillip with the granting of a three-year project of Rs 1.5 million by the Advisory Board on Energy for conducting studies on the recovery of energy from high strength wastewater. This has made it possible for a group of eight scientists to be working on anaerobic treatment systems. Doctoral work on the treatment of distillery wastes using fluidised bed reactors, fixed-film fixed-bed reactors and moving bed reactors have been or are being done in the laboratory. Based on the above studies, a pilot plant of 1000 litres per day capacity has been commissioned at Ajudhia distillery at Moradabad for verification/scale up purposes (NEERI, 1986b).

*UASB Reactor:* Studies using the upflow anaerobic sludge blanket (UASB) reactor were first done at NEERI by the student from Wageningen, Leon Urlings, during 1981-82 for his Master's degree in environmental engineering. Studies using this reactor were incorporated into the research which was going on in NEERI (AR 1982-83, p 38) and sewage treatment using the UASB reactor, upflow anaerobic fixed-film fixed-bed reactor and downflow sand filtration were conducted (AR, 1983-84, pp 54-55).[26] By 1983-84 the studies generated enough design criteria to undertake pilot plant studies. It was concluded that flow rates of 3 l/hr with detention period of 16.6 hours was the most suitable, since satisfactory reductions in organic loads were achieved, as well as the danger of loss of biomass was reduced (AR 1984-85, p 73).

*Anaerobic Treatment of Tannery Waste:* By 1975 studies conducted at NEERI showed conclusively that anaerobic method is effective in the treatment of vegetable tannin effluents. 90 per cent reduction of COD and BOD was recorded at organic loading rates of 0.86-1.344 kg/m$^3$/d and tannin removals of 50 per cent (Arora, H C et al (1975).[27] The results of the study was published as a special report in 1982 entitled 'Treatment of Vegetable Tannin Effluent by Anaerobic Contact Filter Process-Multiple Unit'. This process was also applied in practice. The 1982 annual report of NEERI reported the performance of the full-scale treatment unit established at U P Tannery, Jajmau, Kanpur. The data revealed that satisfactory results were achieved in reducing COD, BOD and tannin levels.[28] In 1981-82 NEERI also undertook a study for the treatment of wastewater from a proposed leather complex at Devas, Madhya Pradesh. Further a demonstration full-scale tannery wastewater treatment plant is being put up at Wasan Tannery, Agra by NEERI (AR 1985-86, p 33). The above discussion shows that even on the basis of the incomplete information available, it is possible to conclude that a viable basis for research on anaerobic wastewater treatment technology in general and in the treatment of sewage and tannery waste in particular existed in the country.

Apart from wastewater treatment, there is a widely dispersed know-how basis available, on the utilisation of anaerobic processes in sludge treatment. This work is closely related to the work on biogas plants. Excellent research in this area, including on the newer diphasic reactors have been conducted in India.[29] Apart from this the hundreds of thousands of gobargas plants set up in India, have created expertise which is also of relevance to the anaerobic treatment of wastewater. The research work on the production of biogas from different substrates, received a boost with the programmes supported by the department of non-conventional energy sources (DNES), ministry of energy. DNES has chosen substrate diversification as one of the thrust programmes. This diversification brings it into the same area as the anaerobic treatment of wastewater where the production of biogas is really a by-product.

## DUTCH CONNECTION

In spite of the existence of this research infrastructure in anaerobic wastewater treatment, the project in Kanpur does not link up with this structure, but with that in the Netherlands. Indeed the Kanpur project is a logical extension of the research work conducted in the Netherlands and naturally connects with it. The project at Kanpur is being executed as a turnkey job by a consortium of Dutch consulting engineers, with Haskoning B V as the leading consultant. Euroconsult, a rival cartel of consulting engineers in the Netherlands are also part of the project.[30] These consultants have many advisors, including G Lettinga of the Water Pollution Control Laboratory in Wageningen, the Netherlands. The process engineering data and basic design are supplied by the Dutch consultants. Indian engineering consultants are employed by the prime consultants who participate in detailed engineering. The Indian consultant employed by the Dutch in Kanpur is Associated Industrial Consultants, Bombay.

The UASB process was developed at the Water Pollution Control Laboratory at the Agricultural University of Wageningen, the Netherlands. The laboratory was established in 1965 and the work on anaerobic processes started in 1970 when G Lettinga joined the department. The immediate impulse came from the publication of the results of the work done by Young and McCarty in 1969. The UASB reactor was developed around 1972.

The new UASB reactor functioned satisfactorily and laboratory tests were conducted with different substrates such as the extracts from beet sugar and potato starch. In 1974 a 6 $m^3$ pilot plant was put up at a sugar factory at the Netherlands (Lettinga, G 1975). The bioreactor was scaled up and by 1978 a full-scale 1200 $m^3$ plant was set up. Later pilot scale experiments were conducted on different wastewater such as municipal sewage, slaughter house sewage, etc, in collaboration with the engineering consultants belonging to the cartel Euroconsult. The experimental work conducted at the laboratory has helped in the wide diffusion of this technology. It is reported that, so far about 60 plants have been put up in the Netherlands and about 200 plants all over the world. But beyond the pilot plant stage, the Water Pollution Control Laboratory is not normally involved, unlike NEERI.

This bioreactor developed at the Water Pollution Control Laboratory at Wageningen, Netherlands has been exploited by many engineering consultants in the Netherlands. They continue to work closely with the laboratory and very often fund short research projects at the laboratory. The research conducted at the lab helped in diffusing the technology to new substrates. Although research on sewage was conducted in the Netherlands, it was not applied in practice due to the low temperatures prevailing in the Netherlands. One of the engineering consultants in the Netherlands, Haskoning B V with considerable interest in Latin America, was interested in utilising UASB technology for treatment of sewage in Latin America. A pilot plant was put up in Cali, Colombia financed by Dutch development aid and the consulting firm Haskoning B V worked very closely with the University of Wageningen. The final report on these pilot scale experiments was submitted in February 1985. It is the design data generated in Colombia, that is to be applied in Kanpur for treating the municipal sewage mixed with tannery effluents. A series of three reactors of 1,200 $m^3$ volume is to be designed in Kanpur. Apart from this, a 10 $m^3$ pilot plant is also being put up at one of the tanneries in Jajmau. The Kanpur treatment plant is a clear continuation of the plant put up at Colombia, since the data generated by the pilot plant studies form the basis for the plant at Kanpur. Here we have an interesting case of the international dispersal of the innovation chain. Table 3 gives an idea of how the Kanpur project links up with the R and D structure in the Netherlands and how it is a natural continuation of the developments in the Netherlands.

As part of the project, there is also plan to 'transfer technology'. Although the UASB process is considered as a simple-to-operate process, it does need fairly skilled handling, especially during the starting-up period.[31] The quality of the granular sludge produced during the start up determines the efficiency of the process. Indeed as expressed by Lettinga and his colleague, the UASB needs a team of 'anaerobe experts' to maintain the plants satisfactorily. It is proposed to have training programmes in the Netherlands for engineers, for the satisfactory maintenance of the UASB plants.

TABLE 3: DEVELOPMENTS IN ANAEROBIC TREATMENT TECHNOLOGY IN INDIA AND THE NETHERLANDS

| Year | India/NEERI | Netherlands/LUW |
|---|---|---|
| 1959 | NEERI established | |
| 1962 | Lab at Kanpur established | |
| 1965 | | Establishment of the Pollution Control Lab |
| 1969 | Lab work on AF for sewage started by V Raman | |
| 1970 | Success of AF reported at international conference | Lab work on AF started by Lettinga |
| 1972 | Success of the field trials reported in JWPCF | First results of UASB reported in $H_2O$ |
| 1974 | | Pilot plant put up at sugar factory |
| 1975 | Success of AF treatment of vegetable tannins reported | |
| 1976 | | 30 $m^3$ pilot plant |
| 1978 | AF studies on the treatment of slaughter house waste | Full-scale plant at sugar factory |
| 1979 | AF pilot plant studies on sewage completed and design data generated | Pilot plant studies with municipal sewage and slaughter house effluent |
| 1980 | Papers on the utilisation of AF for tannery and slaughter house effluents published | |
| 1981 | Studies with UASB reactor for sewage | |
| 1982 | Results of full-scale AF plant for vegetable tannins at Kanpur published | Pilot plant for domestic sewage started at Colombia |
| 1983 | New lab for anaerobic processes started | |
| 1984 | Generated enough lab data to start UASB pilot plant studies with distillery waste | |
| 1985 | Second full scale treatment plant for tannery effluent undertaken; | Final results of Colombia pilot plant prepared; Identification mission on environment to India; |
| | AF pilot plant for distillery wastewater commissioned | Fact finding mission to Kanpur |

## CONCLUSION

The description of the current processes taking place under Dutch development aid show that rather than bridging the gap that exists between technological know-how and its application in production, the same is being maintained or rather being widened. Without any proper technology assessment, the anaerobic filter on which the scientists in the national laboratories have been working for two decades has been in fact rejected.

In the project as envisaged there is no room for an indigenous research organisation such as NEERI. The fact that NEERI might get incorporated as a testing laboratory or as a monitoring/evaluating unit is besides the point.

The UASB plant currently being put up by the Dutch at Jajmau does not make use of the capabilities developed by NEERI. As a matter of fact, the chief of the wastewater section of Haskoning, who is in charge of the design of the treatment plants at Jajmau, Kanpur was not even aware of the fact that in the same Jajmau, a full-scale anaerobic treatment plant had been functioning.[32]

On the basis of the information available to us, it appears that the project built under Dutch development aid, has no positive additive effect on the Indian economy. It is even likely that it has negative additive effect. The superiority of the Dutch alternative as compared to the alternatives proposed indigenously has been argued without proper technology assessment, especially by putting forward the Dutch alternative which is a pre-treatment as a full treatment facility.

In spite of the fact that considerable expertise exists in India in precisely the area of anaerobic treatment of wastewaters, including sewage and vegetable tannery wastes, this development project does not link up with them. There apppears to be a disconnecting effect operating, since in the absence of the 'aid' the technology chosen would have most probably resulted by linking up with the research done in NEERI, as has happened in the case of Patna. Even the chief process engineer of Haskoning, A F M Van Velsen admitted during interview that under the current organisational structure, there was no transfer of technology, understood as the capability to adapt modify and improve the process.

This criticism of the role of Dutch development aid should not be construed to mean a criticism of all technical collaboration programmes between governments. Even in the specific case of the UASB technology we have studied, it can be envisaged that a rational decision to import the Dutch know-how in the field can be taken, in spite of the existence of local expertise, since the Dutch are the originators and the leaders in this technology. But our conclusion after a study of the collaborative processes is that supplementing our expertise in the field of UASB technology was hardly the motive for the involvement of the Dutch in the Ganga Action Plan. In case it was decided that UASB technology had to be introduced into India, it would have been better to have started with a soluble wastewater rather than a comparatively more difficult substrate as sewage.[33] In case the expertise developed in the Netherlands was to be utilised, it could have been done better by appointing an Indian organisation as the prime consultant, and bringing in experts such as Lettinga as advisors. In this case the costs in foreign exchange would have been also much less. In the current situation, this development aid appears to be a subsidy to Haskoning, a comparative newcomer to the field of UASB technology,[34] and has served as an entry point for them into the growing Indian market in this sector.

At various levels in India the demand has been raised[35] that import of technology should take place only on the basis of a clearly formulated plan and that in case the decision to import technology is taken, then the prime consultant should be Indian and the concerned research organisation should be involved in the process. None of these conditions were fulfilled in this case of the import of Dutch technology for the Ganga Action Plan.

Given the negative additive and connecting effect of the technology imported under Dutch development aid, there can be no upgradation of the technical level in India through the import of this technology. The question which arises is whether the loan of 60 million Dutch guilders is worth the damage done to the development of Indian technological know-how and to long-term economic development.

## Notes

1 "The ways in which technological changes coming from one industry constitute sources of technological progress and productivity growth in other industries defy easy summary or categorisation" (Rosenberg, 1979, p 74). Apart from the diffusion of a technology from one industry to another, inter-industry impact of a new technology is felt through the sale of intermediate outputs by the industry where the technological changes takes place and through the impact of complementary innovations.

2 There has been a lot of criticism of the concept of innovation chain. This criticism is basically valid for a linear concept where the flow is considered to be from basic research to applied research or inventive activity to development. We maintain that the concept of the innovation chain is a valid concept when the interlinks are not assumed to be in one direction. For reasons which cannot be gone into here we prefer to use the term, invention rather than applied research and follow in this the definitions given by Schmookler, J (1966). For a discussion of these definitions see Freeman (1974).

3 See for example Herrera (1972). He puts forward the position that in underdeveloped countries, the science and technology are consumption items and not inputs for production. Our difference with his position would be that this should not be seen as a static situation. In practice, there are factors operating to widen the gap as well as to bridge the gap, and the specific dynamics and the equilibriums reached need to be studied. This type of non-recognition of the positive role of the local bourgeoisie is typical of the dependency school to which his study belonged. Yet this school has provided valuable insights which are unfortunately lost by the current critiques of the dependency school.

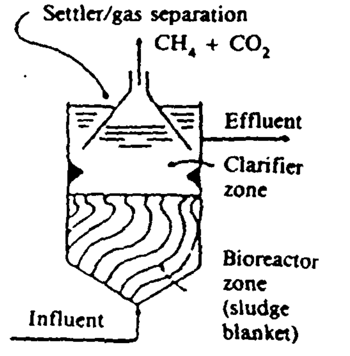
4 By technological distance we refer to the amount time required to train those operating, maintaining, designing, etc, of an existing technology to do the same functions for a new technology being introduced.

5 Economic, institutional and technological criteria function as selection criteria in mapping out the path of a technological trajectory. (See Dosi, 1982 for a good exposition of the concept.) The possibility of a new trajectory is inherent in the fact that the economic and institutional environment changes during the transfer of technology from a developed country to an underdeveloped country.

6 The Ganga Action Plan was announced as a science and technology mission. The Seventh Five Year Plan (1985-90) characterises the GAP as follows: "A major programme on prevention of pollution of Ganga would be undertaken as a Science and Technology Mission in the Seventh Plan. This is an interdisciplinary programme. For this the technological inputs would be provided by the concerned scientifc organisations." (Quoted in Krishna Murti, 1986, p 1, emphasis added.)

7 Wastewaters which contain organic matter can be treated either aerobically (in the presence of air or oxygen) or anaerobically in the absence of air. During aerobic treatment the wastes are degraded to carbon dioxide and water and the process is energy-intensive since energy has to be utilised to pump air through the wastewater. Further due to the presence of moving parts, the possibility of breakdowns are also higher. This process is in principle irrational since, energy is being utilised to destroy the potential energy which exists in the wastewater. In contrast to this, in the anaerobic process, in the absence of air, the wastes are converted into methane, which can be used directly or for the generation of electricity.

8 UASB is one of the bioreactors used in anaerobic treatment of wastewaters. The wasterwater enters from below a sludge blanket (see figures below) which consists essentially of anaerobic bacteria. In this system no support material is used and the bacteria is retained in the reactor since granules are formed in the process of ripening and starting up the bioreactor.




Upflow anaerobic sludge blanket reactor

9 Technology missions can be considered as conscious and planned interventions in technological development focusing on the transition from inventions to innovations. The development of nuclear energy, for example, was undertaken on a mission basis.

10 The report of this mission is the document DGIS, 1986.

11 Additive effect is a narrower effect than appropriateness, since it considers the question of appropriateness only by considering the immediate and local effects, while appropriateness would have to consider the connecting effect also.

12 The process suggested in the Ganga Action Plan for the treatment of sewage consists of primary settling followed by methane recovery from the digestion of the primary sludge and effluent treatment in a high rate pond from which algae is harvested.

13 BOD (biological oxygen demand) and COD (chemical oxygen demand) 13.6 indicate the oxygen required to degrade the wastes present in the water. When wastewaters with high COD or BOD enter water courses, they deplete the oxygen dissolved in these waters and thus lead to the death of aquatic life and to putrefaction. According to the Ganga Action Plan the the treated effluents to be released into the Ganga should have a BOD of less than 20 mg/l.

14 At the same time, the studies conducted in India have shown that the other anaerobic reactor, the anaerobic filter gives total removal of the parasities ova (ascaris and hookworm) and 70-75 per cent removal of total coliform (Raman, V and B B Sunderesan, 1989, p 40).

15 The COD removal efficiency of about 68 per cent was achieved in Colombia, with a loading rate of about 250g COD/$m^3$ d and a HRT of 6 hours (Lettinga et al, 1987, fig 5). The BOD treatment efficiency was 74 per cent at an HRT of 6 hours (DGIS, 1985, pp 8-5). Strictly speaking these results cannot be extrapolated for a different type of sewage in a totally different geographical and socio-economic area as in Kanpur. At a loading rater of 250g COD $m^3$/d and a HRT of 12.5 hours the COD and BOD removal efficiencies were observed to be 72 per cent and 87 per cent respectively in the UASB reactor in the experiments conducted with sewage at NEERI zonal laboratory at Kanpur (P P Pathe, et al, 1987, p 86). But the Dutch reactors are being designed with 6 hours HRT and therefore it is rational to assume that the rates would be lower. Hence it is not likely that the system as designed would achieve the necessary effluent standards.

16 According to the values mentioned in the DGIS report the suspended solids were 882, 529, 434, and 704 mg/l (DGIS, 1986, Appendix III) as compared to TSS of 215, 189 and 156 mg/l in Cali (Lettinga, G et al, 1987, p 27).

17 "At a conservative hydraulic detention time of 6 hours (25 C) the COD—loading rate is approximately 2 kg COD/m, day, whereas loading rate up to 6-8 kg COD/m, day are admissable under these conditions. In view of this, an increase in the wastewater concentration, e g, by additional discharge of tannery wastewater will not affect the process performance" (DGIS, 1986, 5.1.3..b).

18 Even about 700 mg/litre of gallotannic acid lead to a 50 per cent inhibition of methanogenic activity (Field and Lettinga, 1987, p 370). According to the data available in the Dutch report (DGIS, Appendix III) the concentration of tannic acid in the effluent at Jajmau was 380 mg/litre, a concentration at which substantial reduction of the activity of methanogenic bacteria could take place. A reduction which could be large enough to totally change the economics, the efficiency of the process under the given conditions. In case, more tanneries are to be connected to the sewerage system as a result of the upgradation of the environment in Jajmau then the concentration of tannins in the effluent might even go up, leading to further deterioration of the efficiency. Of course, in case the tannins are present in the monomeric form, then the toxicity is much less, and it might even fall in the zone where an increase in the efficiency is noticed. The study by Fields and Lettinga reported that the toxicity of gallic acid and pyrogallol were much less, and that the efficiency of production of methane at 1 g/litre of pyrogallol was even more than 100 per cent.

19 In the given conditions, it is calculated that sludge will have a chromium concentration of 5-6 g/kg total solids. The Dutch are also trying to sell their technology for chromium recovery for the tannery units. In case that, or other indigenous processes for chromium recovery are implemented, then the chromium concentration would come down to 1.25 –1.5 g/kg total solids (DGIS, 1986, p 47).

20 NEERI has also made comparative studies on the costs (both capital and running) and land requirement of each method for the population range of 5,00-2,00,000. Based on the above studies type designs of these plants have been prepared. A manual *Waste Stabilisation Ponds: Design, Construction and Operation in India* has been published.

21 Interview with V P Thergaonkar in Nagpur, November 10, 1987.

22 Utilisation of anaerobic decomposition to treat municipal waste has a very long history, beginning with the simple air tight tanks developed in France in 1882. In India itself, it is reported that in 1897, waste disposal tanks at a leper colony in Matunga, Bombay not only employed anaerobic treatment, but also employed the gas produced to drive gas engines. But wastewater treatment usually followed aerobic treatments, except for the digestion of the sludge produced.

In the last three decades, many developments have taken place in the desig of anaerobic reactors because of whic anaerobic processes can be utilised for th treatment of wastewater. The anaerob fixed-film reactor was first developed b J C Young and P L McCarty in 1969 an the first full-scale application of the pr cess took place in the treatment of whe starch wastewater in 1972. Further moc fications in this type of reactors took pla with the introduction of anaerobic attache film expanded bed in 1980. Yet anoth modification in the reactor design is th developed by G Lettinga of the Univers of Wageningen in the Netherlands. It w a modification of the reactor developed G J Stander in 1950 for the treatment the wastewater from the fermentation dustry. By 1966, the validity of this proc was demonstrated by full-scale applicati for winery wastewater. Further develc ments in the reactor design include t rotating reactors (1980) and the baffled re tor developed in the United States.

23 V Raman and A N Khan, 'Upfl

Anaerobic Filter: A Simple Solution for Sewage Treatment', presented at the International Conference in Water Pollution Control in developing countries, Bangkok, Thailand, February 21-25, 1970. Referred to in Lettinga et al, 1983, and Raman V and A N Chakladar, 'Low Cost Septic Tank Effluent Treatment by Up Flow Filter' Proceedings of the symposium on Low Cost Waste Treatment (1969), NEERI, Nagpur, referred to in V Raman et al (1982).

24 V Raman and N Chakladar, 1972, *Journal of the Water Pollution Control Federation*, 44, 1552, referred to in Mira, 1976.

25 This and the following information is based on interview with S N Kaul, leader of the anaerobic group at NEERI, Nagpur on November 10, 1987.

26 More information on this process can be obtained from Pathe (1987).

27 The following is based on the information available in the various annual reports of NEERI.

28 The treatment plant put up at UP tannery showed less satisfactory results than the laboratory results, partly due to the smaller size of the plant opted for due to financial constraints, and partly due to the normal problems of development and upgrading. But the results which showed that more than 65 per cent of COD and BOD was removed by this process was certainly encouraging enough to justify further developmental work on this treatment plant. In the upgradation studies, the help of Agarwal, professor of Environmental Engineering at IIT Kanpur was taken, showing the existence and linking up of scientific and engineering knowledge, necessary for the successful transition from the stage of invention to innovation.

29 Work has been conducted at the Centre for Environmental Science and Engineering, Indian Institute of Technology, Bombay under P Khanna. See Saraswat, N and P Khanna (1986), and Annachhatre, A P and P Khanna (1986).

30 Haskoning belong to NEDECO, the other cartel of Dutch consultants. Although they do not normally work together, apparently due to the fact that this project is financed by the Dutch ministry for development aid, the rivals have to function together.

31 See Hulshoff Pol, 1986, tables 2 and 3 for the problems encountered in starting up operations.

32 Based on interview.

33 This is all the more so, since the project financed by the Dutch department for the development of new technologies for developing countries (DPO-OT) under which the application of UASB technique for sewage treatment (in Cali, Colombia) was undertaken has not yet submitted its final assessment. Although the pilot plant studies were completed by February 1985, the full-scale plant based on these results and a cost benefit analysis of the utilisation of UASB technique as compared to others is yet to be undertaken. Interview K Soels, chief DPO-OT on February 4, 1988.

34 There are no UASB plants put up by Haskoning which are operating anywhere in the world. In the development and application of the UASB reactor in the Netherlands, the university of Wageningen collaborated with other engineering consultants. The involvement of Haskoning with UASB dates only from the design made for the wastewater treatment of the city of Marseilles, France between 1979-1981, the reactor of which is under construction. Three UASB reactors designed by Haskoning are under construction in South America. Interview with A F M van Velsen at Nijmegen, January 15, 1988.

35 These demands have become rather unfashionable in the government circles these days, but this should not generate the impression that they have no support among the people. For example, the recently held Bharat Jan Vigyan Jatha has argued for these conditions from its own perspective. (BJVJ, 1987, p 22). These demands are also reflected in the demands of progressive solidarity movements in the Netherlands.

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